CHILEAN JOURNAL of AGRICULTURAL RESEARCH

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RESEARCH ARTICLE

Comparison of iron application ways in coffee seedlings

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Received: 14 March 2023; Accepted: 10 June 2023, doi:10.4067/S0718-58392023000500616

ABSTRACT

Iron (Fe) is shown to be of great importance in some specific functions, and without it, the plant can experience a nutritional imbalance, thus affecting its development. The present study aimed to evaluate the effects of the application of Fe doses in coffee (*Coffea arabica* L.) 'Obatã IAC 1669-20' seedlings via foliar, previous fertilization of the substrate, and aqueous solution on the substrate and identify the best management. The experiment was carried out in a completely randomized design, with seven treatments and five replicates. The treatments were five Fe concentrations via foliar (0.30, 0.45, 0.60, 0.75, and 0.90 g of Fe L^{-1}), previous fertilization on the substrate (0.372 g Fe m^{-3}), and aqueous solution on the substrate (0.30 g Fe L^{-1}), totaling seven treatments. Fertilization with Fe via foliar at 0.45 g Fe L^{-1} in the production of coffee seedlings showed significant influence on seedling height, stem diameter, and leaf area, in addition to having one of the highest values of Dickson quality index. Thus, coffee seedlings with the application of 0.45 g Fe L^{-1} via foliar had the best results, with 11.2 cm height, 4.1 mm diameter, 17.3 cm^2 leaf area, and 0.32 Dickson quality index. It promoted seedlings with more significant gains in the foliar area (24.2%) and stem diameter (27.4%), allowing a shorter time in nursery. The treatment aqueous solution 0.30 g Fe L^{-1} on the substrate is a second option for the Fe application in coffee 'Obatã IAC 1669-20' seedlings. The treatment with the previous fertilization of the substrate with 0.372 g Fe m^{-3} is the less recommended.

Key words: *Coffea arabica*, coffee seedlings, Fe concentrations, foliar application, nutrition.

INTRODUCTION

Coffee production is one of the leading agricultural activities in Brazil, and the country is the largest producer in the world. This production is essential for its economy, with emphasis on the species *Coffea arabica* L. (Arabica coffee). The leading coffee-producing state in Brazil is Minas Gerais, and Arabica production is mainly concentrated in the South of Minas, Triangulo Mineiro, and Alto Paranaíba (Jesus and Pereira, 2020). World production in 2020/2021 was estimated at 169.64 million bags (ICO, 2021). Brazil obtained an estimated production of 58.4 million bags of 60 kg and exceeded the 2021 harvest by 5.6% (Conab, 2022).

Brazil, the world's largest producer of coffee, also faces some difficulties in production. Increasingly, producers are using new coffee cultivars that are more tolerant to pests and diseases and have a higher yield potential. To choose a cultivar, producers aim to increase grain yield and reduce the cost of farming and be resistant to pests, nematodes, diseases, heat and drought (Pereira et al., 2022). Some cultivars, such as Obatã IAC 1669-20, seek to meet some requirements of producers; this cultivar was bred and has some desirable characteristics such as short height; good secondary branching, large, red fruits with medium to late maturation, and moderately resistant to rust (Guerreiro Filho et al., 2006; Resende et al., 2021). However, producers of coffee seedlings in the northeast region of the State of São Paulo have problems of Fe

deficiency, since the foliar application at a dose of 60 g Fe per 200 L water (0.30 g Fe L^{-1}) has been presenting problems, such as loss of quality of seedlings and financial losses.

Iron is a primordial and essential micronutrient for forming chlorophyll in the plant and has catalytic and soil structural functions (Dias dos Santos et al., 2021). It is a constituent of enzymes, it also works in photosynthesis, respiration, lignin and suberin synthesis, and auxin metabolism. Iron presents a characteristic low mobility in the plant; the deficiency symptom is presented primarily in the youngest leaves due to its low translocation. The characteristic Fe deficiency symptom is the yellowing of leaves due to lesser chlorophyll synthesis; therefore, only the leaf veins can remain green for a period. As the deficiency symptom progresses, leaves may turn whitish (Bautista-Tulin et al., 2018). One of the characteristic symptoms presented in a plant with Fe deficiency is chlorosis (Li et al., 2019) between the veins, which initially stands out in the young leaves because Fe cannot move from the old leaves to the younger ones (Taiz et al., 2014).

The omission of the micronutrient Fe can present symptoms such as necrosis, which can occur at the tip of the blade and on the margins of leaves and may even advance to the center of leaves, causing, in some cases, leaf fall. It was also observed that necrotic scores occurred in the center of the leaf blade of some plants (Lange et al., 2005; Freitas et al., 2015; Wang et al., 2020). In coffee production, some nutrients are essential, and the micronutrient Fe is one of them. It is shown to be of great importance in some specific functions, and without it, the plant can experience a nutritional imbalance, thus affecting its development (Alves et al., 2019).

The study aimed to evaluate the effects of Fe application in coffee seedlings via foliar, substrate fertilization, and aqueous solution on the substrate and identify the best management.

MATERIALS AND METHODS

The experiment with coffee (*Coffea arabica* L.) 'Obatã IAC 1669-20' seedlings was carried out from October 2020 to January 2021 in Ribeirão Corrente, São Paulo (47°33' W, 20°30' S, and average altitude 910 m a.s.l.), to meet the demand of a company that produces coffee seedlings. They use the dose 60 g Fe 200 L^{-1} water via foliar = 0.30 g Fe L^{-1} and are having problems with Fe deficiency in the seedlings. We used this dose (60 g Fe 200 L^{-1} water via foliar = 0.30 g Fe L^{-1}) as a control treatment. According to the Köppen classification, the climate of the region is subtropical/altitude tropical climate (CWA), with rainy summers and dry winters, average annual rainfall of 1564 mm, and average annual temperature is 18 °C.

The production environment consists of a nursery measuring 50 m long by 30 m wide, with a height of 4 m, covered with a monofilament screen with 50% shading. Within this environment, beds were made of concrete blocks 2.5 m wide, 1.10 m high, and 18 m long, filled with sterilized sand. At 75 d after sowing (DAS), seedlings were transplanted into 180 mL tubes containing the commercial substrate Sphagnum. The irrigation of seedlings was automated by sprinkler at 06:30 and 17:30 h for 12 min.

A completely randomized design (CRD) was used, with seven treatments and five replicates with three plants per plot. The treatments were five Fe concentrations via foliar, one application in the substrate, and one application as aqueous solution on the substrate. The seven treatments were designated as follows: via foliar 0.30 (T1), 0.45 (T2), 0.60 (T3), 0.75 (T4), and 0.90 g Fe L^{-1} (T5); substrate fertilization 0.372 g Fe m^{-3} substrate (T6); and fertigation with aqueous solution on the substrate 0.30 g Fe L^{-1} (T7).

The concentrations of 60, 90, 120, 150, and 180 g Fe 200 L^{-1} (200 L applied in 900 thousand seedlings), considered treatments T1 (control), T2, T3, T4, and T5, respectively, were applied by a hand sprayer. In treatment T6, 0.372 g Fe m^{-3} were applied. This Fe application was done manually, distributed, and homogenized in the substrate. The treatment T7, with the application of an aqueous solution on the substrate, 60 g Fe 200 L^{-1} water was applied with a manual sprayer on the substrate. The Fe was supplied by the commercial product Basafer Plus (COMPO EXPERT

GmbH, Münster/Westphalia, Germany), which has 6% Fe in its composition; it was applied at 110, 125, 145, and 165 d after sowing (DAS).

Seedling height, number of leaves, stem diameter, and leaf area were evaluated at 125, 145, 165, and 180 DAS, corresponding to 55, 75, 95, and 105 d after transplanting (DAT). At 180 DAS, DM of the shoot and root system was collected. Based on this evaluation, total DM (TDM), relationship between the seedling height and stem diameter (RHD), relationship between DM of the shoot and root system (RSR), and Dickson quality index (Dickson et al., 1960) were estimated. The absolute growth rate (AGR, cm d^{-1}) was determined between collections at 125 and 180 DAS (Benincasa, 2003).

The leaf area was collected by measuring the average length and average width of leaves with the aid of a ruler graduated in millimeters. Leaf area was calculated by the estimation methodology proposed by Partelli et al. (2006): $LA = 0.2027 \times MLG^{2.1336}$; where LA is estimated leaf area for seedlings (cm^2) and MLG is midrib length (cm), 2.1336 is exponent of the regression equation.

The height of the seedling was collected with a ruler graduated in centimeters, and the diameter of the stem with a digital caliper in millimeters. The seedlings were kept in an air circulation oven at 65 ºC for 72 h to obtain DM and weighed on a precision scale. And then, the collected material was sent to the laboratory of the company PRIMORLAB for analysis of the Fe content. Leaf Fe was determined by atomic absorption spectrometry (Carmo et al., 2000).

The data obtained were submitted to ANOVA, applying the F test at a 5% probability level, and the means, when significant, were evaluated by the LSD test (t-student).

RESULTS AND DISCUSSION

The concentrations 0.45 g Fe L^{-1} (T2) via foliar and 0.30 g Fe L^{-1} via aqueous solution on the substrate (T7) provided the highest leaf content of Fe, with greater emphasis on T7 (Figure 1).

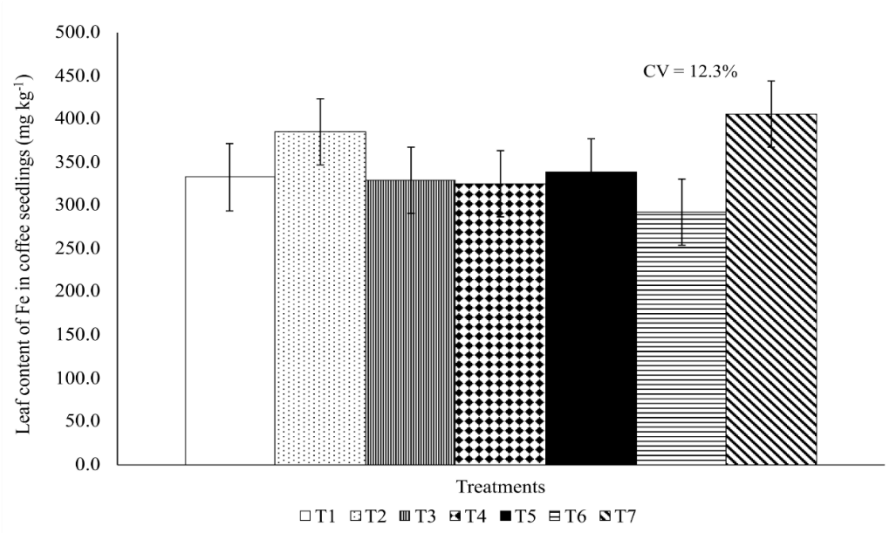

Figure 1. Leaf content of Fe in coffee 'Obatã IAC 1669-20' seedlings. Franca, São Paulo, 2021. T1: Foliar 0.30 g Fe L^{-1}; T2: foliar 0.45 g Fe L^{-1}; T3: foliar 0.60 g Fe L^{-1}; T4: foliar 0.75 g Fe L^{-1}; T5: foliar 0.90 g Fe L^{-1}; T6: substrate with 0.372 g Fe m^{-3}; T7: aqueous solution on the substrate 0.30 g Fe L^{-1}; CV: coefficient of variation. Vertical bars correspond to standard deviation.

Observing the height of coffee seedlings at 180 DAS (Figure 2A), it was found that in T2, which did not differ from treatments 0.30 g Fe L^{-1} (T1), 0.75 g Fe L^{-1} (T4), and T7 (via aqueous solution), the seedlings were larger than the seedlings from the other treatments (Table 1; Figure 2A).

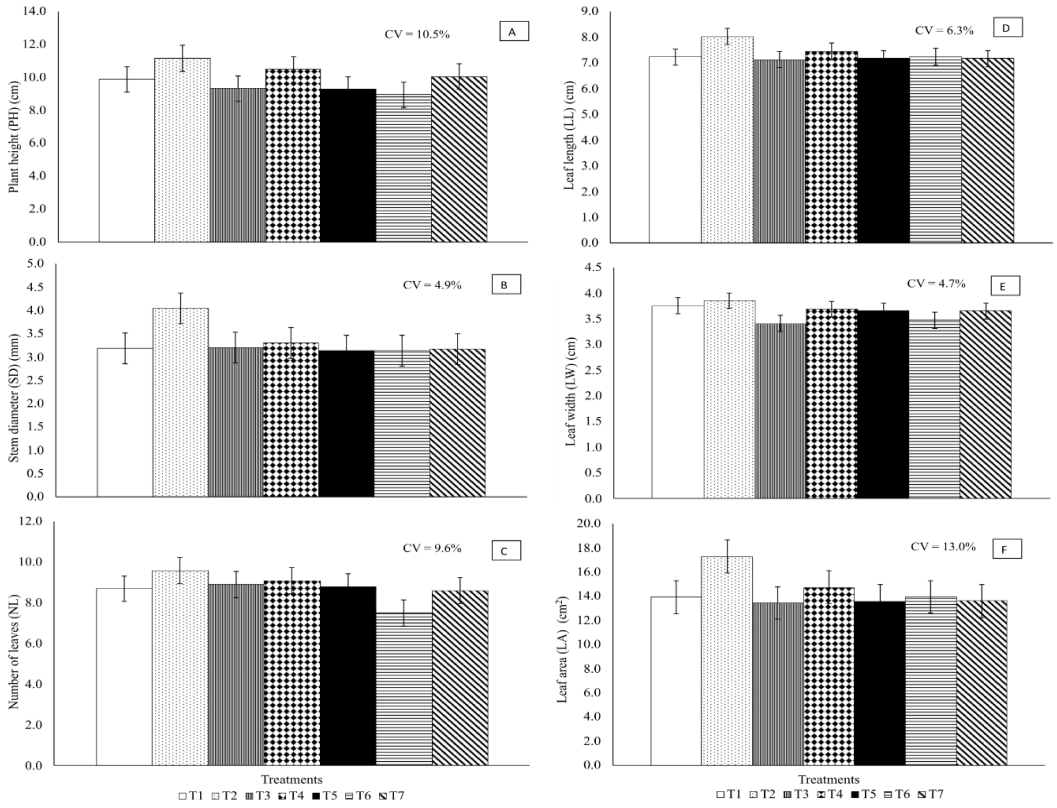

Figure 2. Plant height (PH), stem diameter (SD), number of leaves (NL), leaf length (LL), leaf width (LW), leaf area (LA) at 180 d after sowing (DAS) of coffee 'Obatã IAC 1669-20' seedlings, according to Fe concentrations and ways of application. Franca, São Paulo, 2021. T1: Foliar 0.30 g Fe L^{-1}; T2: foliar 0.45 g Fe L^{-1}; T3: foliar 0.60 g Fe L^{-1}; T4: foliar 0.75 g Fe L^{-1}; T5: foliar 0.90 g Fe L^{-1}; T6: substrate with 0.372 g Fe m^{-3}; T7: aqueous solution on the substrate 0.30 g Fe L^{-1}; CV: coefficient of variation. Means followed by the same letter for each variable do not differ from each other by the LSD test (Student's t) at 5% significance. Vertical bars correspond to standard deviation.

Evaluating the coffee seedlings 'Obatã IAC 1669-20', at 110 d after sowing, it was verified that in all treatments, the stem diameter did not show significant differences; however, at 125, 140, 155 (Table 1), and 180 DAS (Figure 2B), the largest stem diameter was found by the seedlings with T2 (Table 1; Figure 2B). It is observed that the stem diameter of the treatment with T2 promoted significant performance in the seedlings from 125 DAS until the end of the experiment since this dose favored the growth of the stem in thickness (Table 1; Figure 2B).

In the course of the evaluations on the number of leaves per plant, the treatment with previous fertilization of the substrate with 0.372 g Fe m^{-3} (T6) showed a result lower than 180 DAS compared to the other treatments that do not differ from each other (Figure 2C).

Table 1. Plant height, stem diameter, number of leaves, leaf length, leaf width, and leaf area at 110, 125, 140, and 155 d after sowing (DAS) of coffee 'Obatã IAC 1669-20' seedlings, according to Fe concentrations and ways of application. Franca, São Paulo, 2021. T1: Foliar 0.30 g Fe L^{-1}; T2: foliar 0.45 g Fe L^{-1}; T3: foliar 0.60 g Fe L^{-1}; T4: foliar 0.75 g Fe L^{-1}; T5: foliar 0.90 g Fe L^{-1}; T6: substrate with 0.372 g Fe m^{-3}; T7: aqueous solution on the substrate 0.30 g Fe L^{-1}; CV: coefficient of variation. Means followed by the same letter for each variable do not differ from each other by the LSD test (Student's t) at 5% significance.

	110 DAS	125 DAS	140 DAS	155 DAS	110 DAS	125 DAS	140 DAS	155 DAS
	Plant height				Stem diameter			
	cm				mm			
T1	2.83^{b}	4.83^{b}	6.82^{ab}	8.29^{b}	2.83^{ab}	2.92^{bc}	3.01^{b}	3.08^{b}
T2	2.83^{b}	5.19^{a}	7.41^{ab}	9.50^{a}	2.84^{ab}	3.21^{a}	3.63^{a}	3.79^{a}
T3	2.83^{b}	5.09^{ab}	6.67^{b}	7.99^{b}	2.83^{b}	2.87^{c}	2.93^{b}	3.01^{b}
T4	2.81^{b}	5.08^{ab}	7.33^{ab}	8.77^{ab}	2.86^{ab}	2.98^{b}	3.06^{b}	3.12^{b}
T5	2.89^{a}	4.98^{ab}	6.89^{ab}	7.89^{b}	2.89^{a}	2.95^{bc}	2.98^{b}	3.03^{b}
T6	2.89^{a}	4.94^{ab}	6.78^{ab}	7.79^{b}	2.89^{a}	2.93^{bc}	3.00^{b}	3.04^{b}
T7	2.93^{a}	4.91^{ab}	7.46^{a}	8.66^{ab}	2.88^{ab}	2.96^{bc}	3.02^{b}	3.06^{b}
CV, %	1.6	4.8	8.4	10.0	1.7	2.9	3.7	4.3
	Number of leaves				Leaf length			
	nr				cm			
T1	3.1^{ab}	4.1^{ab}	6.3^{ab}	6.8^{ab}	4.77^{ab}	5.60^{bc}	6.13^{b}	6.72^{b}
T2	3.1^{ab}	4.4^{a}	6.7^{a}	7.6^{a}	4.78^{ab}	6.20^{a}	6.95^{a}	7.53^{a}
T3	2.4^{b}	4.0^{ab}	6.3^{ab}	7.1^{a}	5.01^{a}	5.64^{b}	6.04^{b}	6.57^{b}
T4	3.1^{ab}	4.1^{ab}	6.5^{a}	7.3^{a}	4.76^{ab}	5.52^{bc}	6.11^{b}	6.85^{b}
T5	3.7^{a}	4.0^{ab}	5.7^{bc}	6.9^{a}	4.51^{b}	5.42^{c}	6.10^{b}	6.62^{b}
T6	3.5^{a}	4.0^{ab}	5.3^{c}	5.9^{b}	4.59^{b}	5.41^{c}	6.05^{b}	6.63^{b}
T7	3.3^{a}	3.9^{b}	5.5^{c}	6.7^{ab}	4.74^{ab}	5.51^{bc}	6.07^{b}	6.56^{b}
CV, %	20.6	9.9	7.8	10.7	5.7	2.9	4.8	5.6
	Leaf width				Leaf area			
	cm				cm^2			
T1	2.26^{b}	2.77^{bc}	3.13^{bc}	3.47^{ab}	5.70^{a}	8.00^{bc}	9.75^{b}	11.89^{b}
T2	2.31^{b}	2.97^{a}	3.35^{a}	3.63^{a}	5.72^{a}	9.97^{a}	12.71^{a}	15.09^{a}
T3	2.28^{b}	2.69^{bc}	2.99^{c}	3.21^{c}	6.32^{a}	8.14^{b}	9.43^{b}	11.28^{b}
T4	2.45^{a}	2.81^{b}	3.14^{bc}	3.50^{ab}	5.67^{a}	7.77^{bc}	9.65^{b}	12.32^{b}
T5	2.30^{b}	2.79^{b}	3.11^{bc}	3.55^{ab}	5.05^{a}	7.47^{c}	9.61^{b}	11.46^{b}
T6	2.31^{b}	2.64^{c}	3.08^{bc}	3.36^{bc}	5.26^{a}	7.43^{c}	9.44^{b}	11.52^{b}
T7	2.36^{ab}	2.76^{bc}	3.17^{b}	3.55^{ab}	5.64^{a}	7.73^{bc}	9.52^{b}	11.26^{b}
CV, %	4.3	3.8	4.1	4.6	12.3	6.4	10.1	11.7

Variables such as leaf length, width, and number of leaves must be added to obtain the leaf area since leaf area is an indicator of productivity since the photosynthesis process is linked to the interception of light energy that will be converted into chemical energy. Among all treatments, the one that presented the best results in leaf length was T2, which stood out from the others from 125 DAS (Table 1) to 180 DAS treatments (Figure 2D).

For leaves width, T2 showed better gain stability in measurements during the experiment without any variation during the development of the coffee seedlings (Table 1, Figure 2D), but from 140 DAS it did not differ from treatments with foliar application of 0.30, 0.75, 0.90 g Fe L^{-1}, and aqueous solution on the substrate (Table 1).

Treatment 2, at 125, 140, 155, and 180 d after sowing (Table 1; Figure 2F), proved to be significantly superior to the other treatments, expressing better results in the distribution of leaf area since a plant at the beginning of growth, having a larger leaf area, guarantees an interception of light energy that will be converted into carbohydrates that are necessary for its growth (Table 1; Figure 2F).

Shoot and root DM distribution is shown in Figure 3. It is observed that the distribution of shoot and root DM in coffee seedlings in tubes of 180 mL follows a proportion, on average, from 77% to 23%; that is, of the total DM of coffee seedlings, 77% is shoot and 23% are from the roots (Figure 3).

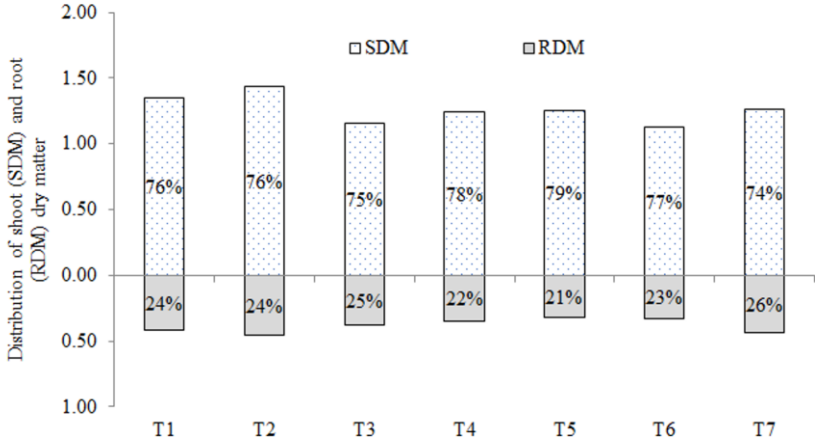

Figure 3. Distribution of shoot (SDM) and root (RDM) dry matter of coffee 'Obatã IAC 1669-20' seedlings, according to different Fe concentrations and ways of application. Franca, São Paulo, 2021. T1: Foliar 0.30 g Fe L^{-1}; T2: foliar 0.45 g Fe L^{-1}; T3: foliar 0.60 g Fe L^{-1}; T4: foliar 0.75 g Fe L^{-1}; T5: foliar 0.90 g Fe L^{-1}; T6: substrate with 0.372 g Fe m^{-3}; T7: aqueous solution on the substrate 0.30 g Fe L^{-1}.

Analyzing the absolute growth rate (Figure 4A), root DM (Figure 4B), shoot DM (Figure 4C), Dickson quality index (Figure 4D), total DM (Figure 4E), and root length (Figure 4F), it was observed that for the most variables, T2 was the better treatment followed by T7. The T6 showed the lowest result.

Applications of T2 and T7 promoted an accumulation of 416.25 and 442.25 mg Fe kg^{-1} in the coffee seedlings, respectively, higher than the annual average of 300 mg kg^{-1} observed by in adult plants. When plants are exposed to high amounts of Fe, their development is affected in all areas, from the roots to the leaves (Moran et al., 1994). The excess of Fe applied to the substrate induces a delay in the development of the seedling because when subjected to excess Fe, they show signs of toxicity throughout the plant, in addition to causing mortality in seedlings that have already emerged (Bertoncelli et al., 2018).

The different Fe concentrations influenced the height of the coffee seedlings since Fe has the function of regulating biochemical activities. Without Fe, the seedling has smaller amounts of RNA. Thus, a lower rate of protein synthesis is obtained, which is linked to lower plant growth, but when the plant receives doses with high concentrations of Fe, the plant has a significant decrease in its height (Bautista-Tulin et al., 2018).

Plants with a thicker stem can remain in the nursery for a shorter time, which makes the seedlings commercialized faster and better management of the internal space of the protected environment is achieved. When the micronutrient Fe is applied to coffee seedlings, there is greater stem growth in thickness; thus, in the present study, coffee seedlings at 110 DAS with the application of Fe promoted better stem diameter in all treatments evaluated.

The leaf area is related to the number of leaves, which indicates the appropriate time for transplanting the seedling to another area, and in addition, the leaf area can indicate the ability of the seedling to carry out photosynthesis (Melo et al., 2019). A plant with a larger leaf area intercepts a greater amount of light and thus increases its photosynthetic rate, causing the plants to present better results (Partelli et al., 2006). When the micronutrient Fe is omitted, plants have lower values in leaf area and in the variables height, number of leaves, and stem diameter (Da Silva et al., 2011), besides it is inducing reduction in photosynthetic rate (Steduto et al., 2000).

The primary root length, when the micronutrient Fe is applied in a solution suitable for the plant, presents more agile growth; however, in the present work, in the root length of coffee plants, it was verified that the different Fe doses applied did not present significant difference between treatments via aqueous foliar treatments of 0.30, 0.45, 0.60, 0.75, and 0.90 g Fe L^{-1} with the fertigation treatment on the substrate 0.30 g Fe L^{-1} (Da Silva et al., 2011) and it was not feasible to apply this element directly to the substrate (0.372 g Fe m^{-3}).

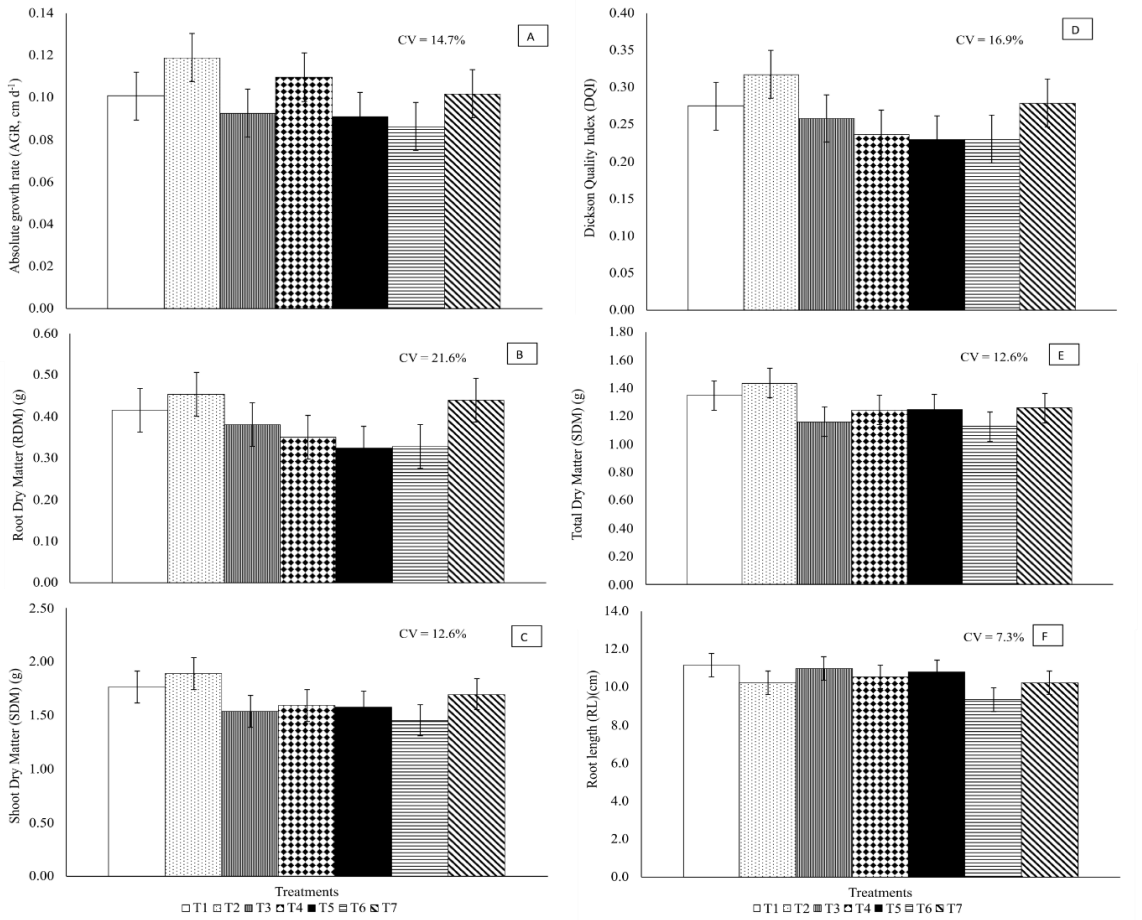

Figure 4. Absolute growth rate (AGR), Dickson quality index (DQI), root DM (RDM), shoot DM (SDM), total DM (TDM), and root length (RL) of coffee 'Obatã IAC 1669-20' seedlings, according to different Fe concentrations and ways of application. Franca, São Paulo, 2021. T1: Foliar 0.30 g Fe L^{-1}; T2: foliar 0.45 g Fe L^{-1}; T3: foliar 0.60 g Fe L^{-1}; T4: foliar 0.75 g Fe L^{-1}; T5: foliar 0.90 g Fe L^{-1}; T6: substrate with 0.372 g Fe m^{-3}; T7: aqueous solution on the substrate 0.30 g Fe L^{-1}. Means followed by the same letter for each variable do not differ from each other by the LSD test (Student's t) at 5% significance. Vertical bars correspond to standard deviation.

The relationship between plant height and stem diameter (RHD) did not significantly differ, evidencing that all Fe supply treatments promoted robust seedlings expressed by their robustness quotient.

In the present study, the ratio between shoot and root DM was not affected by the ways of application and Fe concentrations. It showed that the shoot DM had, on average, 3.33 times the root mass, probably due

to root restrictions imposed by the tube volume. Peroxidases are enzymes responsible for cell growth, lignification, and elongation, and plants with Fe deficiency reduce the activities of these enzymes and cause root reduction (Li et al., 2019), increasing the ratio between shoot and root DM; however, when it is applied in adequate doses, they promote adequate root growth and better distribution in this ratio, as verified in the present work.

The Dickson quality index, which expresses the ratio between the total DM and the distributions between seedling height and stem diameter and between shoot and root DM, showed that the quality of the coffee seedling was affected by the modes and doses applied, especially foliar application (0.45 g Fe L^{-1}) and fertigation (0.30 g Fe L^{-1}) which indicated robustness (Lempe et al., 2013) and allowed adequate development in the definitive area for planting.

Dry matter is a critical quality parameter that indicates the degree of development of a plant, as it indicates the increase in matter accumulation over time in the nursery without considering the water present in the plant. The shoot, root, and total DM of the plants, in the different ways and concentrations applied in the present study, agree with the results of Fe doses applied via nutrient solution (Moschini et al., 2019). Low Fe concentrations decrease shoot (Da Silva et al., 2011; Khan et al., 2020) and roots DM (Li et al., 2019), factors that were not verified in the present study with the forms and doses applied.

The absolute growth rate in height (AGR, cm d^{-1}) is an easy-to-measure variable. It estimates the average plant growth rate, in addition to not requiring the destruction of the seedling. In the present study, the foliar dose 0.45 g Fe L^{-1}, as observed in other variables, provided the coffee seedlings with greater growth speed.

Other species have shown different DM distributions than those observed in the present study, for example, for papaya seedlings (*Carica papaya*), an average of 67% for the shoot and 33% for the root system were observed (Cabral et al., 2020) and for achachairu (*Garcinia humilis*) seedlings, 68% were found for shoot and 32% for root system (Silva et al., 2021); both surveys in 1.8 L polyethylene bags, different from the present study tubes that can restrict root growth and influence this distribution.

CONCLUSIONS

The Fe application via foliar in coffee 'Obatã IAC 1669-20' seedlings, at 0.45 g L^{-1} Fe, solved the problem of the company with the deficiency of the micronutrient, as well as increased quality in terms of leaf area and stem diameter, which are positive indicators of seedling quality for the nursery. The treatment with aqueous solution on the substrate 0.30 g Fe L^{-1} was the second option for Fe application in coffee 'Obatã IAC 1669-20' seedlings. The treatment with previous fertilization of the substrate with 0.372 g Fe m^{-3} was the less recommended.

Author contribution

Conceptualization: W.M.G., T.Z., E.C. Methodology: W.M.G., T.Z., E.C. Investigation: W.M.G., E.C. Resources: G.H.C.V., E.C. Data curation: W.M.G., E.C, T.D., F.F.S.B., E.P.V., M.B.M. Writing-original draft: W.M.G., T.D., E.C. Writing-review & editing: T.Z., E.C., T.D., G.H.C.V., E.P.V., M.B.M. Project administration: T.Z., E.C., F.F.S.B. Funding acquisition: G.H.C.V., E.C., F.F.S.B. All co-authors reviewed the final version and approved the manuscript before submission.

Acknowledgements

To the Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado do Mato Grosso do Sul – FUNDECT (FUNDECT/CNPq/PRONEM – MS, Process n. 59/300.116/2015 – Nº FUNDECT 080/2015), and to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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