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Research Article

Agronomic performance of day-neutral strawberry cultivars as a function of early planting dates

Desempenho agronômico de cultivares de morangueiros de dia neutro em função da antecipação da data de plantio

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ABSTRACT

The cultivation of day-neutral strawberry plants combined with earlier planting dates in regions with mild winters can increase the supply of this fruit between May and September, when prices are at their highest in Brazil. In this context, the present study aimed to analyze the agronomic performance of four day-neutral strawberry cultivars as a function of the anticipation of the planting date in the municipality of São Miguel do Oeste, SC. The experiment was conducted in an umbrella-type greenhouse, on slabs with six plants and fertirrigated with a standard solution for the crop. The randomized block design was bifactorial (4x2), with: a) four cultivars: San Andreas®, Alpina10®, Bellalinda®, and Beauty™ (FL 12 1215®); and b) two planting dates: D1, on 03/10/2022; and D2, on 04/10/2022. The analysis leads to the conclusion that early planting resulted in greater total mass of commercial and defective fruit. While the total mass did not differ between cultivars, 'San Andreas' and 'Alpina10' had higher commercial mass. Bellalinda produced a greater number of fruits, which contributed to a smaller average size, increasing the number and mass of non-commercial fruits. Beauty showed higher commercial production from May to June. The expected economic results differed between cultivars, indicating the need to include the planting date variable in the analysis of genotypic potential. The cultivars 'San Andreas', 'Beauty', and 'Bellalinda' showed better economic results with early cultivation, while 'Alpina10' did not differ between the two dates.

KEYWORDS: Photoperiod. Market window. Protected cultivation. Strawberry.

RESUMO

O cultivo de morangueiros de dia neutro associado a antecipação da data de plantio em regiões de inverno ameno pode ampliar a oferta dessa fruta entre os meses de maio e setembro, época de maior preço. Nesse contexto, o presente estudo objetivou analisar o desempenho agronômico de quatro cultivares de morangueiros de dia neutro em função da antecipação da data de plantio no município de São Miguel do Oeste, SC. O experimento foi conduzido em casa de vegetação tipo guarda-chuva, em slabs com seis plantas e fertirrigados com solução padrão para a cultura. O delineamento em blocos ao acaso foi do tipo bifatorial (4x2), com: a) quatro cultivares: San Andreas®, Alpina10®; Bellalinda® e BeautyTM; e b) duas datas de plantio: D1 10/03/2022; e D2 10/04/2022. A análise permite concluir que a antecipação do plantio resultou em maior massa total, de frutas comerciais e com defeitos. Enquanto a massa total não diferiu entre cultivares, a 'San Andreas' e a 'Alpina10' apresentaram maior massa comercial. A 'Bellalinda' gerou maior número de frutas, o que contribuiu para o menor tamanho médio, elevando o número e a massa de não comerciais. A 'Beauty' apresentou maior produção comercial de maio a junho. Os resultados econômicos esperados diferiram entre cultivares, o que indica a necessidade de incluir a variável data de plantio na análise de potencial genotípico. As cultivares 'San Andreas', 'Beauty' e 'Bellalinda' apresentaram melhores resultados econômicos com a antecipação de cultivo, enquanto a 'Alpina10' não diferiu entre as duas datas.

PALAVRAS-CHAVE: Fotoperíodo. Janela de mercado. Cultivo protegido. Morango.

INTRODUCTION

Strawberry cultivation began to gain commercial importance in Brazil in the mid-20th century. At the time, seedlings were imported from the United States and Europe, and the plants were poorly adapted to the climate and soils of most of the country, resulting in low productivity and fruit quality. Given the slow progress in national genetic improvement, research focused on selecting imported cultivars that were better suited to Brazilian climatic conditions, which led to improvements in productivity and quality (FAGHERAZZI 2013, ANTUNES et al. 2016). As a result of this transformation, the 2023 HF yearbook ranks Brazil as the 9th largest producer in the world, with the 14th largest cultivated area (ANTUNES et al. 2023).

Official data from 2017 recorded crops of approximately 4,500 ha and an annual production of 165,440 t (ANTUNES & BONOW 2020), with indications of increases in subsequent years. The average national yield for the crop was 36.76 t ha-1, below the crop's potential of 60 t ha-1 (ANTUNES & BONOW 2020). Among the reasons are the low technological level in places with conventional cultivation without the protection of tunnels, cultivars that require many hours of cold for floral induction and redirection to the vegetative development of photosensitive materials in the face of high temperatures associated with the lengthening of the day in summer (FAGHERAZZI 2017, FAEDO 2018).

Domestic production fluctuates throughout the year depending on temperature and photoperiod, with higher prices during the winter. During this period, seedlings from the new crop are developing vegetatively before receiving stimulation from low temperatures for floral induction. In addition, early planting is rarely adopted due to the risk of seedlings not taking root during transplantation due to high temperatures, which is why seedlings with root balls are recommended (ANTUNES et al. 2016).

When comparing planting seasons (February, April, June) for ‘Arazá’ and ‘Yvapitá’ strawberry plants in a subtropical environment (Santa Maria, RS), ROSA et al. (2013) found higher productivity in April, indicating the need to test this variable. As the crop responds to heat summation, the time required for pre-flowering development differs between genotypes (TAZZO et al. 2015). In late plantings, many plants are induced by the cold to enter flowering without reaching adequate growth, which reduces photosynthetic capacity and the accumulation of reserves, negatively impacting flowering and/or extending the interval between flowering peaks. On the other hand, very early planting extends the vegetative phase, especially in photosensitive materials, which can result in the emission of stolons that consume the reserves that would otherwise be accumulated (MORITIZ et al. 2021, NAIDK et al. 2022).

Accumulated knowledge indicates that the most suitable planting date varies depending on the interaction between genotype and environment. Based on a review of the literature, the hypothesis was that the use of day-neutral varieties, which are less prone to stolon formation, could enhance early production when planting dates are brought forward. Identifying the best materials and dates for exploiting this potential can optimize the costs of shelter and bench infrastructure in above-ground systems (ZEIST & RESENDE 2019, NAIDK et al. 2022, GRIEBELER 2021).

Early planting combined with the use of cultivars that are less demanding in terms of cold hours represents an opportunity to take advantage of this market window in regions with mild winters. This condition may give the Far West region of Santa Catarina a competitive edge to operate in foreign markets, in addition to local demand. The cultivation system adopted in the region is conventional in semi-hydroponic systems on benches and in high tunnels, with production in small areas, where the viability of investments depends on optimizing economic results (NAIDK et al. 2022).

In this context, the overall objective of this research is to analyze the agronomic performance of day-neutral strawberry cultivars as a function of the anticipation of the planting date in São Miguel do Oeste. This unfolds into: evaluation of the vegetative and productive behavior of day-neutral strawberry cultivars according to the planting season; and estimation of expected income based on the production curve and market prices of fresh fruit for fresh consumption.

MATERIALS AND METHODS

The research was conducted at the Federal Institute of Science and Technology of Santa Catarina (IFSC) campus in the municipality of São Miguel do Oeste, SC. The location has an altitude of 720 m, average annual rainfall of 1,959 mm, average annual temperature of 18.1 °C, and is classified according to Köppen-Geiger as a humid temperate climate with hot summers (Cfa) (CLIMATE DATA 2012).

The experiment was conducted in a greenhouse using a soilless cultivation system on slabs with substrate, arranged on wooden and bamboo benches, 0.90 m high. The semi-hydroponic substrate system with high tunnels was the most widely adopted by farmers in western Santa Catarina in 2020 (MARCHI et al. 2021).

The treatments were two planting dates and four cultivars, characterizing a factorial system experiment (4x2). The four day-neutral cultivars were: 'Beauty™' (FL 12 1215®), 'Bellalinda®', 'San Andreas®', and 'Alpina10®'. The 'San Andreas' cultivar was the second most planted in western Santa Catarina in 2020, behind 'Albion' (MARCHI et al. 2021). The other three materials were preselected in another study conducted in the municipality by GRIEBELER (2021).

The planting dates were: D1: March 10, 2022, 30 days earlier than indicated by the climate risk analysis; and D2) April 10, 2022, at the beginning of the indicated period (PANDOLFO et al. 2017). The experimental arrangement was randomized blocks with four replicates, totaling 32 experimental units. Each sample unit consisted of a slab with six plants spaced every 20 cm. This spacing was adopted to obtain a greater number of commercial fruits when compared to shorter distances (MARTINS DE LIMA et al. 2021).

The slabs used were Carolina Soil® brand, in their first year of use, consisting of inert organic substrate, without fertilizer or contaminants, with a pH of 5.5, retention capacity of 300% m/m, and electrical conductivity of the drained material of 0.1 mS cm^{-1} (millisiemens). After washing the slabs with plenty of water, domestic seedlings with root balls were used, which facilitates adhesion in high temperatures. These were purchased from a commercial nursery, produced in 128-cell trays, with a substrate volume of 22 cm^{-3} per alveolus.

Irrigation and fertigation were performed using drip hoses, with drippers spaced 0.10 m apart and positioned inside the slabs at the top of the substrate. The nutrient solution was prepared in a 3,000-liter water tank, with a timer-activated motor pump. The nutrient solution was prepared to contain the nutrients necessary for the growth and development of strawberry plants, following the recommendation of Embrapa (BORTOLOZZO et al. 2007).

The vegetative stage solution was changed to reproductive when the first plants began to flower. The main source of micronutrients was a commercial product, which required supplementation with boron and molybdenum to reproduce the minimum recommended concentrations (Table 1).

Table 1. Formulation for the production of a nutrient solution for the cultivation of day-neutral strawberry plants, differing in the vegetative and reproductive stages of the plant, adapted from Embrapa's recommendation.

NUTRITIONAL SOLUTION (g per 1000 L)		
FERTILIZER	**VEGETATIVE**	**REPRODUCTIVE**
Calcium Nitrate	480	480
Potassium Nitrate	300	300
Monoammonium Phosphate	45	0
Monopotassium Phosphate	54	216
Magnesium Sulfate	0	360
Torak Boro 17% B	0	1.6
Commercial micronutrient	20	20
Sodium molybdate	0.157	0.157
12% EDTA iron	20	20

Source: BORTOLOZZO et al. (2007).

The fertigation solution was controlled by weekly measurements of electrical conductivity (EC) and pH, both in the box and in the slab drainage. Since rainwater (cistern) was used, no extra measures were necessary to remain within the pH range of 5.5-6.5. During the first two weeks, for seedling establishment, the solution was diluted to EC 0.8 mS cm^{-1} (50%). For the remainder of the experiment, EC 1.6 mS cm^{-1} was adopted. The drainage was maintained in the range of EC 1.2-1.8 mS cm^{-1}. Irrigation with pure water was used only when the EC exceeded the upper concentration.

Pest control was carried out using predatory mites and products registered for use on the crop when pests and diseases appeared. To ensure the comparability of the sample units, the applications took place before reaching the control level. The main problems encountered were gray mold (*Botrytis cinerea*) and spider mites (*Tetranychus urticae*). Occasionally, it was necessary to control caterpillars (*Spodeptera frugirperda*), beetles (*Diabrotica speciosa*), thrips (*Frankliniella occidentalis*), and oidium (*Sphaerotheca macularis*).

Agronomic performance was evaluated based on the variables of development, production, productivity, fruit quality, and expected gross revenue. Crop development was evaluated in terms of the time to onset of flowering and harvest of 100% of the plants. The emission of stolons was recorded weekly. The fruits were evaluated with harvests carried out on average three times a week, with 75-80% of the skin red in color, at two-day intervals. The following variables were evaluated:

- Number of stolons per plant: removed and counted weekly during the growing season.

- Flowering start: average time for 100% of plants to reach the first fully open flower.
- Start of harvest: average time for 100% of plants to reach first ripe fruit.
- Total fruit mass per plant (MT): average production per plot divided by number of plants;
- Commercial fruit mass (MC): commercial fruit production mass of each replicate divided by the number of plants in each replicate
- Fruit pulp with defects (MD): fruit that had defects, especially those resulting from pest and disease attacks, and was unusable;
- Total number of fruits per plant (NFT): average total number of fruits produced per plant during its cycle;
- Number of commercial fruits (NCF): average number of fruits weighing more than 10 grams and showing no deformities or rot;
- Number of defective fruits (MD): quantity of fruits that presented defects;
- Average mass of total and marketable fruit: assessment of total average mass (total mass/total fruit) and commercial average mass (commercial mass/commercial fruit);
- Fruit production for industry: number (NFNC) and mass (MFNC) of fruit not considered suitable for fresh consumption in relation to total production, considering those with a mass of less than 10 grams and those with deformities;
- Expected gross revenue from commercial production: multiplication of weekly production by the average weekly price recorded at the São José Supply Center (SC) throughout the harvest.
- Total expected gross revenue: sum of the expected commercial gross revenue and possible revenue from production for industry, the latter obtained by multiplying the non-commercial mass by the lowest average weekly value recorded in its sale at Ceasa throughout the harvest.

The data collected from the variables presented above were submitted to analysis of variance (ANOVA) using the F test, with the Sisvar program. When significant, the means of dates and cultivars were separated using Scott Knott's test at a 5% probability of error. When significant interactions between factors were found, comparisons were made between cultivars on the same date and between dates for the same cultivar. When they did not result in interactions, these were compared between cultivars and then between dates.

RESULTS AND DISCUSSION

The order of presentation of the results follows the following structure: a) variables related to plant development (stolons, onset of flowering, and harvest); b) variables without interaction between planting dates and cultivars; c) variables with interaction between planting dates and cultivars.

a) Variables related to plant development

Plant development resulted in distinct behaviors among cultivars in relation to planting date. The four cultivars planted showed greater stolon emission on the first date (D1) than on the second (D2) (Figure 1).

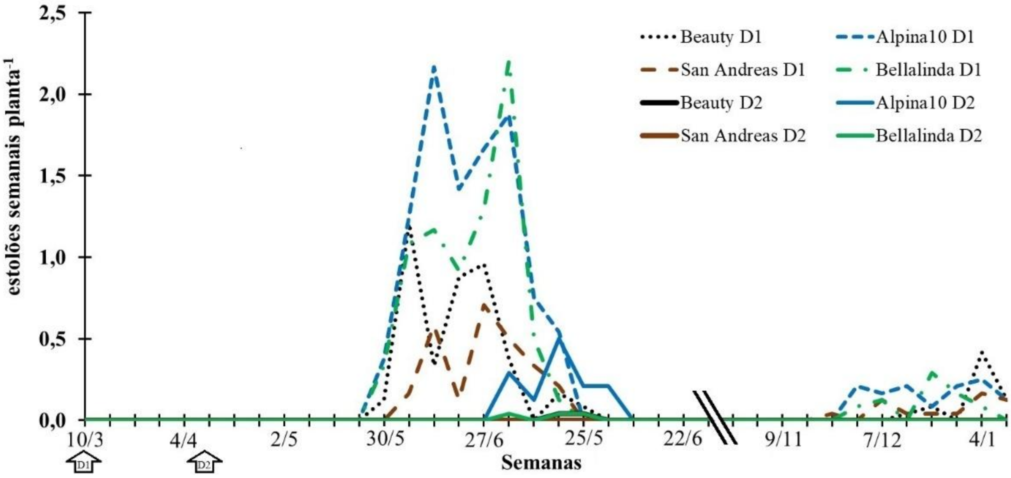

Figure 1. Average weekly stolon production per plant throughout cultivation for four cultivars on two planting dates (D1: 03/10 and D2: 04/10). Note: time axis partially hidden during period without stolon emissions.

In D1, the cultivar that produced the most stolons was ‘Alpina10’, followed by ‘Bellalinda’. The tendency of ‘Alpina10’ to produce more stolons is corroborated by the results in D2, although the number was lower than in D1. In a study conducted in 2020 by NAIDK et al. (2022), in the same municipality, with two short-day cultivars (‘Pircinque’ and ‘Jonica’) and four planting dates (March 10; March 30; April 19; and May 9), there was also an increase in stolon emission in the initial phase when planting dates were brought forward. Short-day materials emitted an average of eight stolons per plant in the initial phase, while the neutral-day materials tested here varied: ‘San Andreas’ (2.6 stolons plant^{-1}); ‘Beauty’ (4.1); ‘Bellalinda’ (7.6); ‘Alpina10’ (10).

The main difference in stolon emission occurs from November onwards, when the authors observed a high number of stolons in short-day materials, while this was almost nil in the day-neutral cultivars tested here. As will be seen below, the best results from early planting occurred with cultivars that produced fewer stolons in the fall, which may be related to the allocation of reserves to the differentiation of productive buds.

The earlier planting date resulted in an earlier average date of entry into production for the four cultivars (Figure 2). However, it is observed that anticipation (D1) generated a higher standard deviation, indicating greater unevenness among the plants. Some plants had already produced crops, while others had not yet flowered. In D2, greater uniformity may be associated with low-temperature environmental stimuli, which practically separated the onset of flowering and harvest within each cultivar. In the phenotype-environment interaction, 'Beauty' in D1 produced earlier harvests with less standard deviation among its plants, with the greatest difference in relation to cultivation in D2, indicating greater potential for early harvests.

'Bellalinda' showed the smallest difference between dates. In addition to genotype, seedling production conditions (domestic, imported, and environment) and production system (DIEL et al. 2017), planting season has a decisive effect on phenology. These data suggest the possibility of further studies on the association of early planting with complementary flowering induction techniques, such as seedling vernalization in cold chambers (OVIEDO et al. 2020). Early production and increased fruit mass can also be achieved by using supplemental artificial lighting with white light or a combination of red and blue light (MACHADO et al. 2018).

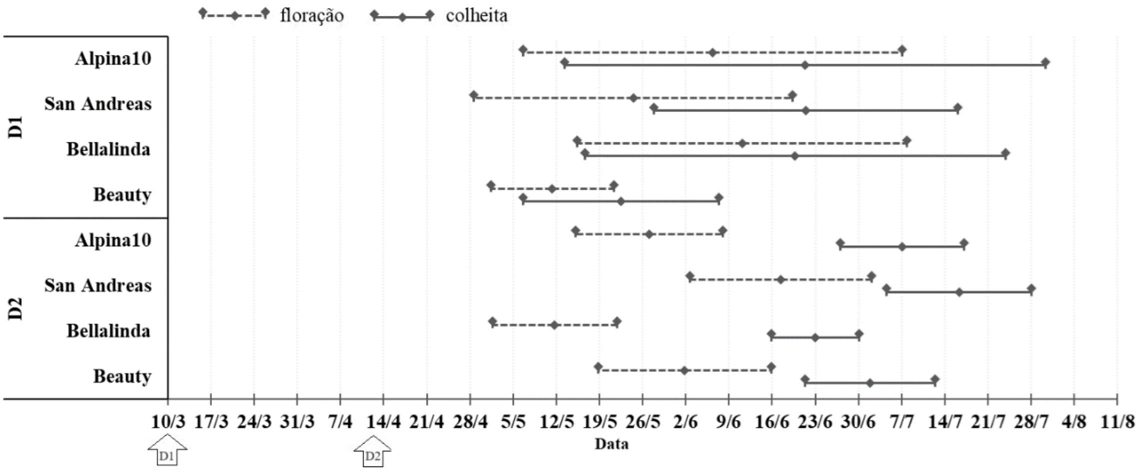

Figure 2. Average flowering and harvest start dates, with a standard deviation above and below, for four day-neutral strawberry cultivars on two planting dates in the Far West of Santa Catarina, 2022 harvest.

Regarding productivity and profitability data, there was no significant interaction between dates and cultivars for the variables: total number of fruits (NFT), number of commercial fruits (NFC), number of defective fruits (NFD), total fruit mass (MT), diseased fruit mass (MD), and average non-commercial mass (MMNC). For these variables, the data were compared between cultivars and between dates. In turn, there was interaction between dates and cultivars for the variables: number of non-commercial fruits (NFNC), mass of non-commercial fruits (MNC), total average mass (MMFT); commercial average mass (MMFC); expected gross revenue (RBE) from commercial production; and RBE from total production. In this case, the cultivars were compared on each date and the possible effect of the date for each cultivar was assessed.

b) Variables without interaction between planting dates and cultivars

In the analysis of total mass, no significant differences were found between cultivars, with an overall average of 589.7 g plant^{-1} (Figure 3). This yield was below the average obtained (770.2 g plant^{-1}) in a trial with fourteen genotypes in a semi-hydroponic system in Vacaria (RS), in which the short-day material 'Strawberry Festival' (1,109.6 g plant^{-1}) and the neutral day ‘FRF 102.21’ (1,138.5 g plant^{-1}) stood out (SANTOS et al. 2021).

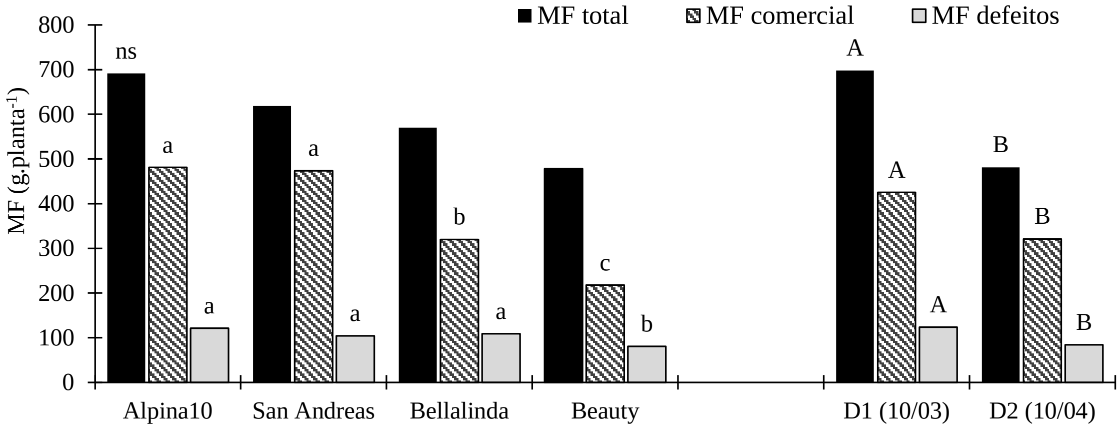

Figure 3. Total, commercial, and defective fruit mass (MF) per plant in a comparison between strawberry cultivars and dates in the 2022 harvest - São Miguel do Oeste (SC). Note: Identical letters (lowercase between cultivars; uppercase between dates) for the same variable did not differ from each other according to the Scott-Knott significance test (α>0.05).

When compared with data obtained by GRIEBELER (2021) in an experiment with later planting (May 18, 2020) in the same municipality, 'Alpina10' reached a total mass of 1157.3 g plant$^{-1,}$ above the 691.4 g plant^{-1} in the present experiment. For the cultivars 'Bellalinda' (652.8 g plant^{-1}) and 'San Andreas' (642.5), the data found by the author in 2020 differ little from those observed in this study (570.1 and 618.7 g plant^{-1}, respectively). Already being tested in the Southern Plateau of Santa Catarina, 'Bellalinda' (FRF 104.1) had lower productive performance, with 460.4 g plant^{-1} (ZANIN et al 2019).

The total fruit mass differed between the dates tested, with 697.9 g plant^{-1} on D1 and 481.5 g plant^{-1} on D2, indicating the benefits of early planting. Although the data indicate that early planting contributed to an increase in the average yield of the cultivars tested, the correlation with the study by GRIEBELER (2021) suggests that bringing forward the planting date does not generate benefits in the total yield of 'Alpina10', which may be associated with the high initial emission of stolons, as shown above.

When analyzing the mass of defective fruits, there was a significant difference between cultivars and between planting dates. 'Beauty' had the lowest mass of defective fruit. In terms of dates, planting on D2 (April 10) resulted in lower production of defective fruit. This greater mass of defective fruit in D1 suggests that early planting may increase the need for phytosanitary control measures.

The total number of fruits differed significantly between cultivars and dates, being higher on D1 (Figure 4).

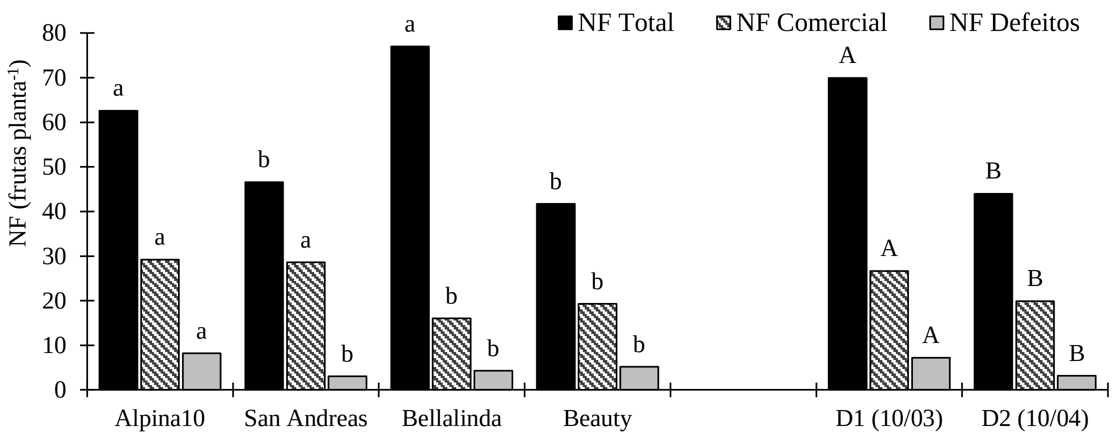

Figure 4. Number of total, commercial, and defective fruits (NF) per plant in the comparison between strawberry cultivars and planting dates in the 2022 Harvest - São Miguel do Oeste (SC). Note: Identical letters (lowercase between cultivars; uppercase between dates) for the same variable did not differ from each other according to the Scott-Knott significance test (α>0.05).

'Bellalinda' and 'Alpina10' had the highest total number of fruits, followed by the others. In the study by GRIEBELER (2021), 'Alpina10' produced a higher total number of fruits (102.1 fruits plant^{-1}) than 'Bellalinda' (71.1) and 'San Andreas' (51.5). In this experiment, with an earlier planting date, 'San Andreas' yielded 46.6 fruits plant^{-1} and 'Bellalinda' yielded 77 fruits plant^{-1}, very similar to the 2020 results, while 'Alpina10' yielded 62.6 fruits plant^{-1}. Although 'Bellalinda' maintained a similar total number of fruits between experiments, early planting reduced the proportion of commercial fruits from 31.6 fruits plant^{-1} (2020) to 16.1 fruits plant^{-1} (2022), resulting in an increase in the proportion of non-commercial fruits.

In terms of the number of commercial fruits, this was highest in the 'Alpina10' and 'San Andreas' cultivars, followed by the 'Bellalinda' cultivar and then 'Beauty'. As a result, the largest commercial masses are obtained with 'San Andreas' and 'Alpina10', followed equally by 'Beauty' and 'Bellalinda'. The average of the four cultivars for the number of fruits and commercial mass was significantly higher for D1 than for D2. In no case was the second harvest better than the first, indicating that early harvesting may not bring benefits for some cultivars (e.g., Alpina 10), but it did not result in losses in commercial mass obtained per plant.

When correlated with the production season, these results will affect expected revenue, as demonstrated below. In an experiment conducted in São Miguel do Oeste in 2020, NAIDK et al. (2022) found that bringing forward the planting date affected commercial productivity for the short-day cultivars 'Pircinque' and 'Jonica'. On the authors' first planting date, the large emission of stolons may have compromised the accumulation of reserves, which caused commercial production on March 10 to be lower than on May 9, although the production season made the expected profitability equivalent. The plantings on March 30 and April 19 did not differ in productivity from May 9, but the earlier planting was significantly more profitable.

c) Variables with interaction between planting dates and cultivars[1]

[1] Despite the absence of interaction for monthly commercial production in September, December, and January, these were presented together with the other months.

The analysis of the average mass of total fruits (MMFT) and commercial fruits (MMFC) indicated interactions between dates and cultivars, which were broken down. MMFT, in D1, the cultivation of larger fruits stands out for the 'San Andreas' and 'Beauty' cultivars, followed by 'Alpina10' and then 'Bellalinda'. In D2, San Andreas was superior, followed by Alpina10, then Beauty, and finally Bellalinda. In the comparison of the same cultivar between dates, MMFT was higher on D1 for 'Beauty', and higher on D2 for the other three cultivars (Figure 5). In the study conducted by GRIEBELER (2021), with planting on May 18, 2020, the 'Bellalinda' cultivar did not differ from 'Alpina10' and 'San Andreas' in terms of MMFT. These data indicate that bringing forward the planting date can affect the proportion of commercial production, with different impacts among cultivars.

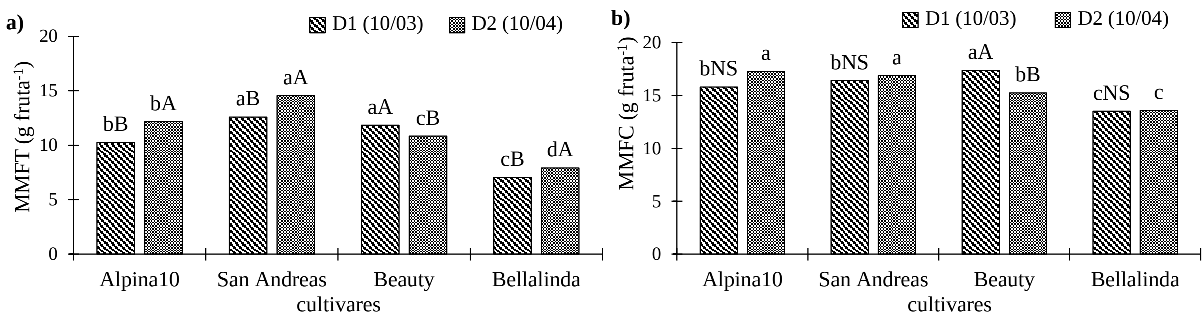

Figure 5. Average mass of total fruit (a: MMFT) and commercial fruit (b: MMFC) per plant for four day-neutral strawberry cultivars on two planting dates in the Far West of Santa Catarina, 2022 harvest. Note: Means with different letters, lowercase in the comparison between cultivars for the same date, and uppercase between dates for the same cultivar, differ from each other by the Scott-Knott significance test (α>0.05).

According to FAGHERAZZI (2017), fruit classification based on weight is very important for strawberries, as those weighing less than 10 g are considered non-commercial (intended for industrial use). When it comes to the final commercialization of the product, there is no point in the genotype having good total productivity per plant if it has a low rate of fruit suitable for *in natura* sale, which has a better consumer acceptance rate and a better price. When separating fruits <10 g and those with defects, the MMFC on D1 was higher for 'Beauty', followed equally by 'San Andreas' and 'Alpina10', with 'Bellalinda' having the lowest mass. In D2, the largest mass occurred for 'San Andreas' and 'Alpina10', followed by 'Beauty'. Once again, 'Bellalinda' produces fruit with a lower average weight, which indicates limitations in supporting a high fruit load. In the MMFC comparison between dates for the same cultivar, D1 was higher than D2 for 'Beauty', with no difference for the other cultivars.

The variables number of non-commercial fruits (NFNC) and non-commercial mass (MNC) resulted in interaction between dates and cultivars (Figure 6). The 'Bellalinda' cultivar had higher NFNC and higher MNC on both dates, followed by 'Alpina10'. In D1, the lowest NFNC occurred for 'San Andreas' and 'Beauty', with no difference between them, while for D2, 'San Andreas' resulted in the lowest NFNC. When standardized by fruit <10 g, these differences are reproduced almost equally for MNC. The only difference is that in D1, 'Beauty' is isolated with the lowest MNC. In the comparison between dates, the cultivars 'Alpina10', 'San Andreas', and 'Bellalinda' resulted in higher NFNC and MNC on D1. For ‘Beauty’, there was no significant difference between D1 and D2.

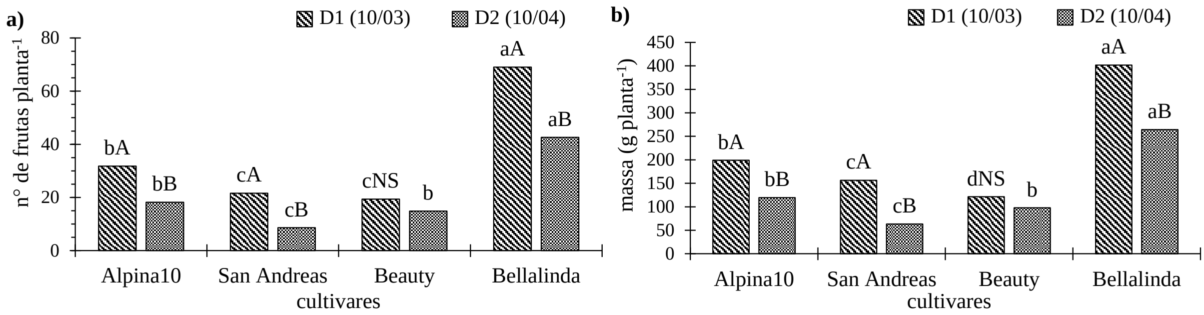

Figure 6. Number (a) and mass (b) of non-commercial fruits per plant for four day-neutral strawberry cultivars on two planting dates in the Far West of Santa Catarina, Harvest 2022. Note: Means with different letters (lowercase between cultivars for the same date; uppercase between dates for the same cultivar) differ significantly from each other based on the significance analysis of the Scott-Knott test (α>0.05).

While non-commercial production can be frozen for industry and its price fluctuates little, commercial mas has different prices depending on the season of supply, being higher in the so-called market windows. When we look at the monthly grouped commercial mass data, early planting contributed to supply in May and June for all cultivars, while the second date only began commercial fruit production in July (Figure 7). The ‘Beauty’ cultivar stands out, as it was more productive in the first three months, indicating potential for early cultivation. In August, ‘Alpina10’ achieves higher productivity in D1, followed by ‘San Andreas’.

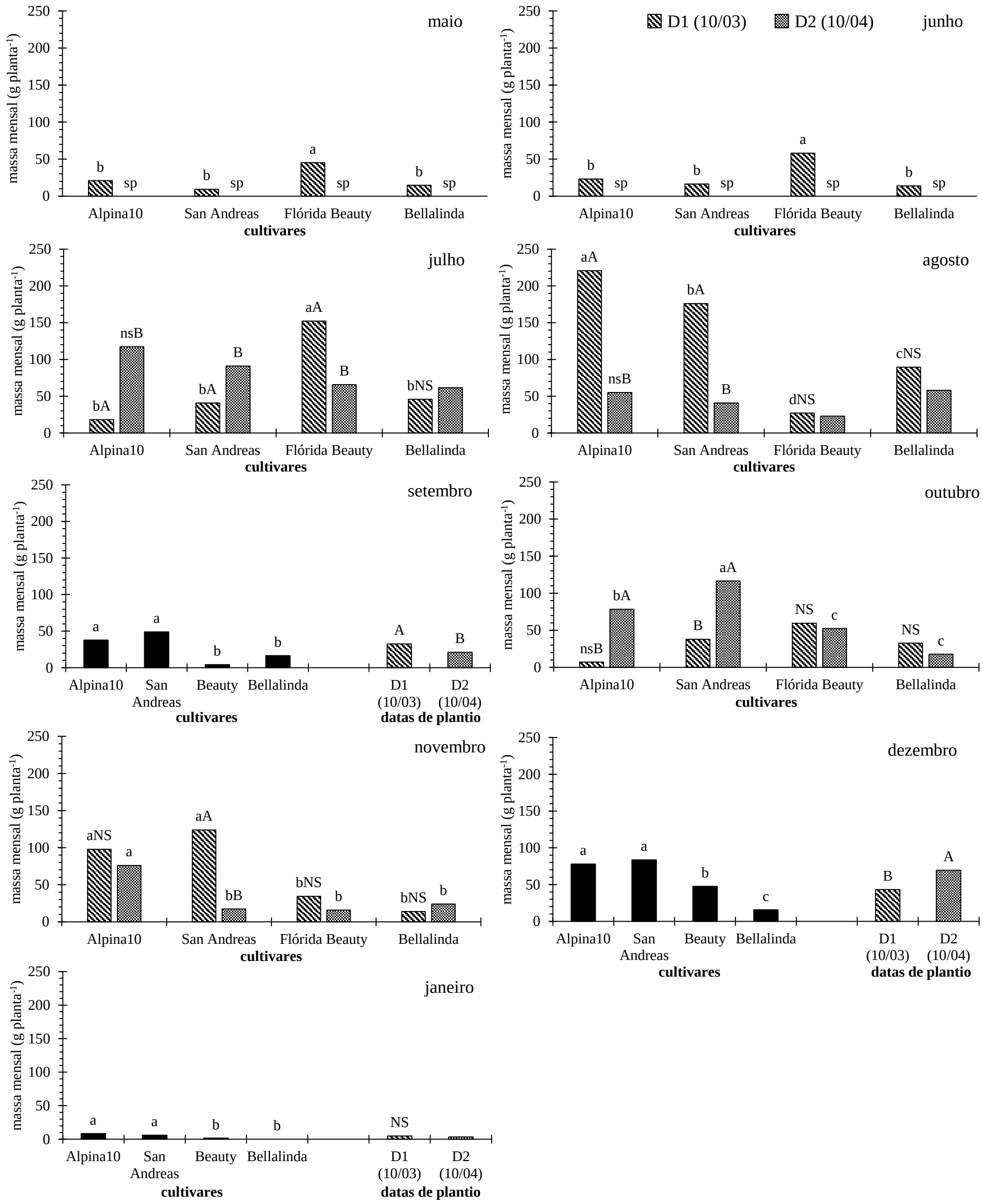

Figure 7. Monthly commercial production per plant for four day-neutral strawberry cultivars on two planting dates in the Far West of Santa Catarina, 2022 harvest. Notes:1) "sp" indicates no production. 2) "ns" or "NS" denotes not significant. 3) September, December, and January (partial) did not show a significant interaction between dates and cultivars: Equal letters (lowercase between cultivars; uppercase between dates) indicate no significant difference according to the significance analysis of the Scott-Knott test (α > 0.05).May, June, July, August, October, and November exhibited a significant interaction between dates and cultivars: Means with different letters (lowercase between cultivars on the same date, and uppercase between dates on the same cultivar) differ significantly from each other based on the significance analysis of the Scott-Knott test (α>0.05).

Commercial production of cultivars on both dates became more significant in July and August, when the second crop also begins to be available. In September, a month with no interaction between dates and cultivars, the best results were obtained with ‘Alpina10’ and ‘San Andreas’, with D1 being the most productive. In October, the best result was achieved by 'San Andreas' in D2, followed by Alpina10. In November, 'San

Andreas' generates the highest commercial production in D1, along with 'Alpina10'. In December and January, there is no interaction, with the most productive cultivars being ‘Alpina10’ and ‘San Andreas’. In December, D2 is higher than D1, but in January there are no significant differences.

When observing the weekly production of cultivars on different dates (Figure 8), it can be seen that the supply of different materials occurs with peaks in productivity, fluctuating over time. In the weeks between July 13, 2022, and August 3, 2022, there were peaks in crop production, especially for the ‘Beauty’ variety on D1. A second significant peak is concentrated between August 10, 2022, and September 7, 2022, with superior performance from Alpina10 and San Andreas, both on D1.

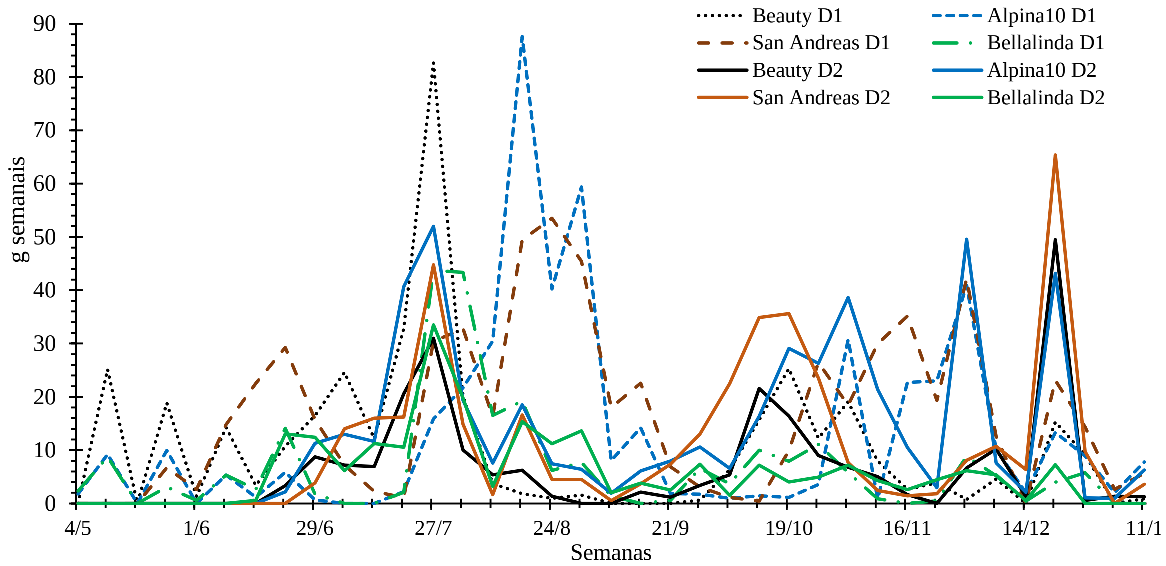

Figure 8. Weekly production curve of four strawberry cultivars on two planting dates (D1: 03/10/2024; D2: 04/10/2024) during the 2022 Harvest in São Miguel do Oeste (SC).

These data are similar to those observed by NAIDK et al. (2022), who found a peak in productivity in the second half of July and another between mid-August and September for the Pircinque and Jonica cultivars when planted early. However, while the authors observed the start of production only in the second half of June, in the early cultivation of the present experiment, with day-neutral cultivars, it began as early as the beginning of May. Another difference in relation to what was observed by the authors stems from the greater susceptibility of short-day materials to the maximum temperature peaks recorded at the end of the crop cycle. Thus, while short-day production becomes unfeasible in early December, neutral-day production continues to achieve good productivity peaks in the following period in the study region.

The analysis of expected gross revenue (RBE) correlated production with the variation in the average weekly commercial price of the product at CEASA in São José, SC. The results indicated significant interaction between dates and cultivars. Planting on D1 generated higher commercial gross revenue expectations than D2 for the cultivars ‘San Andreas’ and ‘Beauty’, with no difference for ‘Alpina10’ and ‘Bellalinda’ (Figure 9). In D1, the ‘San Andreas’ cultivar generated the highest commercial RBE. In D2, 'San Andreas' was no different from 'Alpina10'. By including production for industry (<10 g) in the RBE calculation, multiplied by the lowest price recorded at

CEASA, we obtained the total RBE. The ‘San Andreas’ cultivar maintains higher expected yields in D1, while ‘Bellalinda’ ties with the other two cultivars. In D2, the best results are for ‘Alpina10’ and ‘San Andreas’, followed equally by ‘Beauty’ and ‘Bellalinda’. When comparing dates for each cultivar, planting on D1 generates higher total gross revenue for ‘San Andreas’, ‘Beauty’, and ‘Bellalinda’, while there were no significant differences between dates for ‘Alpina10’.

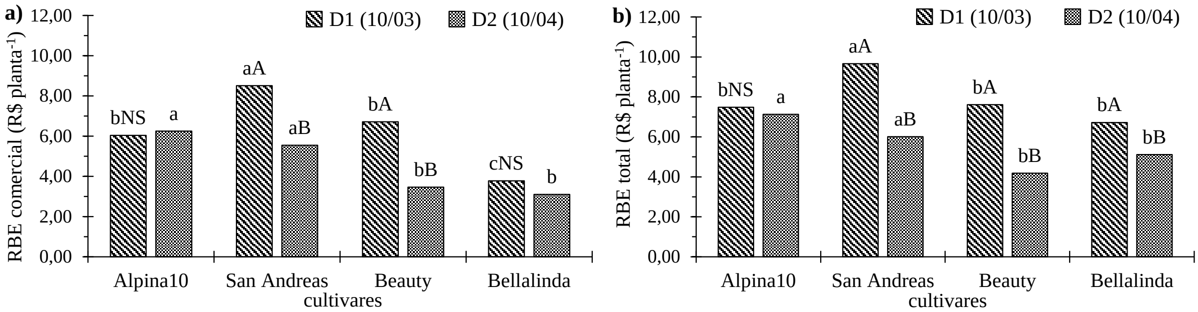

Figure 9. Expected gross revenue (RBE) from commercial production (a) and total production (b) for four day-neutral strawberry cultivars on two planting dates in the Far West of Santa Catarina, Harvest 2022. Note: Means with different letters (lowercase between cultivars for the same date; uppercase between dates for the same cultivar) differ significantly from each other based on the significance analysis of the Scott-Knott test (α>0.05).

In the study conducted by NAIDK et al. (2022), an increase in the economic benefits of bringing forward planting to March 30 and April 19 was observed when compared to May 9. March 10 was no better than May 9, which indicated a limit to this anticipation, but the authors attributed this result to the atypical period of high temperatures. When testing day-neutral genotypes, the current study shows that March 10 may be a good date for planting. In this case, the different effects on cultivars must be considered, but early planting did not cause damage to any of the four cultivars tested in this study. In turn, early planting did not generate economic benefits for commercial and total production income for ‘Alpina10’, indicating that later planting may be more appropriate, as it reduces production time and, consequently, costs.

CONCLUSION

The agronomic performance of strawberry plants is affected by the planting season, with effects differing between genotypes. The planting season, with or without interaction with genotypes, altered the number of stolons emitted, the time to flowering and fruiting, the mass and number of total fruits, commercial fruits, non-commercial fruits per plant, the production period, and the expected commercial and total gross revenues.

Advancing planting to Date 1 (March 10) resulted in greater total and commercial fruit mass than on D2 (April 10). There were no differences in total mass between cultivars. The commercial mass and number of fruits differed among the cultivars tested. 'San Andreas' and 'Alpina10' achieved the highest commercial productivity, followed by 'Bellalinda' and then 'Beauty'.

When forecasting expected gross revenue (RBE), there was interaction between dates and cultivars for economic results. The advance for D1 led to an increase in: a) commercial RBE for 'San Andreas' and ‘Beauty’; and b) total expected RBE for 'San Andreas', 'Beauty', and 'Bellalinda'. The highest commercial and total RBE expected in D1 occur with the ‘San Andreas’ cultivar, while in D2 the total RBE of this cultivar is equal to that of ‘Alpina10’.

Early planting results in greater stolon emission at the beginning of the cycle. These are issued in large numbers, which generates some demand for labor, in addition to increasing the use of supplies with the extension of the cultivation cycle. These criteria should be added to the cost-benefit analysis to verify whether or not it is appropriate to bring forward planting.

NOTES

AUTHORS' CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Cappellesso, A. J., Cardoso, F. L. and Miotto, A.; research, Cappellesso, A. J., Scapin, L. C.; resources, Cardoso, F. L.; writing - preparation of the original draft, Cardoso, F. L., Cardoso, F. L., Miotto, A. and Scapin, L. C.; writing - revision and editing, Cappellesso A. J.; supervision, Cappellesso, A. J., Cardoso, F. L. and Miotto, A.; project management, Cardoso, F. L.; obtaining financing, Cardoso, F. L. and Cappellesso, A. J. All authors have read and agreed to the published version of the manuscript.

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STATEMENT BY THE INSTITUTIONAL REVIEW BOARD

Not applicable to studies that do not involve humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

Data can be made available upon request.

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CONFLICTS OF INTEREST

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