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Productivity, chemical and sensory characteristics of arabica coffee under different water regimes in the Brazilian Cerrado Central Plateau

Abstract – The objective of this work was to evaluate arabica coffee (*Coffea arabica*) under irrigation regimes in the Brazilian Cerrado Central Plateau regarding productivity, chemical quality of raw grains, and sensory quality of the beverage. The experiment was conducted in 2020/2021, with the regimes consisting of two levels of replacement, 100% and 50% of water requirement: irrigation throughout the year, water deficit from April to September, and water deficit from June to September. The chemical characteristics studied were: soluble solids, sucrose, trigonelline, caffeine, caffeoylquinic and citric acids. Sensory analysis was performed by SCA. The regimes of water replacement 100% with irrigation throughout the year and water deficit from June to September present higher productivity of arabica coffee in 2020 and 2021. In regimes with greater water restriction, the levels of sucrose and trigonelline in raw grains increase. In regimes with greater water replacement, the level of citric acid in the raw grains increases. Both regimes with a water deficit from June to September with 100% and 50% of the crop water requirement produce a beverage of excellent quality due to greater uniformity in grain maturation. With 50% of the crop water requirement, the water deficit from April to September is harmful to the quality of the beverage compared to the water deficit from June to September due to the period of two additional months in water stress.

Index terms: *Coffea arabica*, beverage quality, irrigation, water stress.

Produtividade, características químicas e sensoriais de café arábica sob diferentes regimes hídricos no Planalto Central do Cerrado Brasileiro

Resumo – O objetivo deste trabalho foi avaliar o café arábica (*Coffea arabica*) sob regimes de irrigação no Planalto Central do Cerrado Brasileiro, considerando produtividade, qualidade química dos grãos crus e qualidade sensorial da bebida. O experimento foi conduzido em 2020/2021, com os regimes constituídos por dois níveis de reposição, 100% e 50% da necessidade hídrica: irrigação durante todo o ano, déficit hídrico de abril a setembro e déficit hídrico de junho a setembro. As características químicas avaliadas foram: sólidos solúveis, sacarose, trigonelina, cafeína, ácidos cafeoilquínico e cítrico. A análise sensorial foi realizada pela SCA. Os regimes com reposição hídrica 100% com irrigação durante o ano todo e restrição hídrica de junho a setembro apresentam maior produtividade de café arábica em 2020 e 2021. Em regimes com maior restrição hídrica, os níveis de sacarose e trigonelina em grãos crus aumentam. Ambos regimes com restrição hídrica de junho a setembro com 100% e 50% da exigência produzem uma bebida de qualidade excelente em razão da uniformidade da maturação do grão. Com o regime de 50% da exigência hídrica da plantação, o deficit hídrico de abril a setembro

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mostrou-se prejudicial à qualidade da bebida comparado com o deficit de junho a setembro em razão do período adicional de dois meses de estresse hídrico.

Termos para indexação: *Coffea arabica,* qualidade de bebida, irrigação, estresse hídrico.

Introduction

Coffee is one of the most economically relevant crops in Brazil, since the country is the world's largest producer and exporter of the product. In 2024, the total Brazilian area planted with both *Coffea arabica* L. and *Coffea canephora* species was of 2.25 million ha, of which arabica cultivation accounts for 80.9% (Acompanhamento…, 2024).

In recent decades, arabica coffee production has spread to the Cerrado biome, known as the Brazilian Savanna, which occupies 22% of the country's territory, is characterized by its well-defined dry and rainy seasons (Lorençone et al., 2025), and has a great biodiversity. In its Central Plateau region, arabica coffee producers use irrigated instead of rainfed coffee, since there is a long period without precipitation, influencing productivity and grain maturation (Silva et al., 2024), which can be detected by multispectral sensors mounted on unmanned aerial vehicles (Silva et al., 2024). Although the high risk of severe drought challenges sustainable arabica coffee production, it allows controlled induction of plant water stress in irrigated systems, with a synchronized flowering period, uniform maturity at harvest, and a potential increase in grain quality (Guerra et al., 2005), as ripe coffee cherries contain suitable chemical compositions responsible for flavor properties (Hameed et al., 2018).

In recent years, consumers' demand for a higher-quality beverage has increased (Fassio et al., 2016; Barbosa et al., 2019), which has led industries to offer higher-quality coffees on the market. Until 2023, gourmet was the highest coffee classification; however, the Brazilian Coffee Industry Association (Abic, 2024) launched specialty coffee, the fourth quality category of classification. Therefore, to achieve this greater demand for quality, producers must adapt to a new standard of water consumption on plantations, including the Brazilian Cerrado Central Plateau region.

To evaluate the potential of coffee plants for producing grains with a better-quality sensory profile, the following attributes are valued: bitterness, astringency, aromas, citric acidity, and body, which are related to the chemical characteristics, such as: caffeine, caffeoylquinic acid, sucrose, trigonelline, citric acid, and total soluble solids (Sualeh et al., 2020). Among the chemical characteristics, the bioactive compounds: caffeine, trigonelline, and caffeoylquinic acid are highlighted due to their action on human health.

Caffeine, one of those responsible for bitterness, has stimulating effects on the central nervous system: alertness, excitement, and improved cognitive performance, besides indications of protection against cognitive impairment, decline, and dementia (Panza et al., 2015). Nehlig (2016) reports that daily intake of up to 400 mg of caffeine, or about five cups of coffee, is not harmful to health.

Trigonelline, responsible for coffee aromas, is converted into vitamin B complex (niacin) during roasting, increasing the nutritional value of roasted coffee (Abrahão et al., 2008). Caffeoylquinic acid, a powerful antioxidant, plays an important role in neutralizing or sequestering free radicals, acting both in the initiation stage and in the propagation of the oxidative process (Abrahão et al., 2008). However, increased contents of caffeine and caffeoylquinic acid in raw coffee beans is detrimental to sensory classification, as they are responsible for undesirable attributes, such as bitterness and astringency.

Chemical and sensory qualities of coffee, as well as changes in productivity, are related to the use of water deficit. Therefore, fruit yield and chemical and sensorial attributes of coffee grains might be affected by the genotype choice and the water regime.

The objective of this work was to evaluate arabica coffee production under irrigation regimes in the Brazilian Cerrado Central Plateau regarding productivity, chemical quality of raw grains, and sensory quality of the beverage.

Materials and Methods

The study was carried out at Embrapa Cerrados, Distrito Federal (15°35'S, 47°42'W at 1,007 m of altitude), in an experiment area, where coffee had been planted in 2015, and the water regimes started in 2017. The row spacing was 3.50 m and plants were spaced 0.50 m in a total area of 0,74 ha with 5,700 plants ha^{-1}.

According to the Köppen-Geiger classification, the climate is Aw type with two well-defined dry and rainy seasons. The average temperature is 21ºC, and the average precipitation is 1,500 mm. The precipitation and temperature data during the experiment are described in Figure 1. The soil was classified as clayey Oxisol (Burt, 2014), with a soft undulating relief and a clayey texture. The soil analysis before the experiment started and after liming and gypsum addition is described in Table 1.

The experiment consisted of five *Coffea arabica* genotype seedlings planted on the same day: Iapar 59, Topázio MG 1190, E 237, IPR 98, and Catuaí Vermelho IAC 99, submitted to six water regimes, of which irrigation was carried out by sprinklers, using an irrigation bar pulled by a self-propelled reel. The irrigation level and interval applied were based on the climatological and soil water balance and on the Cerrado Irrigation Monitoring Program (Embrapa, 2024), using climate data obtained from a meteorological station located next to the experiment. Data on soil water availability in the experimental area and crop coefficients for coffee were defined by Guerra et al. (2005). The Penman-Monteith method was used to estimate reference evapotranspiration (ETo).

The water regimes consist of two levels of water replacement: 100% and 50% of the crop water requirement, in which all and half of the water required by the crop were applied, respectively, followed by two periods of water deficit (WD): April to September

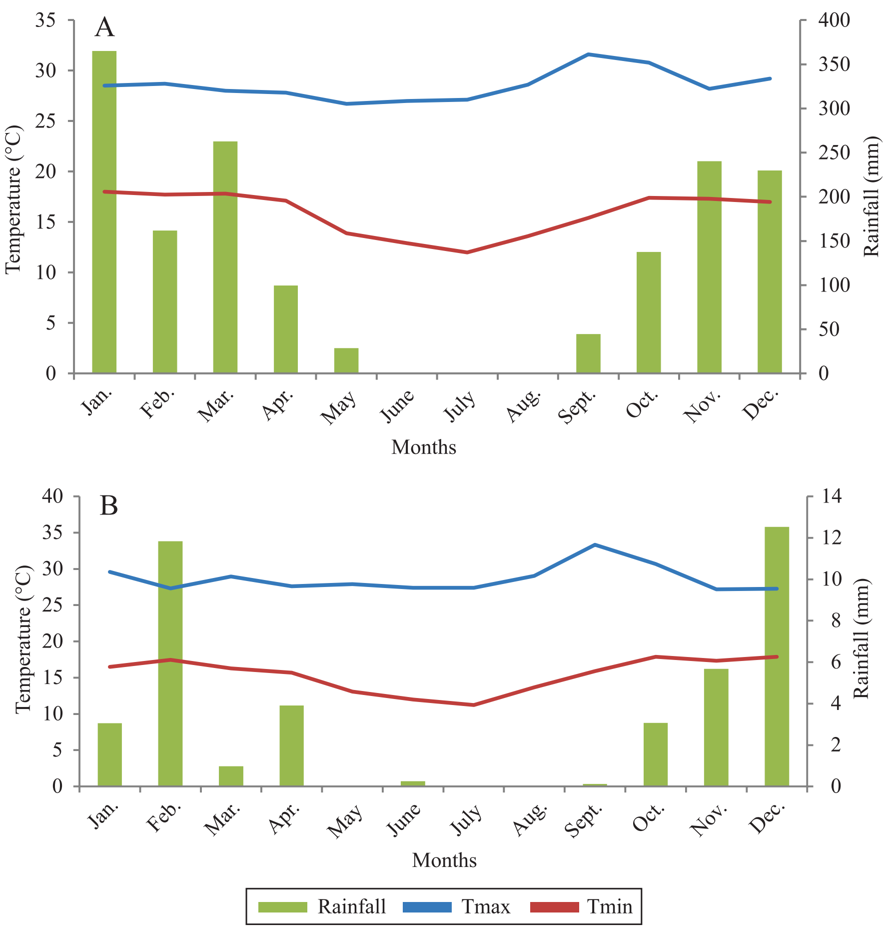

Figure 1. Climatological data (temperature and precipitation) for the years 2020 (A) and 2021 (B) collected from the weather station near of the experiment in Brazilian Cerrado Central Plateau. Planaltina, DF, Brazil.

(WD1) and June to September (WD2), throughout the irrigation regime (FI). The water regimes started in April 2017, and between 2017 and 2021, the water consumption of the coffee genotypes was evaluated.

The plants received an average annual accumulated water depth of 1,706 mm (FI 100), 1,367 mm (FI 50), 1,435 mm (WD2 100), 1,217 mm (WD2 50), 1,270 mm (WD1 100), and 1,137 mm (WD1 50). The irrigation management criterion was the soil water balance, based on the Cerrado Irrigation Monitoring System, which provided information to determine the amount of water and the interval (Embrapa, 2024) based on the nearest weather station. The grain yield in 2020 and 2021 was obtained from three coffee plants per experimental plot, with the fruits harvested by stripping on the cloth. The fruits were dried in the sun on a concrete surface until they reached the final water content of the coffee cherry of approximately 10% to 11%, and then the value was converted into bags of processed coffee per hectare (bag ha^{-1}).

Samples of the 2020 coffee yield with only coffee cherries were processed. The fruits were peeled, and the parchment grains free of mucilage were dried in a closed room at an average temperature of 35°C. After ten days, with a water content of 10%, the parchment grains were removed. Part of the raw grains were ground and passed through a 20 mesh sieve to carry out chemical analyses of: total soluble solids content (AOAC, 2009), sucrose content (Santos et al., 2018), trigonelline, caffeoylquinic acid, caffeine, and citric acid contents (Figueiredo, 2013). All analyses were carried out in three replicates, and the results were expressed in dry mass.

Sensory analysis was conducted using the Specialty Coffee Association methodology (SCA, 2024). The sensory test of the coffee beverage was performed by four Q-graders at the Coffee Grading Laboratory of the Savassi company, located in the municipality of Patrocínio, MG, Brazil. The coffee was roasted, left for a rest period of 8 hours, and grounded. The grains from the three field replicates were mixed, constituting a sample, and then roasted in batches of 200 g of beans for approximately 12 min in a model TP3 coffee sample roaster (Carmomaq, Espírito Santo do Pinhal, SP, Brazil), aiming for a medium roast, at a final temperature of 200°C. The roast color was between Agtron-SCA Discs #65 and #55.

Five cups of each coffee sample were tasted, maintaining a ratio of 8.25 g of coffee per 150 mL of water. To prepare the infusion, the water with a temperature of 93°C was poured over the ground coffee. The evaluations began 4 min after the infusion when the water temperature stabilized at 55°C, and ten important attributes of the coffee beverage were evaluated: aroma, flavor, completion, citric acidity, sweetness, body, clean up, uniformity, balance, and general, with scores from zero to ten for each attribute. After the evaluation, the results of all attributes were added, obtaining the overall score, with the ones scoring over 80 being considered specialty coffee.

For the statistical analysis, initially, an analysis of variance (ANOVA) was performed in randomized blocks for each variable within each water regime. Subsequently, the Hartley F Max's test was performed using the mean square error of each variable in each treatment. The test result was used to validate the experiments as a group and use the joint analysis of groups of experiments. After that, water regimes and genotypes were considered sources of variation, and a new ANOVA was performed. The analysis of variance was performed using F, Tukey's, and Scott Knott's tests at 5% probability to compare the means of yield and chemical characteristics. To carry out the statistical analysis, the version 9 of SAS software (SAS Institute Inc., Cary, NC, USA), and RStudio (2020), version 4.3.1. were used.

Table 1. Soil chemical analysis in the experimental area at the installation of the experiment with arabica coffee, at depths 0–20 and 20–40 cm, in the region of Planaltina, in the Federal District, Brazil.

Depth (cm)	pH (H_2O)	Ca	Mg	Al	H+Al	K	P (mg L^{-1})	CEC[1]	SB	V (%)	OM (g kg^{-1})
		(cmol$_c$ dm^{-3})						(cmol$_c$ dm^{-3})			
0–20	6.17	3.87	1.81	0.001	3.99	175	55.41	10.13	6.13	60.53	24.02
20–40	6.01	2.73	1.09	0.001	3.49	94	14.78	7.56	4.06	53.78	18.28

[1]CEC, cation exchange capacity; SB, sum of bases; V%, base saturation; OM, organic matter.

Results and Discussion

Temperature and precipitation data show that the climatic differences between winter and the rest of the year (Figure 1 A and B) caused water stress. The genotypes studied had higher yields under the FI 100 treatment than the other ones, except for E 237, which showed no statistical difference between FI 100 (66 bags ha^{-1}) and FI 50 (52 bags ha^{-1}) (Figure 2 A). 'Topázio MG 1190' was superior to the other genotypes in the FI 100 and FI 50 treatments, with yields of 169 and 127 bags ha^{-1}, respectively. On the other hand, 'Iapar 59' showed high productivity in all water-restricted treatments, superior to the others in WD1 100 and WD2 50, with 77 and 47 bags ha^{-1}, respectively. Under FI 50 and WD1 100, there was no significant difference for 'Iapar 59' (Figure 2 A). The greater productivity of 'Iapar 59' in all regimes with water restriction is due to its great tolerance to drought, as verified by Rakocevic et al. (2023) and Silva et al. (2022). Although the highest yield in this study was in treatments with full irrigation, a period of drought, as proposed by Guerra et al. (2005), is fundamental for the uniformity of flowering and fruit maturation (Silva et al., 2022).

Furthermore, high production in the first two years can result in depletion of the plant, resulting in low productivity in the following year. Silva et al. (2022) obtained average yields ranging from 19 to 110 bags ha^{-1}, with higher values for the genotypes under WD2 100 treatment, as seen in this experiment in 2021 (Figure 2 B). Chemical characteristics, related to coffee grain quality, were verified using Principal Component Analysis (PCA), which allows to infer the variables, or chemical characteristics, responsible for most of the divergence found (Figure 3 A and B). The dispersions of treatments generated by PCA permit to carry out an exploratory analysis and identify the treatments that stand out in the variables studied. Table 2 presents the estimates of percentages of variance and the percentage of accumulated variance explained by the three main components and the respective correlations of the variables.

The first component (PC1) contributed 26.5% to the data variability, with emphasis on the correlation presented by caffeine (CAF) and citric acid (CA); the second component (PC2) contributed 22.4%, with the highest correlation shown by total soluble solids (SS). The variable sucrose (SUC) closely correlates with the two axes PC1 and PC2. The third component (PC3) contributed 20.6%, caffeoylquinic acid (5-CQA) and trigonelline (TRIG) have the highest correlations

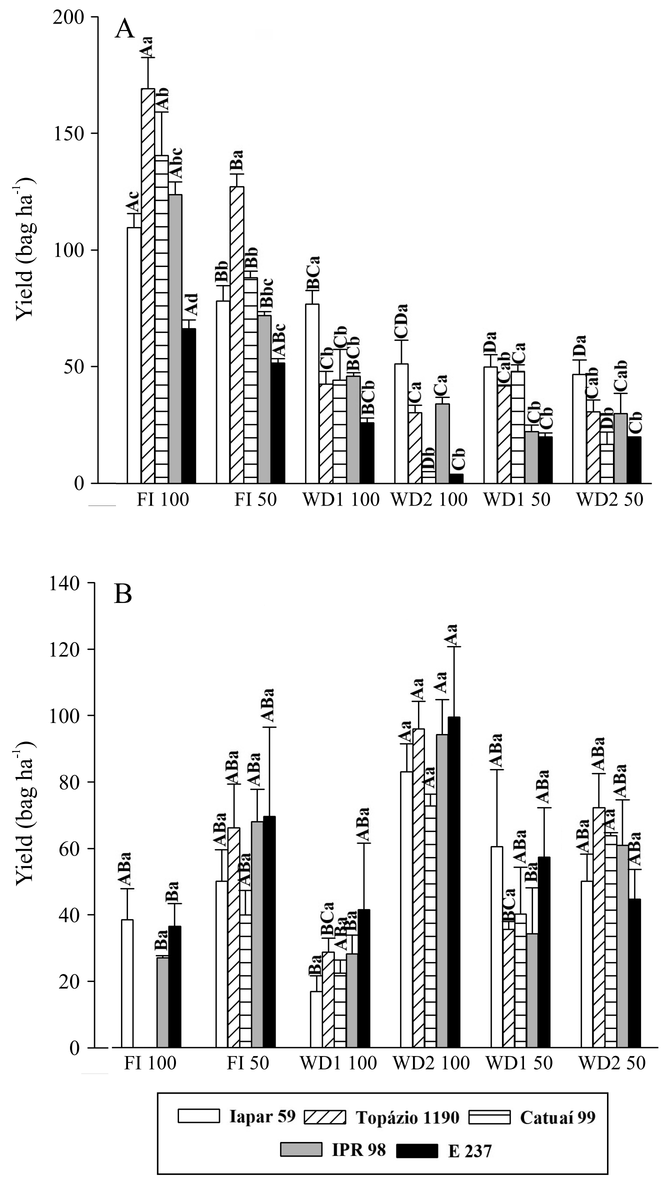

Figure 2. Yield of the coffee (Coffea arabica) genotypes: Iapar 59, E 237, Catuaí Vermelho IAC 99, Topázio MG 1190, and IPR 98 in 2020 (A) and 2021 (B) subjected to six water regimes (FI 100, FI 50, WD1 100, WD2 100, WD1 50, WD2 50) in the Brazilian Cerrado Central Plateau. Capital letters compare the genotypes of each irrigation system, separately. Lowercase letters compare irrigation systems, individually, depending on genotypes. Means followed by equal letters do not differ from each other by Tukey's test, at 5% probability.

with this axis. The three main components presented an accumulated variance of 69.5%. Hair et al. (2006) suggested that the accumulated variance should continue until at least 60%. Therefore, all variables were important and considered in the analysis of variability among treatments.

Table 3 presents the average per dry matter of raw grains of the chemical characteristics for all treatments. Four groups were formed to evaluate the CAF variable, responsible for the bitterness of the coffee beverage, with values from 1.06% to 1.59%, highlighting 'IPR 98' and 'Iapar 59', which presented the higher content. Mehari et al. (2016) obtained a CAF content for arabica coffee varieties ranging from 0.87% to 1.38%. Gichimu et al. (2014) indicated that the contents of CAF should be within the range of 0.80% to 1.40%. Therefore, the present study showed that the CAF contents coincide with the values of other authors.

SUC, the main sugar present in mature arabica coffee grains, is a precursor of aromas responsible for roasted coffee dark color in the Maillard and caramelization reactions (Portillo & Arévalo, 2022), consequently, raw grains with high SUC contents are desirable for obtaining quality roasted coffees. The compound SUC presented three groups with lower variability than other chemical characteristics. All treatments presented high values of this characteristic, except for 'Topázio MG 1190', which presented lower values in the WD2 100 water regime.

Higher levels of CA are desirable in raw coffee since they provide more intense acidity in medium-roasted coffee, as this acid decomposes during the roasting process (Puerta Quintero & Echeverri Giraldo, 2019). Four groups were formed for CA, with values from 0.65% to 1.49%. 'Iapar 59' and 'Topázio MG 1190' stand out with the values 1.21% and 1.11%, respectively. Nascimento et al. (2024) found an average CA value of 1.2% in arabica coffee varieties grown in the Cerrado biome.

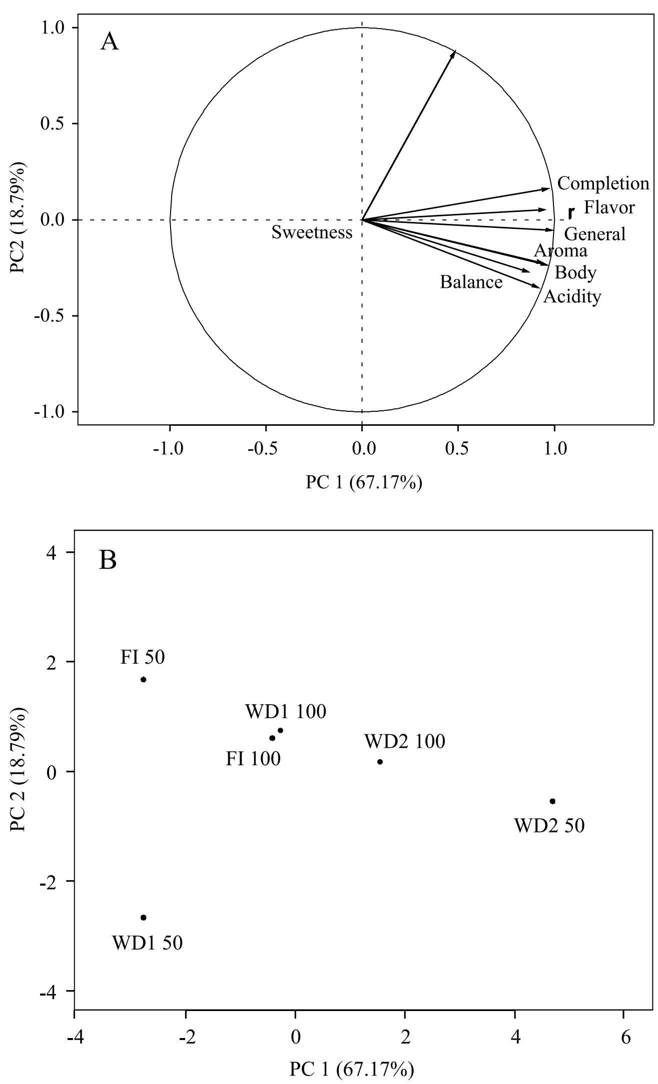

Figure 3. Graphical dispersion of the sensory analysis of *Coffea arabica* beverage attributes (A) and water regimes (B) in the Brazilian Cerrado Central Plateau, with the reference axes first (PC 1) and second component (PC 2).

Table 2. Correlations of caffeoylquinic acid (5-CQA), caffeine (CAF), trigoneline (TRIG), sucrose (SUC), total soluble solids (SS), and citric acid (CA) of raw coffee (*Coffea arabica*) grains with the percentage of variance explained by the principal component analysis (PC), for all treatments of the crop 2020 in the Brazilian Cerrado Central Plateau. Planaltina, DF, Brazil.

Chemical characteristic	Correlation		
	PC1	PC2	PC3
5-CQA	0.170	0.489	0.701
CAF	0.680	0.297	0.137
TRIG	-0.448	-0.171	0.760
SUC	0.467	-0.589	0.376
SS	0.029	0.790	-0.050
CA	0.823	-0.133	-0.055
Variance (%)	26.5	22.4	20.6
Accumulataed variance (%)	26.5	48.9	69.5

Lower 5-CQA values are desirable in raw coffee, as it is responsible for the astringency and bitterness of roasted coffee and can cause excess bitterness in the drink (Santos et al., 2015). Thus, the increase in 5-CQA is inconsistent with specialty coffee grains (Mintesnot & Dechassa, 2018). Fassio et al. (2016) evaluated the quality of 'Topázio MG 1190' grains and their interactions with two different environments. The authors found 3.97% and 3.20% of 5-CQA, which were lower than those observed in the genotype in all water regimes studied. Six groups were formed for 5-CQA, with lower values for 'Topázio MG 1190' and 'Catuaí Vermelho IAC 99'. The contents of 5-CQA of this study were close to the maximum limit aligned with those reported by Sualeh et al. (2020), who found values ranging from 2.8% to 5.4%.

Table 3. Averages (%) of chemical characteristics in dry basis of caffeine (CAF), sucrose (SUC), citric acid (CA), chlorogenic acid (5-CQA), trigonelline (TRIG), and soluble solids (SS) of raw coffee (*Coffea arabica*) grains for all water regimes of the crop 2020 in the Brazilian Cerrado Central Plateau. Planaltina, DF, Brazil[(1)].

Genotype	Water regime	CAF	SUC	CA	5-CQA	TRIG	SS
Iapar 59	FI 100	1.19c	4.49c	1.39a	6.13a	1.97a	30.20a
	WD1 100	1.28c	5.03b	1.49a	6.33a	1.45a	28.60a
	WD2 100	1.26c	5.74a	1.27b	5.68c	1.07c	28.60a
	WD2 50	1.35b	5.64a	0.85d	6.27a	1.38a	24.10b
	FI 50	1.27c	5.24b	1.31b	5.71c	1.07c	25.60b
	WD1 50	1.48a	6.26a	0.93c	5.77c	1.62a	28.60a
	Average	1.31	5.40	1.21	5.98	1.43	27.62
Topázio MG 1190	FI 100	1.26c	5.44a	1.22b	4.77e	1.89a	31.60a
	WD1 100	1.16d	5.59a	1.24b	4.41f	1.05c	28.60a
	WD2 100	1.11d	4.59c	1.17b	4.40f	1.28b	26.40b
	WD2 50	1.15d	6.02a	0.90c	4.49f	1.09c	25.40b
	FI 50	1.16d	6.05a	1.18b	4.68e	1.04c	26.40b
	WD1 50	1.11d	5.51a	0.95c	4.56f	1.08c	25.40b
	Average	1.16	5.53	1.11	4.55	1.24	27.30
E 237	FI 100	1.11d	4.66c	1.07c	5.34d	1.95a	29.40a
	WD1 100	1.13d	5.66a	0.93c	5.58c	1.32a	27.90a
	WD2 100	1.20c	5.24b	0.97c	4.96e	1.42a	28.60a
	WD2 50	1.19c	5.98a	0.65d	5.31d	1.79a	29.40a
	FI 50	1.08d	5.74a	0.95c	5.29d	1.08c	25.60b
	WD1 50	1.21c	6.23a	0.79d	5.23d	1.46a	27.90a
	Average	1.15	5.59	0.89	5.29	1.50	28.13
IPR 98	FI 100	1.19c	5.73a	1.09b	5.88b	1.87a	30.20a
	WD1 100	1.23c	5.60a	1.19b	5.91b	1.08c	26.40b
	WD2 100	1.40b	4.54c	0.94c	5.56c	1.26b	26.40b
	WD2 50	1.43a	6.06a	0.87c	5.85b	1.38a	28.60a
	FI 50	1.59a	5.12b	0.82d	6.21a	1.43a	25.60b
	WD1 50	1.30c	5.30b	0.84d	5.65c	1.26b	26.40b
	Average	1.36	5.39	0.96	5.84	1.38	27.27
Catuaí Vermelho IAC 99	FI 100	1.06d	4.24c	1.17b	4.36f	1.81a	30.20a
	WD1 100	1.12d	5.35a	1.43a	4.51f	1.97a	27.90a
	WD2 100	1.16d	5.10b	1.02c	4.67e	1.01c	25.60b
	WD2 50	1.16d	5.69a	0.90c	4.69e	1.24b	27.90a
	FI 50	1.21c	5.55a	0.95c	4.99e	1.97a	27.10b
	WD1 50	1.22c	5.86a	0.89c	4.57f	1.25b	25.60b
	Average	1.16	5.30	1.06	4.63	1.54	27.38
Coefficient of variation (%)		6.20	9.30	9.40	3.70	7.60	6.10

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Scott-Knott's test, at 5% probability.

TRIG compound is a precursor of aromatic compounds in roasted coffee and its thermal degradation generates pyrroles that can present pleasant, sweet aromas (Li et al., 2023), so its high content in raw grains represents quality-roasted coffee. Three groups were formed for TRIG, with all cultivars presenting high contents. The contents found in this study are higher than those obtained by Gichimu et al. (2014) and Mehari et al. (2016), who obtained values from 0.60% to 1.20% and 0.98% to 1.32%, respectively.

Higher SS values in raw grains represent a greater body in medium-roasted coffee, characterizing a better quality beverage (Hameed et al., 2018). Only two groups were formed for SS, ranging from 24.1% to 31.6%, while Nascimento et al. (2024) documented SS content variation from 27.4% to 29.5% in raw arabica coffee grains grown in Cerrado. 'Topázio MG 1190' submitted to regime FI 100 showed the highest value.

The averages of the chemical characteristics for the simple water regime factor are presented in Table 4. CAF and 5-CQA results showed that the water regimes did not influence the concentration of these compounds. In a study by Silva et al. (2005), 5-CQA content does not vary with irrigation, while the CAF content of coffee grains increases in non-irrigated coffee grown in warmer regions.

In the following regimes of Group 2 with greater water restriction: WD1 50, WD2 50, and FI 50, there was an increase in the levels of both SUC and TRIG. Silva et al. (2005) showed that the SUC content was higher in non-irrigated coffee grains grown in warmer regions. A higher SUC content in coffee under water stress may be associated with the higher percentage of cherry grains at harvest promoted by the synchronization of flowering in an area with suspended irrigation (Guerra et al., 2005). On the other hand, the following regimes of Group 1 with greater water replacement: WD1 100 and FI 100 presented the highest CA contents. Khosravi-Nejad et al. (2022) showed that drought stress decreased CA in wheat crops.

Table 4. Averages (%) of chemical characteristics in dry basis of caffeine (CAF), sucrose (SUC), citric acid (CA), chlorogenic acid (5-CQA), trigonelline (TRIG), and soluble solids (SS) of raw coffee (*Coffea arabica*) grains subjected to water regimes in Brazilian Cerrado Central Plateau. Planaltina, DF, Brazil(1).

Water regime	CAF	SUC	CA	5-CQA	TRIG	SS
Group 1						
FI 100	1.16a	4.91b	1.19a	5.29a	2.89b	30.3a
WD1 100	1.18a	5.45a	1.26a	5.35a	2.77b	27.9b
WD2 100	1.23a	5.04b	1.07b	5.05a	3.00b	27.1b
Group 2						
WD2 50	1.25a	5.88a	0.84c	5.32a	3.37a	27.1b
FI 50	1.26a	5.54a	1.04b	5.37a	3.12a	26.1b
WD1 50	1.26a	5.83a	0.88c	5.15a	3.33a	26.9b
CV(2) (%)	10.94	10.70	10.64	9.87	9.52	6.83

(1)Means followed by equal letters, in the columns, do not differ from each other by Scott-Knott's test, at 5% probability. (2)CV, coefficient of variation.

For SS, only the FI 100 full irrigation regime presented a significantly different value for all genotypes. Compared to full irrigation, moderate deficit irrigation, with 80% of the total irrigation, in addition to the efficient use of water, decreases arabica coffee productivity by only 6.4%; however, it improves the beverage quality (Tesfaye et al., 2013). Table 5 shows the beverage quality results in the six water regimes for 'Topázio MG 1190' and 'IPR 98', which are productive and have chemical characteristics for quality beverages. 'Topázio MG 1190' had lower average values for CAF and 5-CQA, and higher for SUC and CA, while 'IPR 98' had intermediate values (Table 3).

SUC and TRIG (Table 4), two key compounds for high-quality coffees due to their potential to result in more intense aromas, did not present differences in Group 1 or 2, with equal averages of 7.58 for both groups (Table 5). The same was observed for the CA attribute, with an average around 7.3 for both groups, even the group with the highest water replacement presenting the highest CA levels (Table 4). The higher SS value for FI 100 (Table 4) did not result in a higher body value for this regime (Table 5). Therefore, the statistical differences presented in Table 4 for SUC, TRIG, CA, and SS did not result in sufficient distance in the intensity of the stimuli to be evident for the expert tasters (Q-graders). This direct relationship between a chemical characteristic in the raw grain associated with a certain beverage attribute is difficult to establish due to the complex chemical composition of the grain and the influences of processes, such as the type of roasting, which can enhance an attribute, and even the way the beverage is prepared.

The sensory evaluation of beverage quality was carried out using SCA, the most used methodology for classifying specialty coffee. The overall score was calculated regarding the quality of the coffees subjected to each individual regime. Coffees with a total score equal or greater than 80 points are classified as specialty coffees. 'IPR 98' in the WD2 50 regime had the highest overall score (84.5), much higher than in the WD1 50 regime (71.75) (Table 5). The same occurred with 'Topázio MG 1190', which had a higher overall score for the WD2 50 regime compared with the WD1 50 regime, but with only 1 point of variation between the scores. The 90 days of water restriction under the WD2 regime was more favorable to the beverage quality for these cultivars than the 150 days of water restriction under the WD1 regime, with a water replacement level of 50%, especially for 'IPR 98'. The WD2 50 regime had the highest overall scores for 'Topázio MG 1190' and 'IPR 98'.

The overall average scores for the water regimes, WD2 50, WD2 100, WD1 100, FI 100, FI 50, and WD1 50 were 83.75, 81.88, 80.75, 80.75, 79.25, and 76.75, respectively, with the first four regimes producing specialty coffees, especially WD2 50 and WD2 100 (Table 5). An exploratory principal component analysis (Figure 3 A and B) was carried out to verify the trend in quality attribute scores between regimes to check the trend of the ten quality attribute scores among the regimes. The PC 1 and PC 2 components accounted for more than 85% of the variability in the data. All the attributes that showed variation between the regimes had converging vectors for the WD2 100 and WD2 50 regimes, with the latter presenting higher values for the attributes.

The regimes WD2 50 followed by WD2 100 presented the best final scores, which showed their potential for producing specialty coffees despite having lower yields in 2020 (Figure 2 A) but higher yields in 2021 (Figure 2 B). This is possibly due to the greater uniformity in the ripening of the coffee cherry, which increases the number of compounds that confer beverage quality. Tesfaye et al. (2013) showed that moderate deficit irrigation could save irrigation water, maintain crop yields, and preserve grain quality. Compared to full irrigation, moderate deficit irrigation, or 80% of the total amount of irrigation, in addition to the efficient use of water, decreases arabica coffee productivity by only 6.4%; however, it improves the quality of the beverage (Tesfaye et al., 2013).

Given the high productivity of FI 100 in 2020 (Figure 2 A) and the overall average of 80.75 points (Table 5), this regime is also suitable for both grain production and beverage quality. Partial drying of the root zone and normal deficit irrigation preserved coffee quality (Tesfaye et al., 2013). WD1 100 also produced specialty coffee with the same overall score as FI 100, but showed low productivity in 2020 and

Table 5. Notes on beverage quality attributes for two *Coffea arabica* genotypes subjected to the six water regimes of the crop 2020 in the Brazilian Cerrado Central Plateau. Planaltina, DF, Brazil.

Water regime	Genotype	Aroma	Flavor	Completion	Citrus acidity	Sweetness	Body	Clean cup	Uniformity	Balance	General	Overall score
Group 1												
WD1 100	Topázio MG 1190	7.75	7.50	7.25	7.50	10	7.5	10	10	7.25	7.25	82.00
WD1 100	IPR 98	7.50	7.00	7.00	7.00	10	7.00	10	10	7.00	7.00	79.50
WD2 100	Topázio MG 1190	7.50	7.50	7.00	7.50	10	7.50	10	10	7.25	7.25	81.50
WD2 100	IPR 98	7.75	7.50	7.25	7.50	10	7.50	10	10	7.25	7.50	82.25
FI 100	Topázio MG 1190	7.50	7.50	7.00	7.25	10	7.50	10	10	7.50	7.25	81.50
FI 100	IPR 98	7.50	7.00	7.00	7.25	10	7.00	10	10	7.25	7.00	80.00
Average		7.58			7.33							
Group 2												
FI 50	Topázio MG 1190	7.25	7.00	6.75	7.00	10	6.75	10	10	6.75	7.00	78.50
FI 50	IPR 98	7.50	7.50	7.00	7.00	10	7.00	10	10	7.00	7.00	80.00
WD1 50	Topázio MG 1190	7.75	7.50	7.00	7.50	10	7.50	10	10	7.50	7.25	82.00
WD1 50	IPR 98	7.25	6.75	6.50	7.00	10	6.75	8	8	6.75	6.75	71.75
WD2 50	Topázio MG 1190	7.75	7.75	7.50	7.50	10	7.50	10	10	7.50	7.50	83.00
WD2 50	IPR 98	8.00	7.75	7.50	7.75	10	8.00	10	10	7.75	7.75	84.50
Average		7.58			7.29							

2021 (Figure 2). Although the FI 50 regime showed the second highest productivity in 2020 and 2021, its cultivar grains were not classified as specialty coffee. However, the productivity of genotypes did not present a biennially as the other regimes, and the overall score was close to 80. Therefore, the water regime is interesting for the crop in addition to the reduction of water in relation to FI 100.

At a 50% reduction, WD1 50 proved to be very detrimental to beverage quality compared to WD2 50, which showed that the interval from April to September without irrigation changed beverage quality compared to the shorter period from June to September.

Conclusions

1. The regimes of water replacement 100% with irrigation throughout the year and water deficit from June to September present higher productivity of arabica coffee (*Coffea arabica*) in 2020 and 2021, in the Brazilian Cerrado Central Plateau.
2. In regimes with greater water restriction, the levels of sucrose and trigonelline in the arabica coffee raw grains increase.
3. In regimes with greater water replacement, the level of citric acid in the arabica coffee raw grains increases.
4. Both regimes with the imposition of a water deficit from June to September with 100% and 50% of the crop water requirement produce a beverage of excellent quality due to greater uniformity in arabica coffee grain maturation.
5. With 50% of the crop water requirement, the water deficit from April to September is harmful to the quality of the beverage compared to the water deficit from June to September due to a period of two additional months in water stress.

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