BIOSCIENCE JOURNAL

AGRONOMIC PERFORMANCE OF NEW ARABICA COFFEE CULTIVARS IN IRRIGATED CULTIVATION SYSTEMS

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How to cite: SILVA, I. S., et al. Agronomic performance of new arabica coffee cultivars in irrigated cultivation systems. *Bioscience Journal*. 2025, **41**, e41017. https://doi.org/10.14393/BJ-v41n0a2025-72534

Abstract

The agronomic performance of *Coffea arabica* cultivars can vary depending on the production region, cultivation system, and adopted technologies. The Cerrado of Minas Gerais stands out in both the Brazilian and global coffee sectors for its high productivity and bean quality, supported by widespread mechanization and irrigation. Therefore, this study aimed to evaluate the agronomic performance of new *C. arabica* cultivars—focusing on productivity, yield, and grain size—under irrigated cultivation in the Cerrado, with the goal of identifying cultivars with superior adaptation and performance under controlled water management. Ten cultivars were assessed, including eight rust-resistant cultivars (Catiguá MG2, MGS Ametista, MGS Aranãs, MGS Paraíso 2, Paraíso MG H419-1, Pau Brasil MG1, MGS Catucaí Pioneira, and Sarchimor MG8840) and two rust-susceptible standards widely used in the region (Catuaí Vermelho IAC 144 and Topázio MG 1190). Evaluated traits included productivity, yield, and bean size (granulometry). Principal Component Analysis (PCA) was applied to explore correlations and cultivar clustering. Sarchimor MG8840, MGS Catucaí Pioneira, Topázio MG1190, and Catuaí Vermelho IAC 144 exhibited superior productivity and favorable bean size profiles, indicating good adaptation to irrigated conditions. In contrast, Paraíso MG H419-1 and Pau Brasil MG1 had smaller bean sizes. Uniform water availability throughout the crop cycle minimized yield differences, highlighting the role of controlled irrigation in optimizing coffee productivity. These findings contribute to informed cultivar selection for irrigated coffee systems in the Cerrado region.

Keywords: Cerrado of Minas Gerais. *Coffea arabica* L. Granulometry. Irrigation. Productivity. Yield.

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Received: 23 February 2024
Accepted: 11 June 2025
Published: 27 September 2025

1. Introduction

Over the years, knowledge and technologies have been generated through research in coffee farming. Coffee genetic improvement programs have allowed obtaining cultivars with high productive potential, resistance to pests and diseases, superior beverage quality, better fruit maturation uniformity, physical and chemical quality, and tolerance to abiotic stresses, among other agronomic characteristics of interest to producers and consumers.

The Ministry of Agriculture, Livestock, and Supply (MAPA) currently lists in the National Register of Cultivars (RNC) 126 Arabica coffee cultivars available for cultivation in the country (MAPA 2025), most resistant to rust and some resistant to other pests/diseases that threaten the coffee crop. However, despite the large number of cultivars available, most coffee crops in Brazil consist of varieties from the Catuaí and Mundo Novo groups , which are susceptible to rust (Sera et al. 2022). The adoption of new cultivars has been slow, mainly due to the lack of information regarding the new genetic materials. Additionally, many producers are still unaware that rust-resistant cultivars can also exhibit excellent beverage quality.

The agronomic performance of cultivars can vary depending on regional characteristics, cultivation systems, and adopted technologies (Pham et al. 2019). This is especially relevant for the Cerrado biome, which plays a prominent role in Brazil's coffee sector. The Cerrado of Minas Gerais is characterized by distinct edaphoclimatic conditions, including well-defined rainy and dry seasons, average annual temperatures between 20 and 23 °C, and rainfall concentrated between October and March (Aragão et al. 2020). These climatic conditions directly influence coffee plant development, especially when combined with modern cultivation practices such as mechanization and controlled irrigation.

Given the perennial nature of coffee and the high investment required to establish plantations, the selection of well-adapted cultivars is a critical decision (Matielo et al. 2020). In this context, understanding the agronomic performance of cultivars in irrigated systems in the Cerrado is essential to guide producers toward sustainable and profitable decisions.

Therefore, this study aimed to evaluate the agronomic performance of new *Coffea arabica* cultivars under irrigated cultivation conditions in the Cerrado of Minas Gerais, focusing on productivity, yield, and bean size distribution. The goal was to identify cultivars with superior adaptation and performance under controlled water management systems.

2. Material and Methods

The experiment was conducted in the experimental field of Terrena Agronegócios, located in Patos de Minas, Minas Gerais (MG), Brazil. The municipality lies at 18°52' S and 46°44' W, with an average altitude of 950 meters. According to the Köppen climate classification, the region has a humid subtropical climate with dry winters and rainy summers (Cwb) (Alvares et al. 2013). The soil in the experimental area is classified as a dystrophic Red Latosol, typical of the Cerrado biome, with good drainage and medium fertility, making it suitable for mechanized coffee production.

Figure 1 presents the climatic conditions of Patos de Minas during the experimental period, with an average temperature of 22 °C and total annual rainfall of approximately 1,080 mm. The climate is characterized by well-defined seasonality, marked by a dry season from May to August and a rainy season from September to March (Instituto Nacional de Meteorologia – INMET 2021).

The experimental trial was established in April 2017 using seedlings of *Coffea arabica* L. cultivars. Plants were spaced 3.8 m between rows and 0.53 m between plants within rows, resulting in a stand density of 4,965 plants per hectare. A total of ten cultivars were evaluated: eight rust-resistant cultivars—Catiguá MG2, MGS Ametista, MGS Aranãs, MGS Paraíso 2, Paraíso MG H419-1, Pau Brasil MG1, MGS Catucaí Pioneira, and Sarchimor MG8840—and two rust-susceptible cultivars widely adopted in the region as productivity standards—Catuaí Vermelho IAC 144 and Topázio MG 1190 (Fernandes et al. 2012) (Table 1).

All cultural practices followed technical recommendations for irrigated coffee cultivation in the Cerrado region, including fertilization, weed control, pest and disease monitoring, and pruning. Data were collected during the 2019 and 2020 harvest seasons to evaluate productivity, yield, and grain size distribution.

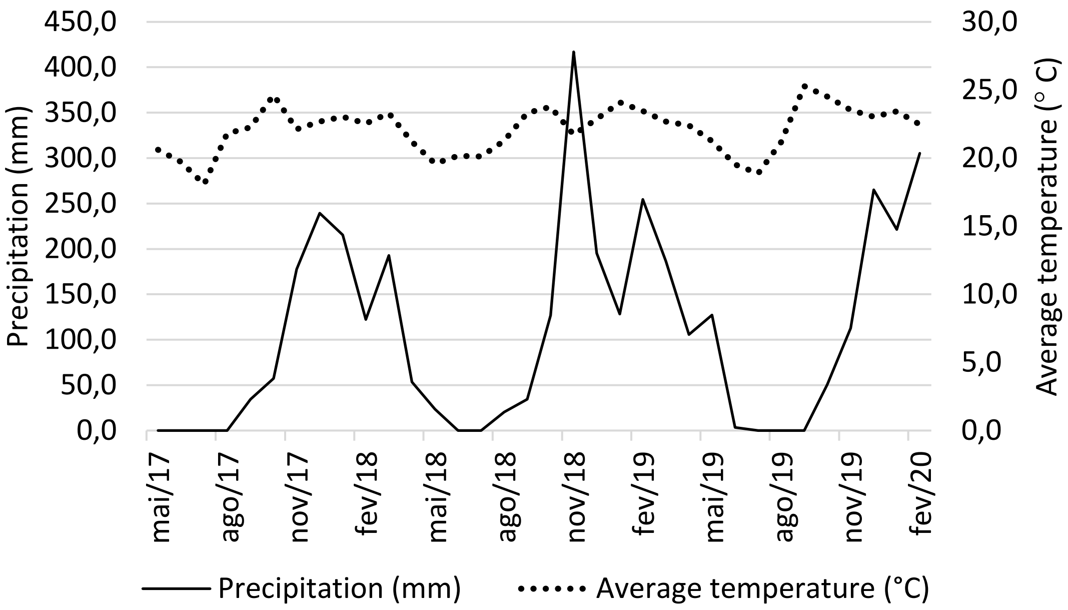

Figure 1. Accumulated monthly precipitation and average monthly temperature in Patos de Minas – MG, during the experimental period from May 2017 to February 2020.
Source: Adapted from INMET (2021).

A chemical sampling and analysis of the experimental area was performed for soil correction. The corrective dose was based on increasing saturation by bases, aiming to reach 70% (Raij et al. 1996). The limestone and gypsum were applied to the entire area, with the limestone incorporated into the soil and the gypsum applied to the surface.

A drip-irrigated cultivation system was adopted, with two weekly applications primarily during the dry season, each lasting three hours. Drippers were spaced 0.6 meters apart, with a flow rate of 1.6 liters per hour. Irrigation management was based on water balance calculations provided by the Sistema de Monitoramento da Irrigação do Cerrado (SMIC), which considers climatic variables such as rainfall, temperature, and evapotranspiration to estimate crop water requirements. All other cultural practices were performed according to technical recommendations for coffee cultivation in the Cerrado region.

Table 1. Evaluated cultivars and their genealogies.

Nº	Cultivars	Genealogy
1	Pau Brasil MG1	Catuaí V. IAC 141 x Híbrido Timor UFV 442-34
2	MGS Catucaí Pioneira	Icatu V. x Catuaí
3	MGS Aranãs	Catimor UFV 1603-215 x Icatu V. IAC 3851-2
4	Topázio MG 1190*	Catuaí A. x Mundo Novo
5	MGS Paraíso 2	Catuaí A. IAC 30 x Híbrido Timor UFV 445-46
6	MGS Ametista	Catuaí A. IAC 86 x Híbrido de Timor UFV 446-08
7	Paraíso MG H419-1	Catuaí A. IAC 30 x Híbrido Timor UFV 445-46
8	Catiguá MG2	Catuaí A. IAC 86 x Híbrido de Timor UFV 440-10
9	Catuaí V. IAC 144*	Caturra A. IAC 476-11 x Mundo Novo IAC 374-19
10	Sarchimor MG8840	Villa Sarchi x Hibrido de Timor CIFC 832/2

V. Vermelho, A. Amarelo. *Cultivars used as control.

The experiment followed a randomized complete block design (RCBD) with ten *Coffea arabica* cultivars (Table 1) and three replicates, totaling 30 plots. Each plot consisted of a single row with ten plants. All plants were included in the evaluations, as no border effects were expected under the uniform conditions of the irrigated system.

The production of each plot was measured in liters per total fruit harvest and later converted into bags of 60 kg of processed coffee ha^{-1}, according to the yield of each cultivar. Yield was calculated using a five-liter sample of coffee harvested from each plot, which was packed in a braided polyethylene bag and kept for drying in the yard until the beans reached approximately 11% water content. Subsequently, the samples were processed and weighed.

A sample of 300 g of processed coffee with no impurities or broken was passed through a set of sieves (19/64 to 12/64 for flat and 13/64 and 08/64 for mochas) to calculate the granulometry. For this purpose, we considered the sum of the weights of the retained in sieves 16/64 and above for flat and in sieves 13, 12, 11, 10, 09, and 08/64 for mocha, according to MAPA Normative Instruction nº 8 (Brasil 2003). Data were expressed as a percentage.

Statistical analysis

Data analysis was divided into two stages: univariate and multivariate approaches.

In the univariate analysis, analysis of variance (ANOVA) was performed using Sisvar software (Ferreira 2019) to test for significant differences among cultivars. When significance was detected by the F-test at the 5% probability level ($p \leq 0.05$), means were grouped using the Scott-Knott clustering test, which is appropriate for comparing cultivars in breeding trials.

For the multivariate analysis, Principal Component Analysis (PCA) was employed to explore relationships among variables and to distinguish the performance of the evaluated cultivars. Prior to PCA, all mean values were standardized (z-scores) to a mean of zero and a standard deviation of one to ensure comparability across variables. The analysis was conducted using the FactoMineR package in R software, version 4.3.2 (R Core Team 2020), and biplots were generated to visualize cultivar distribution and variable contributions. The following variables were included in the PCA: percentages of flat beans retained on sieves 13, 14, 15, 16, 17, 18, and ≥16; mocha beans retained on sieves 10 and 12; as well as productivity (bags per hectare) and yield (kilograms of processed coffee per hectare) for the 2019–2020 biennium.

3. Results

Although the experiment was conducted under a drip-irrigated system, climatic variability during the 2019–2020 biennium may have influenced the agronomic performance of the evaluated cultivars. Figure 1 presents the average monthly climate data for Patos de Minas (MG), revealing the typical seasonality of the Cerrado, with a distinct dry period from May to August and a rainy season extending from September to March. The average temperature was approximately 22 °C, with moderate thermal amplitude. These environmental conditions, particularly during flowering and fruit development, may have affected the physiological responses of the plants and contributed to performance differences among genotypes, even under controlled water supply.

Productivity is a predominant attribute in the selection of coffee cultivars since it directly influences the profitability of the crop. Therefore, we considered average productivity, yield, sieve, and the biennium for the analysis. The average productivity was 70 bags $ha^{-1.}$ Two groups were formed, with emphasis on the cultivars Topázio MG1190 (77.13 bags ha^{-1}), Catuaí Vermelho IAC 144 (75.36 bags ha^{-1}), Sarchimor MG8840 (79.89 ha $bags^{-1}$), and MGS Catucaí Pioneira (77.96 ha $bags^{-1}$) (Figure 2a). The group with lower productivity was represented by the cultivars Pau Brasil MG1, MGS Aranãs, MGS Paraíso2, MGS Ametista, Paraíso MG H419-1, and Catiguá MG2, ranging from 56.11 to 69.97 ha^{-1} bags. The cultivar that obtained the lowest productivity in the biennium was Paraíso MG H419-1, presenting a reduction of approximately 30% in productivity compared to the average of the most productive cultivar.

When referring to yield, which is the amount in liters of coffee harvested to obtain a bag of 60kg of processed coffee, there are no significant differences between the cultivars studied (Figure 2B), with variations in yield values between 426.93 L (MGS Paraíso 2) and 499.16 L (MGS Ametista).

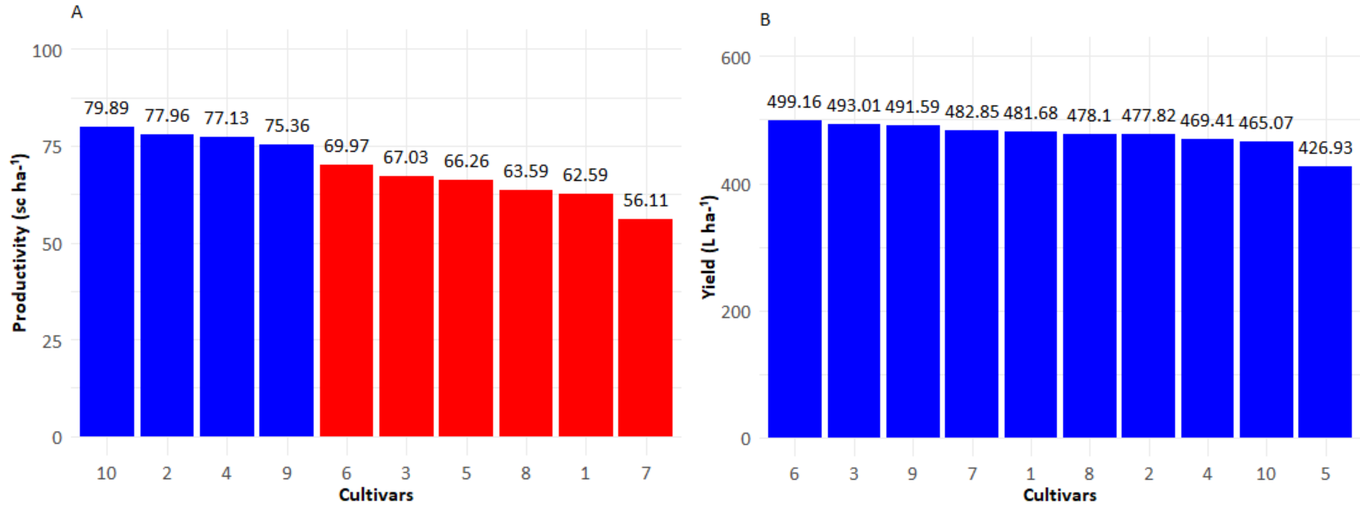

Figure 2. (A) Productivity (bags ha^{-1}) and average yield (L ha^{-1}) (B) of *Coffea arabica* L. cultivars evaluated in the 2019 and 2020 biennium. Bars of the same color do not differ significantly by the Scott-Knott test, at a 5% significance level. Cultivars: 1 – Pau Brasil MG1, 2 – MGS Catucaí Pioneira, 3 – MGS Aranãs, 4 – Topázio MG1190*, 5 – MGS Paraíso 2, 6 – MGS Ametista, 7 – Paraíso MG H419-1, 8 – Catiguá MG2, 9 – Catuaí Vermelho IAC 144*, 10 – Sarchimor MG8840. *Cultivars widely adopted by producers in the region.

Principal Component Analysis (PCA) was employed to explore the relationships among productivity, yield, and grain size distribution in the evaluated *Coffea arabica* cultivars. The first two principal components explained 69.4% of the total variance, with Dim1 accounting for 61.1%, as shown in Figure 3. This level of explained variation indicates that the biplot captures a substantial portion of the information and provides a reliable basis for interpreting trait relationships and cultivar positioning.

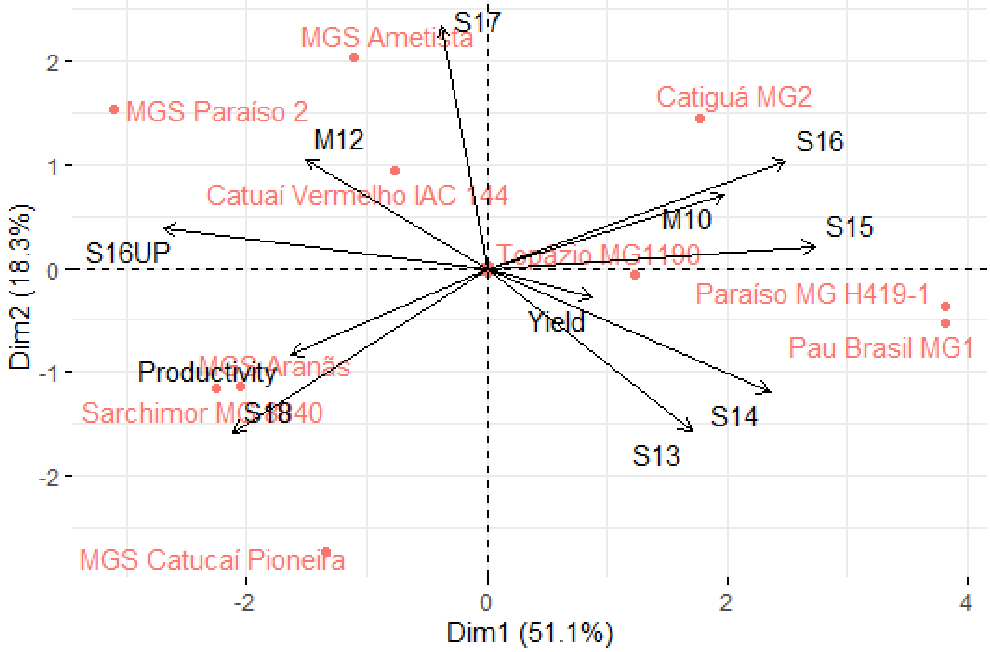

Figure 3. Principal Component Analysis (PCA) of *Coffea arabica* L. cultivars in the 2019–2020 biennium, showing the projection of vectors and dispersion of cultivars based on the following variables: percentage of beans retained in sieves 13 (S13), 14 (S14), 15 (S15), 16 (S16), 16 and above (S16UP), 17 (S17), 18 (S18); mocha beans retained in sieves 10 (M10) and 12 (M12); as well as productivity and yield during the biennium.

Cultivars Sarchimor MG8840, MGS Aranãs, and MGS Catucaí Pioneira stood out in the positive quadrant of PC1, being associated with higher productivity, greater retention in sieve 18, and lower mocha bean retention in sieve 10. These traits indicate superior agronomic performance and desirable physical quality. In contrast, MGS Ametista was distinguished along PC2, characterized by greater retention in sieve 17, suggesting a predominance of larger beans, although not necessarily reflected in higher productivity.

Catiguá MG2 was separated from the other cultivars due to higher percentages of beans retained in sieve 16 and mocha sieve 10, indicating a grain profile with a higher proportion of intermediate and smaller sizes. Meanwhile, Paraíso MG H419-1 and Pau Brasil MG1 were associated with higher retention in sieves 14 and 15, which represent smaller bean classes and may contribute to their lower market value.

Interestingly, no strong correlation was observed between yield (volume in liters of harvested coffee) and productivity (bags of processed coffee per hectare). This can be attributed to differences in bean size and density. For example, a cultivar that produces a high volume of fruit (liters) may not necessarily translate that volume into greater productivity if the beans are predominantly smaller or less dense. Cultivars like MGS Ametista, which showed a high yield (500 L bag^{-1}), had a greater proportion of beans retained in sieve 17 but did not exhibit significantly higher productivity.

4. Discussion

Maximizing productivity is especially critical in irrigated crops, given the need to optimize available water resources (Nikolaou et al. 2020). Faced with this concern, our research group evaluated the performance of several Arabica coffee cultivars under irrigated conditions in the Cerrado of Minas Gerais, a region notorious for its importance in global coffee farming and its socioeconomic impact (Volsi et al. 2019).

It is imperative to note that bienniality is an inherent characteristic of coffee crops and requires careful consideration when assessing productivity (Fanelli Carvalho et al. 2020). The results reveal that the Topázio MG1190, Catuaí Vermelho IAC 144, Sarchimor MG8840, and MGS Catucaí Pioneira cultivars stood out in productivity in the study biennium (Figure 2A). This observation corroborates previous studies that have also highlighted the productive potential of these cultivars under drought (Ávila et al. 2020) or irrigated conditions (Karasawa et al. 2002). The superior performance of these cultivars under irrigation conditions suggests a promising adaptability to controlled water management.

The average productivity of 70 bags ha^{-1} observed under irrigation over two years confirms the positive impact of water management. This result is significantly higher than the regional average of 27.84 bags ha^{-1} (Conab 2020). Cultivars such as Topázio MG1190, Catuaí Vermelho IAC 144, Sarchimor MG8840, and MGS Catucaí Pioneira exceeded 77 bags ha^{-1}, demonstrating superior responsiveness to irrigation. Similar gains were reported by Voltolini et al. (2025), with a 38% increase in grain yield under irrigation—particularly in Sarchimor MG8840 and Pau Brasil MG1—and corroborated by comparative studies showing an average 38% productivity rise in Cerrado irrigated systems

A highlight in our research is the inclusion of the yield parameter associated with production, which allows us a broader view of the performance of cultivars in irrigated cultivation systems (Hao et al. 2022). This approach enriches the economic evaluation of cultivars. It is vital for informed decision-making by producers since important implications arise from the relationship between coffee at harvest time and benefited coffee. The crop yield estimate refers to the amount of coffee harvested required to obtain a 60 kg bag.

Gaspari-Pezzopane et al (2004) found in a study on coffee yield variability that the cultivars of the Sarchimor group, Obatã IAC 1669-20 and Tupi IAC 1669-33, had lower yields. The researchers defined intrinsic yield as the ratio between the dry mass of two normal flat-type and the dry mass of the respective fruit containing these two. In contrast, cultivars such as MGS Paraíso 2 demonstrated a higher yield, evidencing that a smaller volume is necessary to obtain a bag of coffee. This result is consistent with the literature, highlighting the direct influence of husk thickness on the efficiency of coffee processing (Toledo et al. 2016).

The results suggest that the uniformity of water availability throughout the crop cycle, particularly ensured by supplemental irrigation during the dry season (May to August), contributed to reducing yield variability among cultivars. This period is physiologically critical for post-harvest recovery and vegetative development, with direct implications for the subsequent production cycle. The absence of significant differences in yield suggests that optimal water availability may have played a predominant role in homogenizing cultivar performance.

Multivariate analyses allowed a more comprehensive interpretation of the results, in line with those obtained in univariate analyses. This technique provides a solid basis for discriminating and selecting cultivars with superior performance under specific growing conditions (Almeida et al. 2021, Ferreira et al. 2021, Hao et al. 2022).

The absence of a strong correlation between yield (volume in liters of harvested coffee) and productivity (bags of processed coffee per hectare), as observed in this study, underscores the importance of bean size and density in determining actual yield efficiency. For instance, although the cultivar MGS Ametista recorded the highest yield (499.16 L ha^{-1}), it did not exhibit a proportional increase in productivity, likely due to a higher proportion of intermediate-sized beans retained in sieve 17.

This finding is particularly relevant when contrasted with the performance of cultivars such as Sarchimor MG8840, MGS Aranãs, and MGS Catucaí Pioneira. These genotypes not only stood out for their higher productivity but also for their greater retention in sieve 18 and lower percentages of mocha beans retained in sieves 10 and 12 (Figures 2 and 3). Such a combination of high productivity and superior bean size distribution reinforces their potential for both economic return and market quality.

The physical quality traits observed are consistent with previous reports, in which cultivars like Sarchimor MG8840 and MGS Aranãs were also associated with a high proportion of large beans (Pereira et al. 2019; Reichel et al. 2023). This characteristic is essential for specialty coffee production, where bean uniformity and appearance significantly influence the final product value (Silva et al. 2016; Alves et al. 2016).

On the other hand, cultivars Paraíso MG H419-1 and Pau Brasil MG1 distinguished themselves from the others by exhibiting a higher proportion of retained in sieves 14 and 15 (Figure 3). These results converge with previous studies that also found a reduced percentage of retained in a high sieve for these cultivars in different growing conditions, including dry farming systems (Carvalho et al. 2012, Veiga et al. 2018, Pereira et al. 2019, Reichel et al. 2023).

These findings underscore that the bean size profile of cultivars such as Paraíso MG H419-1 and Pau Brasil MG1 appears to be intrinsically determined and less influenced by environmental or management conditions, such as irrigation. The consistent concentration of medium-sized beans in these genotypes across diverse cultivation systems suggests genetic stability in grain morphology. This stability may limit their potential in premium markets that demand larger bean sizes, despite their agronomic adaptability. Therefore, cultivar selection should consider not only productivity and agronomic suitability but also bean size uniformity and its alignment with market standards for specialty or value-added coffee segments.

5. Conclusions

The cultivars Sarchimor MG8840, MGS Aranãs, and MGS Catucaí Pioneira demonstrated superior performance in irrigated cultivation systems in the Cerrado of Minas Gerais, combining high productivity with favorable bean size distribution. In contrast, Paraíso MG H419-1 and Pau Brasil MG1 showed a predominance of smaller beans, which may affect market value. The overall results suggest that the combination of supplemental irrigation and favorable climatic conditions during the crop cycle contributed to reducing yield variability among genotypes. These findings reinforce the potential of selected cultivars for optimized performance in intensive and irrigated coffee production systems.

Authors' Contributions: SILVA, I dos S .: conception and design, acquisition of data, analysis and interpretation of data, critical review of important intellectual content; NADALETI, D.H.S.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article; SANTOS, C.S. dos: conception and design, acquisition of data, analysis and interpretation of data, critical review of important intellectual content; ABRAHÃO, J.C de R.: conception and design, acquisition of data, analysis and interpretation of data, critical review of important intellectual content; BOTELHO, C. E.: conception and design, acquisition of data, analysis and interpretation of data, critical review of important intellectual content; All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Not applicable.

Acknowledgments: The authors would like to thank the funding for the realization of this study provided by the Brazilian agencies FAPEMIG (Fundação de Amparo à Pesquisa do Estado de Minas Gerais - Brasil), CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico - Brasil), Coffee Research Consortium-Consórcio Pesquisa Café, National Institute of Coffee Science and Technology-INCTCafé/CNPq.

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