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Evaluation of Physicochemical Parameters of Water for Agriculture in the Guamá river Sub-basin, Northern Brazil
Evaluación de Parámetros Fisicoquímicos del Agua para la Agricultura en la Subcuenca del río Guamá, en el Norte de Brasil

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SUMMARY

Water is a vital natural resource crucial for various purposes, including public and industrial supply, agricultural irrigation, electricity generation, and recreational activities. Among the sectors, agriculture stands out as the primary water consumer and a significant contributor to water pollution, particularly nitrate contamination. As water bodies play a crucial role in agronomic activities, any degradation in their quality can adversely affect the community's financial income and local biodiversity. Therefore, this study aims to assess the relationship between water parameters in the Guamá river concerning areas with agronomic activities. Additionally, it explores the impact of seasonality on these parameters in the Guamá river's sub-basin, located in the northeast region of Pará, Brazil. The research focused on the Guamá river sub-basin (SBRG), a selected section of the Guamá river basin. Fieldwork was conducted during six campaigns in June 2015, January 2016, June 2016, November 2016, February 2017, and July 2017. Chemical parameters such as pH, total hardness (DT), alkalinity (ALC), chloride content (LC), and turbidity were determined through volumetric analysis (titration technique) in the laboratory. The obtained data was tabulated using Microsoft Office Excel software, and mean values and standard deviations were calculated. The study found that the overall mean pH during the rainy season was 4.79, and during the less rainy period, it was 5.56. Both values were below the maximum allowed value (MPV) of 6-9. Turbidity was higher during the rainy season, reaching 15.26 UTN. Total hardness varies significantly at the 5% level depending on the seasons, as long as chloride and alkalinity remain stable throughout the year. This study highlights how seasonality affects key water parameters, highlighting the need for careful management of this crucial resource, especially in areas where agriculture plays a key role in the local economy and environmental conservation.

Index words: *chemical analysis, irrigation, regional hydrology, seasonality.*

RESUMEN

El agua, esencial para múltiples propósitos como el suministro público, la industria, el riego agrícola, la generación de energía hidroeléctrica y el recreo, desempeña un papel crítico en nuestras vidas. La agricultura se destaca como el sector más voraz en su consumo y un contribuyente clave a la contaminación del agua, especialmente la provocada por nitratos. La calidad de los cuerpos de agua, vitales para la agricultura, incide en la economía local y la biodiversidad. Por eso, este estudio se enfoca en evaluar los parámetros del agua en el río Guamá en relación con las actividades agrícolas y cómo la estacionalidad afecta estos parámetros en la

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subcuenca del río Guamá, en Pará, Brasil. La investigación se concentró en la subcuenca del río Guamá (SBRG), parte de la cuenca del río Guamá. Se llevó a cabo seis campañas de campo en junio de 2015, enero de 2016, junio de 2016, noviembre de 2016, febrero de 2017 y julio de 2017. Se analizaron parámetros químicos como pH, dureza total (DT), alcalinidad (ALC), contenido de cloruro (LC) y turbidez mediante técnicas de titulación. Los datos se tabularon con Microsoft Excel® y se calcularon promedios y desviaciones estándar. Los resultados mostraron un pH promedio de 4.79 durante la temporada de lluvias y 5.56 en la temporada menos lluviosa, ambos por debajo del rango aceptable de 6 a 9. La turbidez alcanzó 15.26 UTN en la época de lluvias. La dureza total varió significativamente a un nivel del 5% según las estaciones, mientras que el cloruro y la alcalinidad se mantuvieron estables durante todo el año. Este estudio destaca cómo la estacionalidad afecta los parámetros clave del agua, destacando la necesidad de una gestión cuidadosa de este recurso crucial, especialmente en áreas donde la agricultura juega un papel clave en la economía local y la conservación del medio ambiente.

Palabras clave: *análisis químico, riego, hidrología regional, estacionalidad*.

INTRODUCTION

Water is an essential natural resource for life, used in various forms such as public and industrial supply, agricultural irrigation, electricity generation, and recreational activities. However, water bodies are experiencing significant pressures due to uncontrolled growth and occupation, compromising their quality and quantity, and consequently affecting their multiple uses (Barbosa *et al*., 2020a).

Currently, the population has more than 7888 million inhabitants, and the demand for food production increases, whether of animal or plant origin, leading to a corresponding rise in water resource use for agronomic activities (Silva, Silva, and Pires, 2014). However, water availability is not uniform and ends up affecting the quantity and quality of water for all users, necessitating monitoring of its use for these activities. Investigating the anthropogenic activities practiced in water bodies to assess their degree of interference in contamination levels can establish study parameters for water that indicate suitable activities for its use (Barbosa *et al*., 2020b).

Water is essential for plants, mainly acting as a vehicle for their nutrition. However, there are situations where rainfall alone does not meet the water needs of crops, leading farmers to resort to irrigation to supplement the plant's water requirements (Pimentel *et al*., 2004).

Agriculture is the main consumer of water and, consequently, one of the main polluters of water resources, with salinity and nitrate contamination standing out as the primary water pollutants (Brito *et al*., 2005). Under certain climate and soil conditions, combined with the inappropriate use of pesticides, the enrichment of water sources and eutrophication of water bodies may occur (Brito *et al*., 2005).

Therefore, water quality is determined according to the regulations of the National Council for the Environment (CONAMA) no. 357 (Brazil Conselho Nacional do Meio Ambiente, 2005), which establishes the classification of water bodies and environmental guidelines for their categorization. It also defines the conditions and standards for effluent discharge, considering the chemical, physical, and microbiological characteristics (Boareto, Silva, Santos, and Albuquerque, 2019).

The Guamá River Basin is located in the Metropolitan Region of Belém (MRB) and the northeastern mesoregion of Pará, composed of a set of 8 sub-basins and 19 municipalities (Kubota, Lima, Rocha and Lima, 2020). In its vicinity, there are activities related to irrigation systems for agricultural use, such as strong citrus cultivation in the municipality of Capitão Poço, cassava cultivation in the municipality of Inhangapi, and extensive oil palm cultivation in Garrafão do Norte, among many other agricultural activities (Rocha, 2017). However, these activities require frequent use of fertilizers like nitrogen and highly toxic pesticides and herbicides, which can cause pollution in water bodies (Weldeslassie, Naz, Singh, and Oves, 2018).

The uncontrolled growth of cities, combined with inadequate sanitation infrastructure, can contribute to soil sealing, facilitating increased runoff flow that carries organic and inorganic materials (Poleto and Martinez, 2011) into the waters of the Guamá River, altering the physicochemical characteristics and causing degradation of water resources.

Therefore, this study justifies the need to evaluate the physicochemical parameters of the Guamá River, as the use of these water bodies is essential for agronomic activities, and the deterioration of their quality can compromise the community's financial income and local biodiversity. Thus, the objective of this study is to evaluate the relationship between water parameters of the Guamá River in areas with agronomic activities and the influence of seasonality on the parameters obtained in the sub-basin of the Guamá River located in the northeastern region of Pará.

MATERIALS AND METHODS

Study Area

The study area consists of the sub-basin of the Guamá River (SBRG), which represents a selected section of the Guamá River watershed (Figure 1), located between the forests of the municipalities of Ipixuna do Pará and Nova Esperança do Piriá, continuing southwest through Capitão Poço and Garrafão do Norte. It then flows in a north-northeast direction to the municipality of Ourém. From that point, the river turns west, bordering São Miguel do Guamá from other municipalities, and ends just after the urban center of São Miguel do Guamá before the entrance of the large Capim river.

Twelve communities were selected where agricultural activities utilizing the waters of the Guamá River in their production systems are practiced. These communities are located on the banks of rivers and are distributed throughout the area selected for the study.

Sampling

Fieldwork was conducted in six campaigns during the months/years of February 2015, June 2015, January 2016, June 2016, February 2017, and July 2017. Samples collected in January and February were considered to belong to the rainy season (RS), while samples collected in June, July, and November were considered to belong to the less rainy season (LRS) in the study region.

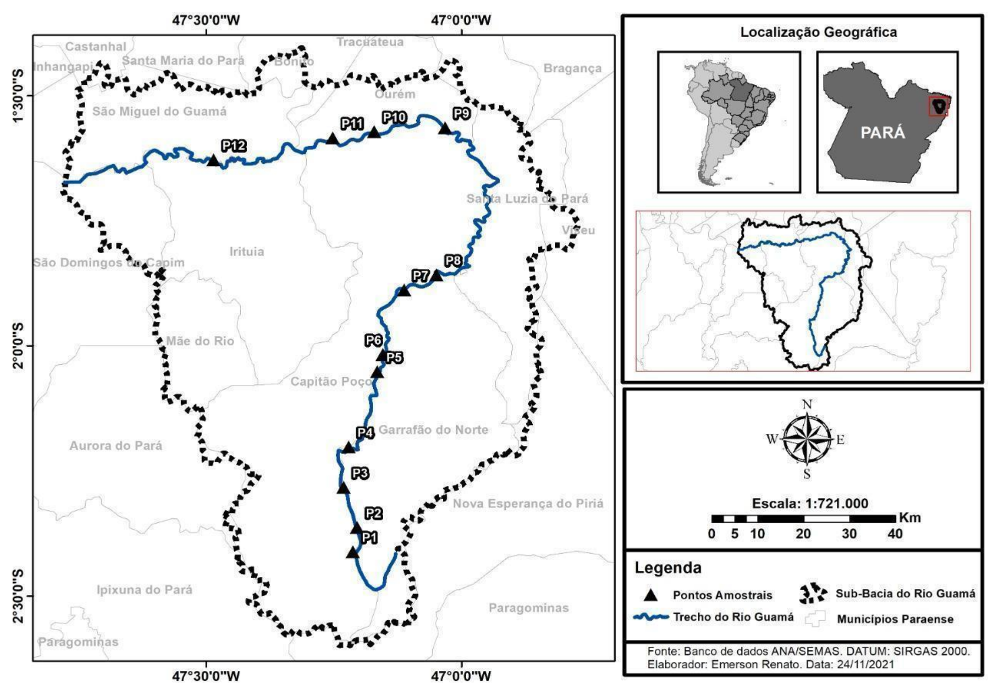

Figure 1. Location map of the sampling points for each studied municipality.

During each campaign, water samples were collected and in situ analyses were performed at a depth of 3 meters below the water surface.

Three sampling points (minimum distance of 200 to 250 meters between each other) were established in each community for the collection of river water samples, located upstream, in the center, and downstream, with reference to the central part of the community along the Guamá river. This resulted in a total of 36 sampling points along the Guamá river section. The geographic coordinates of each of the thirty-six sampling points were recorded using a GPS device (Garmin, GPSMAP®, series 78).

At the collection site, pH values were measured in the water using a calibrated multiparameter probe (Hanna®, model HI 9829). Turbidity data were obtained using the nephelometric method, with the aid of a turbidimeter (Instrutherm®, model TD-300) previously calibrated with 0 and 100 NTU solutions. The readings provided results in turbidity units (uT or NTU).

Water samples were collected at each of the 36 points using a horizontal Van Dorn bottle and stored in polypropylene bottles that were previously decontaminated by immersing them in a 10% nitric acid solution (HNO3 10%) for 24 hours and then rinsed with distilled water, in accordance with ANA (2011). Storage, packaging, and transportation followed the standards stipulated in the specialized literature (APHA, 2017).

The collected samples were transported in Styrofoam boxes and kept refrigerated (±2 °C) until analysis at the Physical and Chemical Analysis Laboratory of the Center for Agricultural Technology (CTA) at the Federal Rural University of the Amazon (UFRA).

Laboratory Procedures

The chemical parameters, total hardness (TH), alkalinity (ALC), and chloride content (CL), were determined in the laboratory. Classic volumetric analysis methods (titration technique) were adopted for the determinations. This technique involves determining the concentration of an unknown compound (analyte) by adding a substance of known concentration. The 23rd edition of the standard methods for the examination of water and wastewater (APHA, 2017) was used as a reference for the methods.

The expiration dates for the chemical analyses were carefully respected, as alkalinity has a validity period of 24 hours. For chloride determination, the expiration period is 28 days, and for total hardness, it is 6 months. The methods 2320B, 2340C, and 4500B (APHA, 2017) were adopted for determining alkalinity, total hardness, and chloride, respectively.

To perform the titrations, samples were taken from the refrigeration environment, which was approximately 4 °C, and allowed to reach room temperature. The sample container was homogenized, and then the burette was prepared by rinsing/conditioning it with the titrant used for each analysis. With the titration apparatus set up, aliquots were prepared according to the reagents and indicators described in the procedures for each analysis.

Statistical Analysis of Collected Data from Collected Data

After the physicochemical analyses, the results were tabulated in Microsoft Office Excel® software, and the means and standard deviations were calculated. Subsequently, to determine whether the analyzed samples showed significant differences or similarities, the means were subjected to analysis of variance (ANOVA), followed by the Tukey test with a significance level of ($P < 0.05$).

RESULTS AND DISCUSSION

The following tables present the values of the means for the rainy and less rainy periods and the standard deviations (SD) obtained from the in situ determinations of the physicochemical parameters of the collected water samples at points P1, P2, P4, P5, P6, P7, P8, P9, P10, P11, and P12, based on Resolution No. 357/2005 of the National Environmental Council - CONAMA (Brasil Ministério da Saúde, 2006), which considers the need to reformulate the existing classification to better distribute water uses, specify the required conditions and quality standards, without prejudice to future improvements (Table 1).

According to the analysis of variance (ANOVA), when evaluating the seasonal periods, there was a significant difference between the rainy and less rainy periods (Table 2). Based on the evaluated periods, the overall average pH (rainy 4.79 and less rainy 5.56) was lower compared to the maximum allowed value (MAV) of 6-9 according to Resolution No. 357/2005 of CONAMA.

Table 1. Mean cumulative precipitation values (mm) for each seasonal period.

Sampling points	Rainy season	Less rainy season
P1	59.28	35.27
P2	66.12	37.56
P3	61.84	37.20
P4	61.12	42.85
P5	57.88	51.88
P6	61.88	26.39
P7	64.09	43.15
P8	54.99	46.15
P9	61.30	18.54
P10	66.11	16.62
P11	59.11	18.74
P12	66.98	19.26

When analyzing the difference between the rainy and less rainy periods, there is a lower pH value of 4.79 (more acidity) during the rainy period, which is consistent with the study conducted by Damasceno, Ribeiro, Takiyama, and Paula (2015) on water quality in the Amazon River (Amapá), which found more acidic waters during the rainy period compared to the less rainy period, which may be related to an increase in the content of organic acids.

Low pH values can be explained by various factors such as decomposition of organic matter, water temperature, and CO_2 concentration, among others. The agronomic activities practiced in this region may be associated with this pH change, due to the constant use of inputs that are not fully utilized in the production process and are leached during rainfall, ultimately ending up in the Guamá River (Silva, Costa, dos Santos Silva, de Souza, and da Costa Barbosa, 2017).

Table 2. Mean and standard deviation values of pH (dimensionless).

Sampling points	Rainy season	Less rainy season
	- - - - - - - - - - - - mean±DP	- - - - - - - - - - - -
P1	4.23±0.03	5.06±0.05
P2	4.43±0.01	5.05±0.01
P3	4.54±0.01	4.98±0.12
P4	4.68±0.04	5.31±0.03
P5	4.67±0.09	5.50 0.05
P6	4.70±0.06	5.53±0.03
P7	4.66±0.02	5.85±0.04
P8	4.83±0.01	5.86±0.02
P9	5.24±0.00	5.96±0.03
P10	5.37±0.05	5.98±0.08
P11	4.92±0.04	5.81±0.03
P12	524±0.06	5.79±0.02
	4.79a±0.35	5.56a±0.37

According to Almeida (2010), the ideal pH for irrigation falls within the range of 6.5 to 8.4, and deviations from this range indicate abnormalities in water quality or the presence of toxic ions, negatively affecting the microbial population of the soil and causing damage to the plant root system. Additionally, according to Lima, Oliveira, Donato, and Bebé (2020), low pH, below 7, can have economic consequences such as corrosion or clogging of pipelines, as well as sanitary consequences such as contamination of crops that rely on this irrigation for their productive cycle.

According to Malavolta (2006), the effect of pH on plant utilization varies, but its greatest influence is on nutrient availability. At pH values lower than 5.5, Phosphorus (P) is fixed by iron, aluminum, and manganese oxides, rendering it unavailable for plants. The results regarding turbidity show significant differences between the studied periods (Table 3).

When comparing the turbidity parameter between the less rainy and rainy periods, it was observed that the rainy period had a higher turbidity value (15.26 NTU). This is due to an increase in suspended particles, which, when mixed with water, hinders the penetration of light beams (Tomazoni, Mantovani, Bittencourt, and Rosa Filho, 2005). According to Alves *et al*. (2008), the reduction in the photosynthetic rate of plants is associated with high water turbidity, which directly affects production and impacts the fish community, causing an imbalance in the aquatic ecosystem.

There was a significant difference when comparing the studied seasonal periods, but the values obtained are lower than the ideal maximum standard turbidity value for irrigation, which, according to the conditions and standards established by Resolution CONAMA 357/05, recommends values up to 100 NTU.

The results obtained corroborate those found by Marinho *et al*. (2020), where the collections made during the rainiest period had higher turbidity values.

According to Nascimento and Barreto (2014), turbidity can be influenced by numerous substances and materials, capable of being naturally or anthropogenically modified. Similarly, Cunha, Garcia, Albertoni, and Palma (2013) state that the decrease in water quality is related to turbidity values.

Turbidity for irrigation expresses the quantity of suspended particles in water sections that can interfere with irrigation handling, leading to several problems such as pipe obstruction, resulting in unregulated irrigation (Sandri, Matsura, and Testezlaf, 2003).

According to Almeida (2010), sediment carried by water reduces the lifespan of irrigation system equipment (nozzles, emitters, and pipes), often necessitating their replacement every year in extreme cases.

Table 3. Mean and standard deviation values of turbidity (NTU).

Sampling points	Rainy season	Less rainy season
	- - - - - - - - - - - - mean±DP	- - - - - - - - - - - -
P1	1.60±0.11	6.35±0.11
P2	11.42±0.08	8.86±0.38
P3	14.47±0.26	10.56±0.02
P4	13.83±0.09	12.40±0.08
P5	16.43±0.04	16.19±0.14
P6	16.27±0.15	16.95±0.19
P7	17.34±0.04	14.34±0.17
P8	17.04±0.05	13.28±0.22
P9	17.50±0.09	9.06±0.22
P10	16.80±0.30	9.04±0.16
P11	16.77±0.25	10.25±0.16
P12	13.62±0.12	9.05±0.27
	15.26a±2.20	11.36b±3.27

Regarding the parameter of alkalinity, there was no significant difference between the seasonal periods (Table 4). Alkalinity was higher during the rainy period. The increase in rainfall during the collection period may have contributed to the increase in alkalinity. The presence of bicarbonate ions (HCO^{3-}) is responsible for increased alkalinity and is common in natural waters with a pH range of 6.73 to 8.45 (Reyes-Toscano *et al*., 2020). Another possible factor for this increase is the likely presence of alkaline compounds in the soils, as it is the factor that most influences water alkalinity.

There is no specific value established in Brazilian legislation for alkalinity in water, but according to Caraballo, Macías, Rötting, Nieto, and Ayora (2011), high alkalinity values are found above 2000 mg L^{-1} of $CaCO_3$. These values are associated with the presence of bicarbonate, carbonate, and hydroxide ions, which can cause pipe or sprinkler clogging in irrigation systems. The values of all analyzed points had minimum alkalinity numbers, with values below 20 mg L^{-1} of $CaCO_3$, representing a lower risk of clogging due to water aggregate accumulation. Water alkalinity in irrigation systems and nutrient solution systems is crucial for plant growth. For example, if alkalinity is too high, the nutrients necessary for plant development will not be available in the solution, rendering the solution inefficient.

For chloride concentration values, there was no significant difference between the rainy and less rainy periods (Table 5). The values found were lower than the VMP (250 mg L^{-1} - Resolution CONAMA No. 357), indicating that the Guamá river section has low levels of toxicity, which favors its use for crop irrigation. The presence of chlorine in water frequently affects cultivated plants, leading to foliar chlorosis concentrated in the most illuminated areas, which can cause necrosis of leaf margins (Almeida, 2010).

The mobility of chlorine with water in the soil allows it to be absorbed by the roots and can also be absorbed by leaves in sprinkler irrigation (Almeida, 2010).

The obtained total hardness values in the analysis of variance showed significant differences between the seasonal periods, with a higher value during the rainy period, 5.17 mg L^{-1} (Table 6).

Hardness is the concentration of multivalent cations in solution. The cations commonly associated with hardness are calcium and magnesium (Ca^{2+}, Mg^{2+}), and to a lesser extent, iron (Fe^{2+}), manganese (Mn^{2+}), strontium (Sr^{2+}), and aluminum (Al^{3+}).

According to Brasil Ministério da Saúde (2011), the Ministry of Health's ordinance establishes that the permitted value for total hardness is 500 mg L^{-1}. Therefore, both analyzed periods are within the allowed limits. However, it is worth noting that high hardness values can cause the precipitation of low solubility phosphate fertilizers when used for fertigation (Borges and Coelho, 2009).

Table 4. Mean and standard deviation values of alkalinity (mg L^{-1} of $CaCO_3$).

Sampling points	Rainy season	Less rainy season
	- - - - - - - - - - - - mean±DP	- - - - - - - - - - - -
P1	5.93±0.33	3.95±0.67
P2	4.51±0.19	3.51±0.38
P3	5.26 0.33	4.40±0.38
P4	5.60±0.57	3.95±0.00
P5	6.14±0.76	5.28±0.01
P6	4.93±0.33	3.95±0.00
P7	5.71±0.38	5.04±0.38
P8	5.71±0.38	5.72±0.37
P9	6.11±1.16	5.26±0.67
P10	4.80±0.38	4.83±0.38
P11	4.57±0.00	5.49±0.38
P12	5.35±0.19	7.03±0.37
	5.39a±0.58	4.87a±0.99

Table 5. Mean and standard deviation values of chloride (mg Cl^{-1}/L).

Sampling points	Rainy season	Less rainy season
	- - - - - - - - - - - mean±DP	- - - - - - - - - - -
P1	13.22± 0.51	37.10±0.19
P2	13.66±1.15	11.11±0.51
P3	11.00±0.67	11.11±0.19
P4	12.11±0.38	10.66±0.00
P5	12.55±0.84	10.77±0.19
P6	12.77±1.35	10.89±0.51
P7	11.44±1.71	10.33±0.33
P8	13.11±2.55	11.22±0.19
P9	13.44±0.19	10.55±0.51
P10	14.11±0.51	10.11±0.77
P11	15.11±1.07	11.33±0.67
P12	14.33±0.67	10.33±033
	13.07a±1.19	12.96a±7.61

Table 6. Mean and standard deviation values of total hardness (mg L^{-1}).

Sampling points	Rainy season	Less rainy season
	- - - - - - - - - - - mean±DP	- - - - - - - - - - -
P1	7.56 ±0.38	2.67±0.00
P2	6.00±0.67	2.67±0.00
P3	4.44±0.38	3.56±0.38
P4	3.33±0.00	3.11±0.77
P5	5.11±0.38	3.56±0.38
P6	4.44±0.38	3.33±0.00
P7	4.89±0.38	3.33±0.00
P8	5.33±0.67	4.00±0.00
P9	6.00±0.67	3.78±0.38
P10	4.67±1.33	3.56±0.38
P11	4.89±0.77	3.56±0.38
P12	5.33±1.15	4.89±0.38
	5.17a±1.04	3.50a±0.59

This parameter results from the presence of alkaline earth salts (calcium and magnesium), which cause scaling in pipes and subsequently obstruct water flow (Driscoll, 1986).

According to Nakayama and Bucks (1986), when it comes to hardness, the main water quality problem for irrigation is the precipitation of calcium and magnesium carbonates, which can occur, mainly if the water has high hardness and pH values.W

CONCLUSIONS

The parameters pH, turbidity, and total hardness are the ones that most influenced water quality for agriculture. These factors directly and indirectly interfere with plant development. Seasonality has shown to have an influence on pH, turbidity, and hardness parameters but does not directly affect chloride and alkalinity. The pH was the only water parameter that did not meet the quality standard of Resolution CONAMA 357/2005, which is within the range of 6.0 to 9.0. Therefore, preventive measures should be taken regarding the irrigation system and irrigation of certain crops. It is important to emphasize that for a more detailed and accurate result, it is recommended to perform soil analysis and survey the crops grown in the region so that the obtained results are more specific, providing direct and clear answers to the producers. Additionally, it is important to include other important parameters such as macronutrients and micronutrients, which are essential elements for the proper development of a crop.

ETHICS STATEMENT

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF SUPPORTING DATA

All data generated or analyzed during this study is included in this published article and its supplementary information files.

COMPETING INTERESTS

The authors declare no competing interests.

FINANCING

Not applicable.

AUTHORS' CONTRIBUTIONS

Conceptualization: A.N.J.L.S.J., H.A.P., E.R.M.S., and I.C.C.B. Methodology: I.C.C.B and E.R.M.S. Validation: I.C.C.B and E.R.M.S. Investigation: A.N.J.L.S.J., H.A.P., and E.R.M.S. Data curation: I.C.C.B., E.R.M.S., and J.R.G. Writing-original draft preparation: A.N.J.L.S.J., H.A.P., and B.K.S.M. Writing-review and editing: B.K.S.M., A.M.O., and M.V.C.P. Statistical analysis: J.R.G. Supervision: E.R.M.S., and I.C.C.B.

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