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Seed formation in banana (*Musa* spp.) in relation to time of year and environmental conditions in the Brazilian subtropics

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ABSTRACT

One of the main methodologies for banana improvement is the crossing between commercial varieties and improved diploids, seeking new genotypes that produce fruits with characteristics already accepted by the consumer market and resistant to the main pests and diseases. However, the vast majority of commercial varieties are triploid with a high degree of infertility, making it difficult to generate new genotypes. Thus, the frequency of formation of complete banana seeds pollinated at different times of the year and environmental conditions was evaluated. It was observed that the highest frequency of seeds was obtained in meteorological autumn and in mid-season environmental conditions, however, the explanatory mechanism is still uncertain.
Keywords: Pome Subgroup, plant breeding, crosses, Genetic.

RESUMEN

Una de las principales metodologías para el mejoramiento del banano es el cruce entre variedades comerciales y diploides mejoradas, buscando nuevas variedades con características ya aceptadas por el mercado consumidor y resistentes a las plagas y enfermedades. Sin embargo, la gran mayoría de las variedades comerciales son triploides con un alto grado de infertilidad, dificultando la generación de nuevos genotipos. Así, se evaluó la frecuencia de formación de semillas completas de banana con polinización en diferentes épocas del año y condiciones ambientales. Se observó que la mayor frecuencia de semillas se obtuvo en otoño meteorológico y en condiciones ambientales de media estación, sin embargo, el mecanismo explicativo aún es incierto.
Palabras Clave: Subgrupo Prata, fitomejoramiento, cruces, Genética.

INTRODUCTION

Banana is one of the most economically and socially important plants in the world, with world trade being restricted, basically, to the Cavendish subgroup, and Brazilian trade to the Pome and Cavendish subgroups (Lichtemberg e Lichtemberg, 2011; Voora et al. 2020). These two subgroups are formed by triploid varieties, all genetically very similar in each subgroup, since the main methodology for generating new varieties in these two subgroups is the selection of spontaneous mutants (Scherer et al. 2023). Varieties of the Pome subgroup and the Cavendish subgroup are susceptible to diseases of the Sigatoka complex and Panama disease (in this case, the Cavendish subgroup only to race 4) (Beltrame et al. 2023), requiring that research institutions solve these problems. In this way, research institutions around the world have been seeking to create new varieties that have commercial importance (domestic or international) and resistance to the main phytosanitary problems. In this sense, hybridization between commercial varieties and improved diploids is one of the main methodologies used, since it allows combining commercial characteristics with other characteristics of interest (Perrier et al. 2011). However, the vast majority of commercial banana varieties are triploid and have a high degree of sterility, which makes it difficult to generate seeds and, consequently, new hybrid varieties (Heslop-Harrison and Schwarzacher, 2007). Thus, the present work aimed to evaluate whether there are temporal/environmental characteristics that provide better conditions for the generation of banana seeds in southern Brazil.

MATERIALS AND METHODS

The experiment was carried out at the Itajaí Experimental Station of the Agricultural Research Company of Santa Catarina State (Epagri), Brazil, located at coordinates 26°57'08.9”S and 48°45'38.9”W, with a humid subtropical climate (Cfa in the Köppen classification) and average annual rainfall of 1,770mm.

A monthly pollination experiment was carried out from October 2019 to September 2021, with crossings taking place in the morning. Regarding the number of pollinated commercial genotypes: 248 variety plants were from the Pome subgroup (‘Prata Anã’, ‘SCS453 Noninha’ and ‘SCS454 Carvoeira’), with an average of 7.29 plants per month; and 238 plants of varieties from the Cavendish subgroup (‘Grande Naine’ and ‘Nanicão’), with an average of 7.0 plants per month. As for the male parents, 16 genotypes were randomly used from a collection of improved diploids, which is maintained at Epagri.

Plants with recently opened bunches (on average, 2.37 open hands) were chosen to start the first day of pollination in each month, which continued in the following days as the plants emitted new hands, with all hands of the chosen bunches being pollinated. Each plant was pollinated with just one male parent. The pollinated bunches were harvested at the harvest point and climatized. When ripe, the fruits were opened to look for seeds manually. For every seed obtained, embryo rescue was carried out and the number of complete seeds (seeds that contained endosperm and embryo) were counted.

Regarding data analysis, it was verified whether temporal conditions (month, year and season) and climatic conditions [Temperature (ºC), Humidity (%), precipitation (mm) and radiation (Wm^2)] influenced the frequency of complete seeds obtained. In the case of environmental conditions, the values used were the morning averages of the period of pollination days in each month, and the data were obtained directly from the Center for Environmental Information and Hydrometeorology (Epagri/Ciram). Factor comparisons were made using the chi-square test, considering 95% reliability.

RESULTS AND DISCUSSION

At the end of the three years of evaluation, 54 complete seeds were obtained from crosses between varieties of the Pome subgroup and improved diploids and no seeds from crosses between varieties of the Cavendish subgroup and improved diploids. Therefore, statistical analyzes were carried out only on data obtained from crosses between varieties of the Pome subgroup and improved diploids.

Regarding the chi-square tests, when the variable number of seed-forming plants was analyzed, the results were not significant neither when the treatments analyzed were the months in each year, nor when the treatments were each month (sum of the three years for each month) (Figure 1A and 1B). However, when the variable analyzed was the number of seeds in relation to the number of pollinated plants, the test indicated significant differences both when the treatments were the months in each year, and when the treatments were each month, however, without providing very relevant information, just that the highest values normally belonged to mid-season months (Figure 1C and 1D). These results provide an isolated ranking of treatments, without bringing any generalist trend, in this way, the months were grouped in the meteorological seasons of the southern Brazilian region, being: summer=December, January and February; Autumn=March, April and May; Winter= June, July and

August; and Spring= September, October and November. The observed results showed that the frequency of obtaining seeds in the meteorological autumn was higher than in other seasons, which did not differ from each other (Figure 1E).

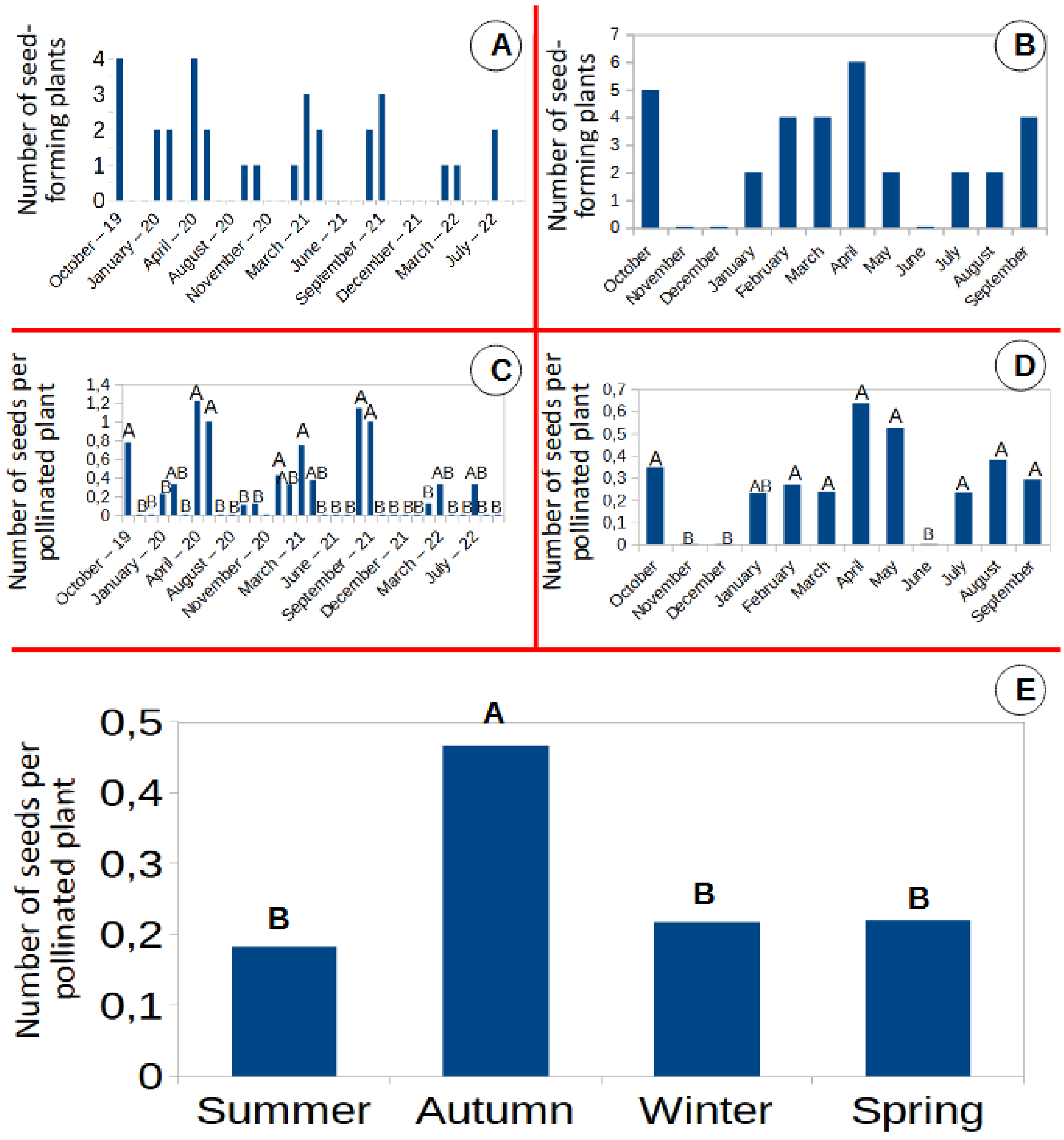

Figure 1. Number of seed-forming plants or seeds per pollinated plant in different times of the year. A) Number of seed-forming plants between October 2019 and September 2022; B) Number of seed-forming plants in each month (sum of three years for each month); C) Number of seeds per pollinated plant between October 2019 and September 2022; D) Number of seeds per pollinated plant in each month (sum of three years for each month); E) Number of seeds per pollinated plant in the different meteorological seasons of the year between October 2019

and September 2022. Means in columns followed by different letters differed by chi-square test (95% reliability).

In relation to environmental variables, the number of seeds formed was related to four temperature ranges, 13 to 16ºC, 17 to 20ºC, 21 to 24ºC and 25 to 28ºC, with the highest frequency of seeds being generated in the medium temperature range from 17 to 20ºC and the other ranges did not differ from each other (Figure 2A). Regarding radiation, the ranges evaluated were: 100 to 199; 200 to 299; 300 to 399; 400 to 499; 500 to 599 and 600 to 699 Wm^2, with the highest frequencies of seeds generated occurring in the ranges of 300 to 399 Wm^2 and 200 to 299 Wm^2, with the remaining ranges showing no differences between them, but the range of 200 to 299 Wm^2, despite not differing from the range with the highest seed frequency, also did not differ from the ranges with lower frequencies (Figure 2B). Regarding rainfall, in addition to the absence of rain (0 mm), ranges between 0.01 and 0.19, 0.2 and 0.39 and greater than 0.4 mm were evaluated, with no differences between treatments (Figure 2C). Similarly, the humidity variation also did not present significant differences, with the ranges studied being: 75 to 79.9%, 80 to 84.9%, 85 to 89.9% and 90 to 94.9% relative humidity (Figure 2D).

The range of average temperatures of 17 to 20ºC and intermediate radiation values (in the ranges of 300 to 399 Wm^2 and 200 to 299 Wm^2) correspond to mid-season conditions (Spring and Autumn) in the southern region of Brazil, however, according to the results obtained, only the autumn meteorological season showed a greater formation of complete seeds, with spring not differing from summer and winter. This may be related to the nutritional conditions of the plants, since, according to Guimarães et al., (2023), in the subtropical region of the study, from September to December, plants are deficient in some nutrients (Ca, Zn, Cu and B) even though they are available in the soil. Precisely elements such as Ca and B that in other studies show to be closely linked to plant fecundity (Zhang et al. 2019; Muengkaew et al. 2016).

In this sense, Waniale et al. (2021) found that the highest frequency of seed formation within each cultivar was observed in more developed bunches, which is linked to plant nutrition. On the other hand, Waniale et al. (2021), found that seed frequency was observed in the hottest and driest months, which differs from the results obtained in this work. This may be related to the specific conditions of each location where the studies took place and/or to a genotype dependence of the *Musa* spp. in relation to fecundity, since the varieties used in the two studies are different.

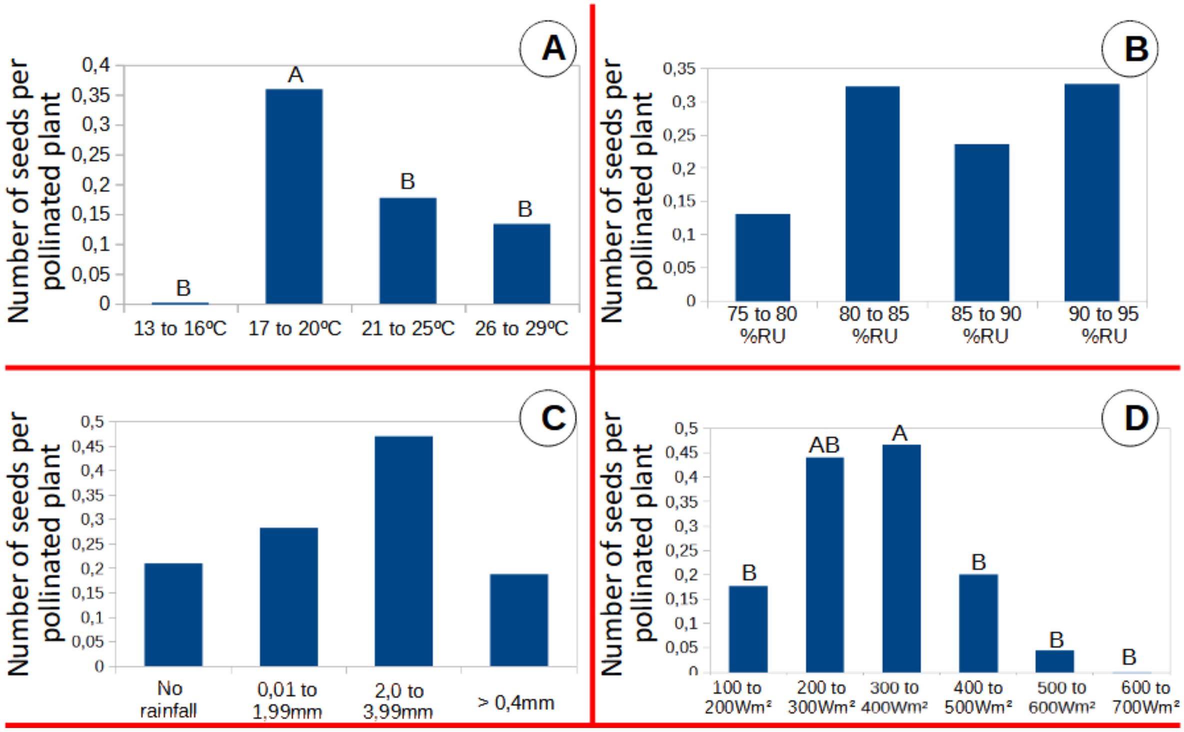

Figure 2. Number of seeds per pollinated plant in relation to different environmental factors. A) Different ranges of average temperature (ºC) during the pollination period; B) Different ranges of average relative humidity (%) during the pollination period; C) Different ranges of rainfall (mm) during the pollination period; D) Different radiation bands (Wm²) during the pollination period. Means in columns followed by different letters differed by chi-square test (95% reliability).

CONCLUSIONS

Based on the results, we can observe that the frequency of complete seed formation in bananas fluctuates throughout the year and that pollination during meteorological autumn was the best time to obtain a higher frequency of complete seeds in the state of Santa Catarina, subtropical region of Brazil. However, it is not possible to say which mechanism(s) explain this seasonality; that is, whether it is due to some meteorological condition(s), or to plant nutrition (which in the subtropics, can also be linked to the meteorological condition), or both or other interactions with more factors. The difficulty in making any statement related to environmental conditions is due to the fact that the data used in this work are the morning averages of pollination periods, since in this experiment the day and time at which each hand was pollinated were not recorded. Therefore, it is suggested that future studies that wish to explore such information consider the environmental characteristics of the moment of pollination of each hand in order to advance knowledge related to the reproductive biology of the banana tree, in particular, the optimum conditions for banana pollination.

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