https://doi.org/10.18406/2316-1817v16nunico20241911 e-ISSN 2316-1817

Efficiency of nitrogen fertilizers in newly implanted coffee crops

Gabriélle de Cássia Alexandre[1], Bruno Manoel Rezende de Melo[2], Sindynara Ferreira[3]

[1] Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais (IFSULDEMINAS) - Campus Inconfidentes, discente do curso de Engenharia Agronômica. E-mail: gabrielle.alexandre@alunos.ifsuldeminas.edu.br.

[2] Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais (IFSULDEMINAS) - Campus Inconfidentes, técnico-administrativo, fitotecnista. E- mail: bruno.melo@ifsuldeminas.edu.br.

[3] Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais (IFSULDEMINAS) - Campus Inconfidentes, docente pesquisadora. E-mail: sindynara.ferreira@ifsuldeminas.edu.br.

Received in: 18/04/2024
Accepted in: 19/07/2024

Abstract

A vigorous and productive coffee crop is the result of adequate nutritional management from its young stage. High yields demand greater investments, especially in fertilization, making nutritional management indispensable. Hence, this study evaluated the growth of coffee crop formation, soil acidity and economic aspects using different fertilizers. The experiment was conducted at Pedra Bela site, Ouro Fino, Brazil, between November 2022 and June 2023. Experimental design consisted of randomized blocks with nine treatments and four replications, totaling 36 plots. Treatments included conventional urea, conventional urea via drench, ammonium nitrate, ammonium sulfate, urea + S^0 + polymers, urea + NBPT, urea formaldehyde, organomineral CPMULT and coffee straw. Plant height, stem diameter, number of plagiotropic branches, defoliation percentage, soil pH, and costs were the variables evaluated. Treatment with ammonium nitrate achieved superior results in terms of pH growth within the range considered ideal for coffee crops compared with the other treatments. It also resulted in the highest number of plagiotropic branches, less defoliation and was the most cost-effective. As for soil acidity, ammonium nitrate and organomineral fertilizers promoted values within what is considered ideal for coffee cultivation.

Keywords: Acidity. *Coffea arabica* L. Growth. Development.

Introduction

Brazil is the largest coffee producer and exporter in the world and its production chain is responsible for generating jobs and serving as a source of revenue for several municipalities, making it one of the most economically important crops for the country (MAPA, 2023). According to the National Supply Company (Conab), the area occupied by Brazilian coffee growing totals 2.25 million hectares, of which 336.6 thousand hectares are crops in formation (CONAB, 2024).

Much of Brazil's coffee growing success is due to the adequate nutrients supply to plants via fertilization, since coffee plantations are almost entirely in areas with low fertility soils, whether impoverished naturally or simply due to previous misuse (MATIELLO et al., 2020).

Nitrogen (N) is the nutrient most required by the coffee plant, as it is essential for vegetative growth and is linked to biochemical processes (MARTINEZ et al., 2014). Hence, coffee growing is a major consumer of nitrogen fertilizers. Research estimates that 6.2 kg of nitrogen are needed for each bag of coffee produced (MATIELLO et al., 2020).

Nitrogen has a complex dynamic in the soil and is only assimilated as ammonium or nitrate. Besides its high mobility, factors such as temperature, soil pH, water availability, amount of organic matter and the fertilizer chosen also to contribute to aggravate nitrogen losses, which can reach 50 % (PIRES; FERNANDES; MICHELIN, 2021).

Urea is the most widely used nitrogen fertilizer in Brazilian agriculture due to its low cost and high nitrogen concentration. However, when applied directly to dry soils and in adverse weather conditions, urea suffers losses due to ammonia volatilization which poses significant obstacle to its use (VILLALBA et al., 2014).

Several technologies have been employed to try to increase the use of nitrogen. Increased efficiency fertilizers are an example and can be classified into three categories: stabilized fertilizers, controlled-release fertilizers, and slow-release fertilizers (GUELFI, 2017). There are also organomineral fertilizers, which are composed partly of organic material and partly of mineral elements (CRUZ; PEREIRA; FIGUEIREDO, 2017). Application technologies can also be an alternative, such as fertilization via drench which consists of dosed applications of fertilizer by directed jet.

Chagas et al. (2016) evaluated the ammonium losses of conventional nitrogen fertilizers, blends and controlled-release nitrogen fertilizers in producing crops. The authors found that ammonium nitrate was more efficient than controlled-release fertilizers. Souza et al. (2018) evaluated nitrate leaching and ammonia volatilization in coffee crops produced under different nitrogen sources. After analysis, they found that the stabilized source was more efficient compared with the conventional source, as it did not result in significant losses. Melo, Reis, and Soares (2022) studied the influence of slow-release fertilizer and conventional fertilizer on the morphological performance of coffee seedlings and observed that slow-release fertilizers had higher efficiency compared with conventional urea.

Although several studies with nitrogen sources in coffee production have already been published, most were conducted in productive crops, so that studies for newly implanted crops are still scarce. Due to the processes of nitrogen loss in the coffee crop, it is of great importance to include new strategies and technologies to improve use effectiveness of nitrogen fertilizers. Hence, this study evaluated the growth of coffee crop formation, soil acidity and economic aspects using different fertilizers.

Material and methods

The experiment was conducted at the Pedra Bela site, located in the municipality of Ouro Fino, southern Minas Gerais, between November 2022 and June 2023. Our experimental area is geographically located at latitude 22° 16’ 06.44” South and longitude 46° 18’ 51.39” West (GOOGLE EARTH, 2024), at an altitude of 926 meters, where coffee has been cultivated for more than 20 years. We used a Macaw cultivar (Procafé, Varginha, Brazil) of the species *Coffea arabica* L.

Planting was performed in January 2022, with a 3.5 m spacing between rows and 0.7 m between plants. For planting, soil preparation followed a conventional procedure. Holes were opened with 40 × 40 × 40 cm and liming and fertilization were conducted according to Ribeiro, Guimarães, and Alvarez (1999): without incorporation of organic matter and manually. Weed management was performed with herbicide in the planting row and mowing between rows. Cover fertilization was performed manually with the fertilizer formulated 30-00-00 at a dosage of 10 grams per plant.

During the experiment, fertilizations were conducted based on the chemical characteristics of the soil in the experimental area (Table 1) and following the recommendations for coffee cultivation (MATIELLO et al., 2020) for one-year-old crops, in which the nitrogen dose is set at 30 grams per plant.

Experimental design consisted of randomized blocks with nine treatments and four replications, as follows: (1) conventional urea; (2) conventional urea via drench; (3) ammonium nitrate; (4) ammonium sulfate; (5) urea + S^0+ polymers; (6) urea + NBPT; (7) urea formaldehyde; (8) organomineral CPMULT; and (9) coffee straw. Experimental plots consisted of eight plants from the same row, and only the six central plants were considered useful for evaluation. Blocks were arranged in the planting rows.

Table 1. Chemical analysis of the experimental area. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024

Date	pH	P[/1]	K[/1]	Al	Ca[/2]	Mg[/2]	H+Al[/2]	SB	CTC	V
	H_2O	--- mg dm⁻³ --		---------- cmol$_c$ dm^{-3} ----------						%
03/10/2022	5.84	12.9	62.0	0.00	5.1	1.19	3.15	6.40	9.55	67.02
M.O.	m	Ca/Mg	Mg/K	Zn[/1]	Fe[/1]	Mn[/1]	Cu[/1]	B	S	P-rem
dag dm^{-3}	%	---- cmol$_c$ dm^{-3} ---		---------- mg dm^{-3} ----------						mg L^{-1}
3.71	0.00	4.24	7.52	1.6	14.1	14.1	1.2	0.0	---------	41.10

[/1]P, K, Fe, Zn, Mn and Cu extractor: Mehlich 1:10.

[/2]Ca, Mg and Al Extractor: KCl 1N 1:10.

Source: Laboratory of Soil Fertility at IFSULDEMINAS – Inconfidentes Campus.

Treatment application was divided according to each treatment, and were performed on December 7, 2022, January 7, 2023, February 8, 2023, and March 9, 2023. Conventional urea and ammonium nitrate are fertilizers composed only of nitrogen; ammonium sulfate, urea + S^0+ polymers, urea + NBPT and urea formaldehyde are composed of nitrogen and sulfur; and the organomineral contains several nutrients (Table 2). We thus balanced the formulas so that, regardless of the amount of fertilizer applied, all plants received the same amount of nitrogen, phosphorus, potassium and sulfur.

With the dosages pre-established and properly weighed (Table 3), the fertilizers were applied to the canopy of the plants at approximately 5 cm from the orthotropic branch. Coffee straw application took place manually, without incorporation, taking care to respect the 5 cm from the root crown. Treatment application via drench was performed with a manual knapsack sprayer and an adapter for directed jet. Conventional urea was dissolved in water and two 50 mL jets were applied to each plant.

All useful plants of each plot were evaluated at time zero, i.e., before fertilizer application, and six months after the first evaluation. Difference in the results between T0 and T1 was used for statistical analysis. Plant height from the ground to the last pair of leaves of the orthotropic branch was evaluated with a ruler graduated in centimeters. Stem diameter was measured with

Table 2. Amount of nitrogen (N), phosphorus (P_2Or_5), potassium (K_2O) and sulphur (SO_4^{2+}) in percentage (%) of each fertilizer used. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024

Fertilizer	N (%)	P_2O_5 (%)	K_2O (%)	S-SO_4^{2-} (%)
1. Conventional urea	46	0	0	0
2. Conventional urea via drench	46	0	0	0
3. Ammonium nitrate	23	0	0	0
4. Ammonium sulfate	21	0	0	20
5. Urea + S^0 + polymers	42	0	0	8
6. Urea + NBPT	43	0	0	2
7. Urea formaldehyde	36	0	0	4
8. Organomineral CPMULT	14	2	14	0
9. Coffee straw*	1.5	0.15	3	0

Source: Authors' own elaboration (2024).

***Source:** Matiello, Jordão Filho, and Souza (2020).

Table 3. Total amount of fertilizer applied per treatment in grams (Total – g), dosage in grams per application per plant (g/apl./pl), number of applications per unit (un) of each treatment. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024

Treatments	Total (g)	Dosage (g/apl./pl)	No. of applications (un)
1. Conventional urea	65.21	21.73	3
2. Conventional urea via drench	65.21	21.73	3
3. Ammonium nitrate	130.43	43.47	3
4. Ammonium sulfate	142.85	47.61	3
5. Urea + S^0 + polymers	71.42	71.42	1
6. Urea + NBPT	69.75	23.25	3
7. Urea formaldehyde	83.33	27.77	3
8. Organomineral CPMULT	214.28	54.00	4
9. Coffee straw*	847.45	847.5	1

Source: Authors' own elaboration (2024).
***Source:** Matiello, Jordão Filho, and Souza (2020).

a digital caliper at a height of 5 cm from the ground in the direction of the row and expressed in millimeters.

Number of plagiotropic branches was counted at the beginning and end of the experiment. Percentage of defoliation was evaluated in the first pair of plagiotropic branches, from the base to the top of the plant, by counting the number of nodes and the loss of leaves and then transforming it into a percentage.

Monthly evaluations were conducted to verify the incidence of rust, brown eye spot and leaf miner. Using a non-destructive method, we evaluated the third pair of leaves of a plagiotropic branch randomly chosen in the middle third of all useful plants in each plot (SANTOS et al., 2008). Percentage of occurrence was defined by the ratio between the total number of attacked leaves and the total number of sampled leaves.

Soil pH was determined by collecting two soil samples below the projection of the plant canopy, one in the upper portion and the other in the lower portion of each plot, at a depth of 20 cm (RIBEIRO; GUIMARÃES; ALVAREZ, 1999).

Costs were calculated considering the purchase price and the percentage of loss of each fertilizer according to Carvalho et al. (2021) using Equation 1:

Equation (1)

$$(R\$) / \{\text{nutrient amount (in kg)} \bullet [1- (\text{percentage of losses} /100)]\}.$$

To verify the influence of precipitation on fertilizer efficiency, rainfall monitoring was performed with a conventional rain gauge.

Data were submitted to analysis of variance (ANOVA) and Tukey test at $p<0.05$ significance. Statistical analyses were performed using the statistical software SISVAR (FERREIRA, 2011). Principal component analysis (PCA) was performed to identify correlations between the variables and treatments using the Genes software (CRUZ, 2013).

Results and discussion

Regarding plant height and stem diameter, we found no significant differences between treatments (Table 4). Abranches, Soratto, and Perdoná (2018), studying the response of coffee crops to the application of coated urea, found no difference in plant height and diameter for treatments with conventional urea and coated urea in any of the evaluation periods. Valderrama et al. (2011), testing NPK sources and doses in maize crops, obtained similar results with no significant difference in basal stem diameter and height of plants treated with conventional urea and polymer-coated urea.

Regarding the number of plagiotropic branches, treatments with conventional urea via drench and ammonium nitrate yielded better results despite no difference found for treatments 1, 4, 5, 6, 7 and 8. Coffee straw had the least significant growth, differing statistically from treatments 2 and 3.

Coffee straw (T9) showed the highest percentage of defoliation, with a value equal to 53.69 %; however, it did not differ statistically from treatments 1, 5, 6 and 7. Differing significantly from the coffee straw application, treatments 2, 3, 4 and 8 exhibited the lowest defoliation percentages (Table 4). Santos et al. (2008), studying coffee nutrition and the progress of brown eye spot and rust as a function of organic fertilization, found that fertilization performed only with coffee straw favored the increase of diseases and, consequently, the higher rate of defoliation compared with other treatments. Such high percentage of defoliation may also be related to a possible nitrogen deficiency, which is probably immobilized, since this deficiency leads to defoliation.

As for pH, treatments with conventional urea (T1), conventional urea via drench (T2), ammonium sulfate (T4), urea+S0+ polymers (T5), urea + NBPT (T6) and urea formaldehyde (T7) presented the highest values of soil acidity (Table 4). High soil acidity can be harmful, as it favors the availability of toxic elements for plants, such as aluminum, and affect the availability of nutrients (MARTINS, 2005). According to Matiello et al. (2020), the ideal pH range for coffee cultivation is between 5.5 and 6.0; thus, only treatments with ammonium nitrate and organomineral are within the appropriate range.

Table 4. Means for the variables: height (H) in centimeters (cm), stem diameter (SD) in millimeters (mm), number of plagiotropic branches in unit (NPB – un), defoliation (DEF) in percentage (%) and pH for the different treatments. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024

Treatments	**H* (cm)**	**SD (mm)**	**NPB (un)**	**DEF (%)**	**pH**
1. Conventional urea	18.62 a	13.18 a	12.50 ab	47.09 ab	5.27 bc
2. Conventional urea via drench	23.12 a	15.05 a	13.24 a	42.12 b	5.20 bc
3. Ammonium nitrate	21.71 a	13.71 a	13.59 a	39.53 b	5.65 ab
4. Ammonium sulfate	20.56 a	13.96 a	11.83 b	39.35 b	4.79 c
5. Urea + S^0 + polymers	23.42 a	13.78 a	11.18 ab	43.67 ab	5.22 bc
6. Urea + NBPT	21.71 a	14.59 a	12.25 ab	44.46 ab	5.16 bc
7. Urea formaldehyde	19.90 a	13.89 a	10.14 ab	43.70 ab	5.31 bc
8. Organomineral CPMULT	19.03 a	13.70 a	10.55 ab	42.56 b	5.74 ab
9. Coffee straw	17.01 a	12.81 a	8.00 b	53.69 a	6.22 a
CV (%) **	19.57	14.53	17.83	10.30	5.39

*Means followed by the same letter in the column do not differ by Tukey test at 5 % probability.

**CV (%): coefficient of variation in percentage.

Source: Authors' own elaboration (2024).

Freitas (2017), studying the efficiency of conventional, stabilized, slow- or controlled-release nitrogen fertilizers in coffee crops, obtained results similar to ours, in which treatments with urea dissolved in water, urea + NBPT, urea + S^0+ polymers and urea formaldehyde caused a significant reduction in pH values.

Nitrogen fertilizers are acidifiers, especially those composed of ammonium. Hence, the acidity index of the fertilizer can be determined by the amount of calcium carbonate needed to neutralize the soil acidity caused by it. According to Batista et al. (2018), the equivalent of calcium carbonate for correcting the acidity generated by ammonium nitrate, ammonium sulfate and urea is 600 kg t^{-1}, 1,100 kg t^{-1} and 840 kg t^{-1}, respectively.

Treatment 9 (coffee straw) resulted in the highest pH value, even when applied on soil surface (Table 4). Paula et al. (2015), studying changes in soil fertility attributes and initial coffee growth with the application of coffee straw, observed that coffee straw incorporated into the soil or on the surface increased the pH.

Regarding costs, treatment with urea + S^0+ polymers (T5) was the most cost-effective when compared with treatments using conventional urea (T1), urea + NBPT (T6) and urea formaldehyde (T7) (Table 5). We found no difference for plant growth between these treatments. Treatment with conventional urea via drench (T2) also showed no significant differences in relation to plant growth; however, it was the second most cost-effective. In turn, despite having resulted in the lowest cost of N per kg, treatment with ammonium sulfate (T4) caused the highest soil acidity.

Knowing that the applications were performed on December 7, 2022, January 7, 2023, February 8, 2023, and March 9, 2023, respectively, and analyzing Figure 1, we observe that after each application there were adequate accumulated levels of rainfall, which may have positively influenced the reduction of nitrogen losses in ammonia form, resulting in similar plant growth for these treatments. Primavesi et al. (2003), in their study on the efficiency of urea fertilization in pasture, identified a reduction in ammonia losses, especially with rain in the first three days after application.

Principal component analysis (Figure 2) shows an association for 75.36 % of the entire assay variation, in which the best indices of stem

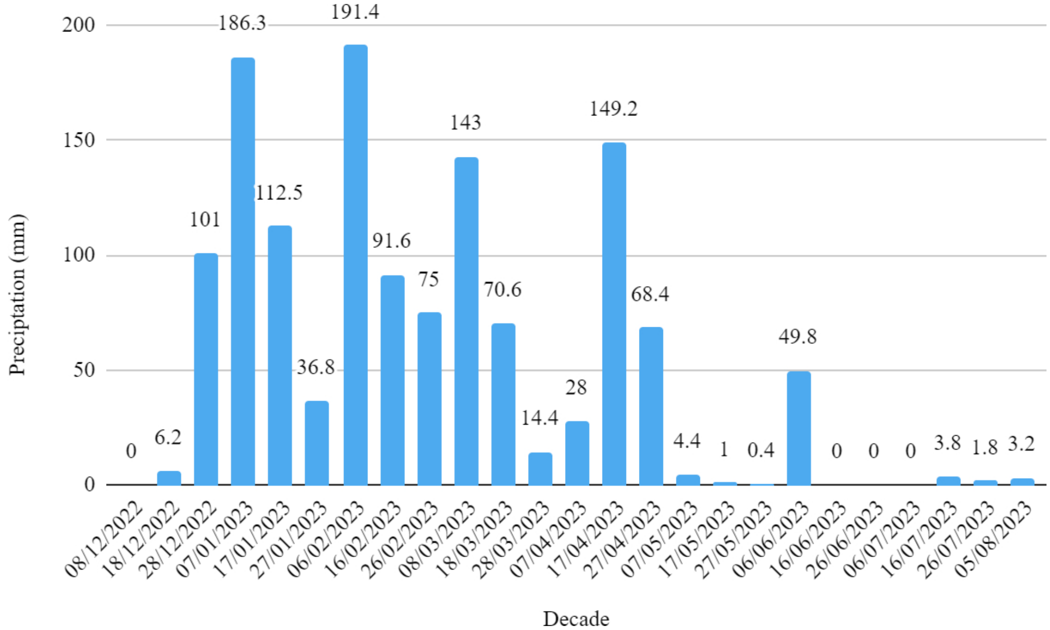
Table 5. Percentage of nitrogen (% N), percentage of losses (% losses), fertilizer cost in 50 kg bag (50 kg bag course), price of N kg without losses and price of effective N kg with losses, for all treatments. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024

Treatments	% N	% losses*	Cost (50 Kg bag)	N kg price	Effective N kg price
				Without losses	With losses
1. Conventional urea	46	22.98	R$ 280.00	R$ 6.09	R$ 7.90
2. Conventional urea via drench	46	9.87	R$ 280.00	R$ 6.09	R$ 6.75
3. Ammonium nitrate	23	0.18	R$ 200.00	R$ 8.69	R$ 8.71
4. Ammonium sulfate	21	0.23	R$ 137.00	R$ 6.52	R$ 6.54
5. Urea + S^0 + polymers	42	4.30	R$ 300.00	R$ 7.14	R$ 7.29
6. Urea + NBPT	43	12.12	R$ 335.00	R$ 7.79	R$ 9.08
7. Urea formaldehyde	36	0.46	R$ 458.90	R$ 12.75	R$ 12.80

Source: Adapted from Freitas (2017).

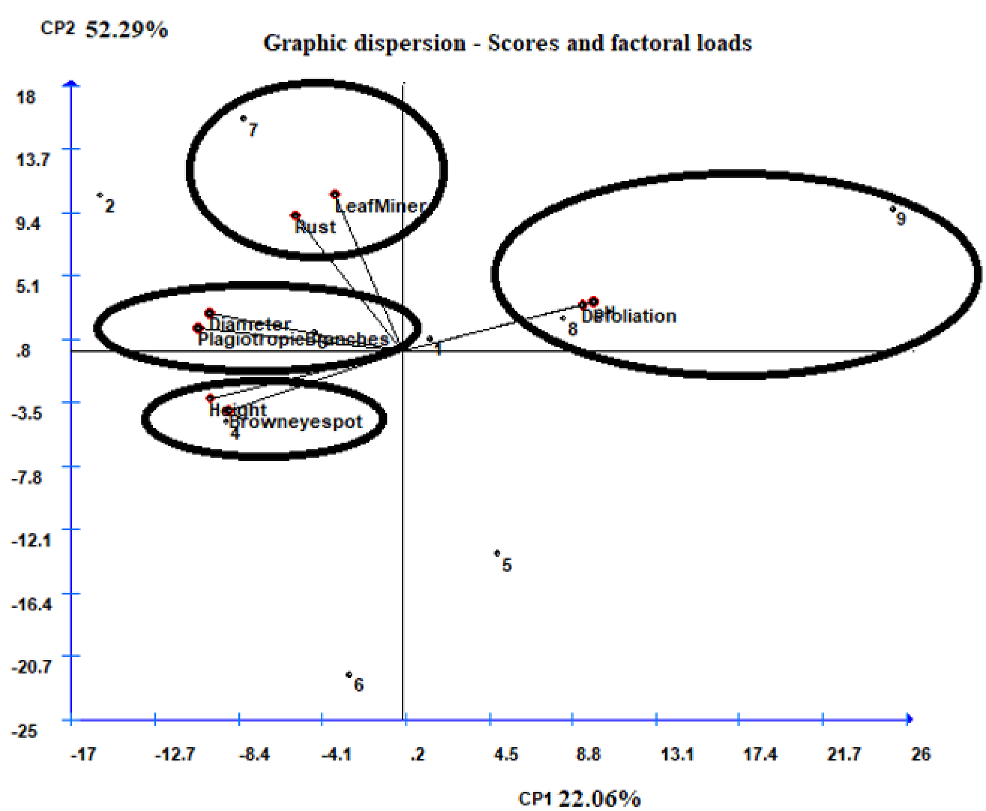
* Freitas, 2017.

Figure 1. Accumulated values of rainfall per decade, during the study period, December/2022 to August/2023. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024



Source: Authors' own elaboration (2024).

Figure 2. Biplot with the projection of the variables in the principal component analysis (PCA), including the breakdown of the nine treatments for the variables: height, diameter, number of plagiotropic branches, pH, defoliation, rust, brown eye spot and leaf miner. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2024



Source: Authors' own elaboration (2024).

diameter and number of plagiotropic branches are associated with T3 (ammonium nitrate). This treatment was the most responsive, as the association of these variables demonstrates balance, making the plant more resistant to adverse conditions and consequently more productive. Considering the physiology of the coffee plant, nitrogen uptake occurs preferentially in the form of nitrate NO_3^- (PAULA NETO, 2015) and the losses of this fertilizer are minimal, about only 0.18 % (FREITAS, 2017).

Treatment 4 (ammonium sulfate) was grouped with taller plants and a higher percentage of brown eye spot disease (Figure 2). In young crops, very tall plants can mean etiolation since taller plants with a smaller diameter are naturally less resistant to environmental conditions and more susceptible to pests and diseases, especially brown eye spot disease. Additionally, it resulted in the lowest pH value. The major problem with ammonium sulfate fertilizer is its great capacity to acidify the soil, which can directly impact its quality and compromise the plant's root system (MELÉM JÚNIOR et al., 2001).

Treatments with conventional urea (T1), conventional urea via drench (T2), urea + S^0+ polymers (T5) and urea + NBPT (T6) were not grouped with any of the variables, indicating a lower degree of association. Treatment 7 had no considerable statistical results compared with the other treatments (Table 4); but according to the PCA, which is an association statistic (Figure 2), this treatment showed the higher occurrence of diseases, together with treatment 4.

Conclusion

Ammonium nitrate resulted in the highest number of plagiotropic branches, less defoliation and was the most cost-effective. As for soil acidity, ammonium nitrate and organomineral fertilizers promoted values within what is considered ideal for coffee cultivation.

References

ABRANCHES, J. L.; SORATTO, R. P.; PERDONÁ, M. J. Ureia revestida e o crescimento do cafeeiro arábica. **Fórum Ambiental da Alta Paulista**, v. 14, p. 100-108, 2018. DOI: 10.17271/19800827143201819448, 2018.

BATISTA, M.A.; INOUE, T.T.; ESPER NETO, M.; MUNIZ, A.S. Princípios de fertilidade do solo, adubação e nutrição mineral. In: BRANDÃO FILHO, J.U.T.; FREITAS, P.S.L.; BERIAN, L.O.S.; GOTO, R. **Hortaliças-fruto**. Maringá: EDUEM, 2018. p. 113-162. DOI: https://doi.org/10.7476/9786586383010.0006.

CARVALHO, G. R.; FERREIRA, A. D.; ANDRADE, V. T.; BOTELHO, C. E.; CARVALHO, J. P. F. (ed.). **Cafeicultura do cerrado**. 22. ed. Belo Horizonte: Epamig, 2021. 564 p.

CHAGAS, W. F. T.; GUELFI, D. R.; CAPUTO, A. L. C.; SOUZA, T. L. de; ANDRADE, A. B.; FAQUIN, V. Ammonia volatilization from blends with stabilized and controlled-released urea in the coffee system. **Ciência e Agrotecnologia**, v. 40, n. 5, p. 497-509, 2016. DOI: 10.1590/1413-70542016405008916.

CONAB - COMPANHIA NACIONAL DE ABASTECIMENTO. **Clima mais favorável e bienalidade positiva apontam produção estimada em 58,08 milhões de sacas de café**. 2024. Disponível em: https://www.conab.gov.br/ultimas-noticias/5362-clima-mais-favoravel-e-bienalidade-positiva-apontam-producao-estimada-em-58-08-milhoes-de-sacas-de-cafe. Acesso em: 04 abr. 2024.

CRUZ, A. C.; PEREIRA, F. dos S.; FIGUEIREDO, V. S. de. Fertilizantes organominerais de resíduos do agronegócio: avaliação do potencial econômico brasileiro. **Indústria química / BNDES Setorial**, n. 45, p. 137-187, 2017. Disponível em: https://web.bndes.gov.br/bib/jspui/bitstream/

1408/11814/1/BS%2045 %20Fertilizantes %20organominerais%20de%20res%c3 %adduos%20 %5b...%5d_P_BD.pdf. Acesso em: 27 fev. 2024.

CRUZ, C. D. Genes - a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum**, v. 35, n. 3, 271-276, 2013.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia,** v. 35, n. 6, p. 1039-1042, 2011.

FREITAS, T. **Fertilizantes nitrogenados convencionais, estabilizados, de liberação lenta ou controlada na cultura do cafeeiro:** eficiência e custos. 2017. 96 f. Dissertação (Mestrado) - Curso de Pós-Graduação em Agronomia/Fitotecnia, Universidade Federal de Lavras, Lavras, 2017. Disponível em: http://repositorio.ufla.br/jspui/bitstream/1/13309/1/DISSERTA%C3 %87%C3%83O_Fertilizantes%20nitrogenados%20convencionais%2C%20estabilizados%2C%20de%20libera%C3%A7%C3 %A3o%20lenta%20ou%20controlada%20na%20cultura%20do%20cafeeiro%20efici%C3%AAncia%20e%20custos.pdf. Acesso em: 27 fev. 2024.

GOOGLE EARTH - **Mapas**. Disponível em: http://earth.google.com/web/. Acesso em: 03 abr. 2024.

GUELFI, D. Fertilizantes nitrogenados estabilizados, de liberação lenta ou controlada. International Plant Nutrition Institute - INPI. **Informações agronômicas nº 157.** Piracicaba: IPNI, 2017. p. 1 - 32. Disponível em: http://www.ipni.net/PUBLICATION/IA-BRASIL.NSF/0/90DE38570A7216CB832580FB0066E3B4/$FILE/Jornal-157.pdf. Acesso em: 27 fev. 2024.

MAPA - MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO. **Café no Brasil**. 2018. Disponível em: https://www.gov.br/agricultura/pt-br/assuntos/politica-agricola/cafe/cafeicultura-brasileira. Acesso em: 21 fev. 2024.

MARTINEZ, H. E. P.; CLEMENTE, J. M.; LACERDA, J. S. de; NEVES, Y. P.; PEDROSA, A. W. Nutrição mineral do cafeeiro e qualidade da bebida. **Revista Ceres**, v. 61, suplemento, p. 838-848, 2014. DOI: 10.1590/0034-737x 201461000009.

MARTINS, C. E. Práticas agrícolas relacionadas à calagem do solo. **Comunicado Técnico nº 47**. Juiz de Fora: Embrapa, 2005. 6 p. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/65417/1/COT-47-Praticas-agricolas-relacionadas.pdf. Acesso em: 03 abr. 2024.

MATIELLO, J. B.; SANTINATO R.; GARCIA, A. W. R.; ALMEIDA S. R de. **Cultura do café no Brasil:** manual de recomendações. Varginha (MG): Fundação PROCAFÉ, 2020. 716 p. ISBN 978-85-6687-97-8.

MATIELLO, J. B.; JORDÃO FILHO, M.; SOUZA, T. de. Não queime a palha de café, mas se queimar aproveite as cinzas na lavoura. **Folha Técnica nº 539**. Varginha: Fundação Procafé, 2020, 2 p. Disponível em: https://www.fundacaoprocafe.com.br/post/n%C3%A3o-queime-a-palha-de-caf%C3%A9-mas-se-queimar-aproveite-as-cinzas-na-lavoura. Acesso em: 27 mar. 2024.

MELÉM JÚNIOR, N. J.; MAZZA, J. A.; DIAS, C. T. S.; BRISKE, E. G. Efeito de fertilizantes nitrogenados na acidificação de um Argissolo Vermelho Amarelo latossólico distrófico cultivado com milho. **Ciência e Tecnologia**, v. 2, n. 1, p. 75 - 89, 2001. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/124767/1/CPAF-AP-2001-Efeito-de-fertilizantes-nitrogenados.pdf. Acesso em: 03 abr. 2024.

MELO, A. dos S.; REIS, I. R. dos; SOARES, D. de A. Influência do adubo de liberação lenta em relação ao convencional no desempenho morfológico de mudas de café. **Revista Brasileira**

de Gestão e Engenharia, v. 13, n. 1, p. 1-9, 2022. Disponível em: https://periodicos.cesg.edu.br/index.php/gestaoeengenharia/article/view/545. Acesso em: 05 fev. 2024.

PAULA, D. W. de; MANTOVANI, J. R.; REIS, R. A. dos; MOREIRA, J. L. A.; AUGUSTO, H. S.; MARQUES, D. J. Alterações em atributos de fertilidade do solo e crescimento inicial do cafeeiro com aplicação de palha do café. In: Congresso Brasileiro de Ciência do Solo, 35., 2015, Natal. **Anais...** Natal: SBCS, 2015. p. 1-4. Disponível em: https://www.eventossolos.org.br/cbcs2015/anais/index_int5e4e.html. Acesso em: 04 fev. 2024.

PAULA NETO, A. P.; FAVARIN, J. L.; DOS REIS, A. R.; TEZOTTO, T.; DE ALMEIDA, R. E. M.; LAVRES JUNIOR, J.; GALLO, L. A. Nitrogen metabolism in coffee plants in response to nitrogen supply by fertigation. **Theoretical and Experimental Plant Physiology**, v. 27, p. 41-50, 2015. DOI 10.1007/s40626-014-0030-2

PIRES, H. D.; FERNANDES, L. M.; MICHELIN, L. H. F. Avaliação da eficiência de adubação nitrogenada na cultura de milho utilizando fertilizantes com inibidores: uma revisão. In: RIBEIRO, J. C. (org.). **A Face transdisciplinar das ciências agrárias 2**. Ponta Grossa: Atena, 2021. p. 106-120.

PRIMAVESI, O.; CORRÊA, L. de A.; PRIMAVESI, A. C.; CANTARELLA, H.; SILVA, A. G. da. Adubação com ureia em pastagem de *Brachiaria brizantha* sob manejo rotacionado: eficiência e perdas. **Comunicado Técnico nº 41**. São Carlos: Embrapa, 2003. 6 p. Disponível em: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/46697. Acesso em: 23 fev. 2024.

RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ, V. V. H. (ed.). **Recomendações para o uso de corretivos e fertilizantes em Minas Gerais:** 5ª aproximação. Viçosa: Comissão de Fertilidade do Solo do Estado de Minas Gerais, 1999. 359 p.

SANTOS, F. da S.; SOUZA, P. E. de; POZZA, E. A.; MIRANDA, J. C.; CARVALHO, E. A.; FERNANDES, L. H. M.; POZZA, A. A. A. Adubação orgânica, nutrição e progresso de cercosporiose e ferrugem-do-cafeeiro. **Pesquisa Agropecuária Brasileira**, v. 43, n. 7, p. 783-791, 2008. DOI: 10.1590/s0100-204x2008000700001.

SCOTT, A.; KNOTT, M. Cluster-analysis method for grouping means in analysis of variance. **Biometrics**, v. 30, n. 3, p. 507-512, 1974.

SOUZA, J. A.; ROCHA, G. C.; GOMES, M. de P.; REZENDE, C. H. S. Nitrogen dynamics in a Latosol cultivated with coffee. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 22, n. 6, p. 390-395, 2018.

VALDERRAMA, M.; BUZETTI, S.; BENETT, C. G. S.; ANDREOTTI, M.; TEIXEIRA FILHO, M. C. M. Fontes e doses de NPK em milho irrigado sob plantio direto. **Pesquisa Agropecuária Tropical**, v. 41, n. 2, p. 254–263, 2011. Disponível em: https://revistas.ufg.br/pat/article/view/8390. Acesso em: 15 fev. 2024.

VILLALBA, H. A. G.; LEITE, J. M.; OTTO, R.; TRIVELIN, P. C. O. Fertilizantes nitrogenados: novas tecnologias. **Informações Agronômicas nº 148.** 2014. Disponível em: http://www.ipni.net/publication/ia-brasil.nsf/0/8A8C436B98265A2983257DB6006A962D/$FILE/Page12-20-148.pdf. Acesso em: 03 abr. 2024.