

Trace elements: nutritional dynamics in different organs and phenological stages of rambutan cultivation in Honduras

Oligoelementos: dinámica nutricional en diferentes órganos y etapas fenológicas del cultivo de rambután en Honduras



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Abstract

Productivity of rambutan (*Nephelium lappaceum* L.) is linked to its nutritional demand, and knowledge about plant stages (time after planting) and plant organs demand, will allow producer to improve crop fertilization. The dynamics of essential and beneficial microelements in different ages and plant organs was evaluated. In the north Honduras, an experiment to evaluate six sampling treatments: 2, 3, 4, 8, 10 and 17 years after crop establishment was evaluated. Treatments were conducted under a completely randomized design with three replications. At harvest time, leaves, branches, husks and seeds were collected to analyze the concentrations of Mn, Fe, Zn, Cu, B and Na. The results show that the concentration of nutrients differed significantly between the organs and ages of the plant, with the highest concentration of Mn, Fe and B in leaves, Zn and Cu in seeds and Na in the seed shell. The nutrients concentration in the plant (leaf + branch + husk + seed) varied over time, with a higher Fe, Zn and Na concentration at the beginning of production (3rd and 4th year), while B concentration was higher 4th year and 10th year and, Mn and Cu concentration was higher at year 10th. In this study, microelement requirements also varied significantly as follow: Mn (73 %), Fe (11 %), Na (6 %), B (5 %), Zn (3 %) and Cu (2 %). As conclusion, the essential and beneficial micronutrients varied in the plant tissue according to the plant age, aspect that was defined in this study.

Keywords: *Nephelium lappaceum* L., tropical fruit, accumulation, demand, micronutrients.

Resumen

La productividad del rambután (*Nephelium lappaceum* L.) está vinculada a su demanda nutricional, el conocer los momentos y lugares de mayor exigencia, le permite al productor mejorar la fertilización. Se evaluó la dinámica de microelementos esenciales y benéficos en diferentes edades y órganos del rambután. En el norte de Honduras, se estableció un experimento bajo un diseño completamente al azar con seis tratamientos

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(muestreo a los 2, 3, 4, 8, 10 y 17 años de establecido el cultivo) y tres repeticiones. En época de cosecha se procedió a recolectar hoja, rama, cáscara y semilla, para analizar las concentraciones de Mn, Fe, Zn, Cu, B y Na. Los resultados muestran que la concentración de nutrientes difiere significativamente entre los órganos y edades de la planta, encontrando la mayor concentración de Mn, Fe y B en hojas, Zn y Cu se observó en semilla y Na en cáscara. La mayor concentración de los nutrientes en la planta (hoja + rama + cáscara + semilla) varió en el tiempo, acumulando más Fe, Zn y Na al inicio (3^{er} y 4^o año) de producción, para B fue en el cuarto y décimo año y, en el décimo año también se concentró más Mn y Cu. Además, el Mn (73 %) fue requerido en mayor cantidad, seguido de Fe (11 %), Na (6 %), B (5 %), Zn (3 %) y Cu (2 %). Los nutrientes esenciales y benéficos variaron en los tejidos conforme a la edad de la planta, lo que permitió identificar cuáles elementos y en qué etapa y órgano vegetal tuvieron una mayor acumulación.

Palabras clave: *Nephelium lappaceum* L., fruta tropical, acumulación, demanda, micronutrientes.

1. Introduction

Fertilization is a practice to which crops in Honduras respond strongly, due to the low natural fertility of soils, and rambutan is no exception. Fertilizer is essential to double or triple plant productivity (FAO, 2002; Monzon Sequeiros, 2016), with the social and economic connotations for the producer.

Essential and beneficial elements are required in small quantities, the contributions in the physiological functions of the plant at the various phenological stages are of equal importance compared to macronutrients (Mengel & Kirkby, 2000; Navarro García & Navarro García, 2013). Agronomically, micronutrients contribute during plant metabolism as enzymatic activators, in electron transfer and nutrient assimilation, during vegetative stages they mainly promote the emission of roots, branches and leaves; while in the reproductive stage, they promote flowering, fruit and seed formation (Marschner, 2003; Rao, 2009).

The main reservoirs of micronutrients in the soil are silicate clays, organic matter and iron and manganese oxides (Mejía de Tafur, 2010; Agrawal et al., 2016). However, in tropical and subtropical regions of developing countries, about 45 % of soils present low natural fertility (Giller, 2001), and biomass production is limited by high decomposition rates (Acevedo et al., 2021; Woormer et al., 1994); these natural limitations are accentuated by the use of economically and environmentally unsustainable production practices, which contribute to soil degradation (Amézquita et al., 1998; Chamba Bernal et al., 2020).

Edaphic and foliar fertilizations are indispensable to achieve crop productivity; however, with soil-directed nutrients, regardless of the methodology used, the process leads to losses of 40 % or more of the amount applied, by leaching, volatilization and runoff (Jordan et al., 2008; Díaz et al., 2019); whereas aerial application is more delicate to execute due to the specific requirements of each plant, and the lack of knowledge as to the management and the supply of chelated nutrients.

The agricultural sector in Honduras lacks technical advice/consulting and technologies allowing producers to improve regional competitiveness, there is also a theoretical and scientific vacuum on the nutritional management of rambutan. Of the approximately 1,000 ha established at/ different phenological stages of the crop, 70 % are in the Atlantic coast (Centro de desarrollo empresarial para la micro, pequeña y mediana empresa del Valle del Leán, 2018), being managed mostly by small producers (3-5 ha) where low credit record, high prices in fertilizers, and /limited use of irrigation systems prevail, causing an inefficient use of nutrients in the system, with its financial and environmental consequences.

Essential and beneficial microelements are responsible for 2 to 3 % of the nutritional needs of plants (Salisbury & Ross, 1994), so that knowing the amounts and the times of greatest nutritional demand in crops is valuable, and will allow growers to improve fertilization programs. The objective of the research was to analyze the content and distribution of essential and beneficial microelements in different organs and stages of development of rambutan.

2. Materials and Methods

2.1. Characterization of the experimental area

The research was conducted from March to December 2017 in rambutan producers' farms, in the municipali-

ties of La Ceiba, La Másica and Santa Ana, department of Atlántida, Honduras. The meteorological station of the National Autonomous University of Honduras located in La Ceiba, characterizes the region with an altitude of approximately 20 to 70 m a.s.l., an average temperature of 29.5 °C, relative humidity of 95 % and average annual rainfall of 3,100 to 3,230 mm.

The soil analyzed was sampled at a depth of 0-20 cm. The results of the chemical properties (Table 1) were interpreted according to nationally used scales (Castro, 2004). The soil presented a strongly acid pH and high level of Al^{3+} , medium concentration of OM and low levels of P and EC. Among the bases, low levels of Na^+ , K^+ , Mg^{2+} and Ca^{2+} were found. For minor elements Fe, Cu and Mn the levels were high, except for B and Zn which were low.

On the Atlantic coast, where rambutan is established, the presence of Nitisols is common (Gardi et al., 2014), characterized by the strong presence of iron oxides and low pH, affecting the availability of macro-nutrients. In addition, the concentration of aluminum is frequently . This allows us to deduce that, similarly to cocoa, cassava and pineapple, rambutan's crop tolerates exchangeable acidity, since several studies have shown that soils with levels higher than $2 \text{ cmol}_{(+)} \text{ L}^{-1}$ (Castro, 2004) or 2-3 ppm (Påhlsson, 1990) are limiting for many crops.

Table 1. Chemical characterization of a Nitisols planted with Rambutan. * Laboratory: WHAL Standard Fruit of Honduras. Atlántida, Honduras, 2017.

Tabla 1. Caracterización química de un Nitisols sembrado con Rambután. *Laboratorio: WHAL Standard Fruit de Honduras. Atlántida, Honduras, 2017.

pH	$\text{cmol}_{+} \text{ kg}^{-1}$	dS/m	g kg^{-1}	$\text{cmol}_{+} \text{ kg}^{-1}$						mg kg^{-1}				
	Al	EC	OM	Ca	K	Mg	Na	P	Zn	Fe	Mn	Cu	B	S
4,61	3,27	0,06	22,59	0,22	0,15	0,19	0,04	2,15	0,82	221,89	81,85	4,15	0,04	13,52

* pH: 1:1 aqueous solution; EC: Saturated extract, Conductance; Al: KCl extraction; Macro and microelements: Mehlich-3 plasma detection.

* pH: solución acuosa 1:1; CE: Extracto saturado, Conductancia; Al: Extracción con KCl; Macro y microelementos: Detección de plasma Mehlich-3.

2.2 Experimental trial description

The dynamics of essential and beneficial nutrients were analyzed in different organs and phenological stages (years) of the rambutan plant (Table 2); under a completely randomized design with three replications.

Table 2. Description of the treatments evaluated to record the nutritional dynamics in rambutan. Atlántida, Honduras, 2017.

Tabla 2. Descripción de los tratamientos evaluados para registrar la dinámica nutricional en el rambután. Atlántida, Honduras, 2017

Developmental stages	Plant organ	Nutrients
2 years	leaves	Mn, Fe, Cu, Zn, B, Na
3 years	leaves, husk, branch, seed	Mn, Fe, Cu, Zn, B, Na
4 years	leaves, husk, branch, seed	Mn, Fe, Cu, Zn, B, Na
8 years	leaves, husk, branch, seed	Mn, Fe, Cu, Zn, B, Na
10 years	leaves, husk, branch, seed	Mn, Fe, Cu, Zn, B, Na
17 years	leaves, husk, branch, seed	Mn, Fe, Cu, Zn, B, Na

Samples were collected during the harvesting stage at producers' farms, where plantations of different ages were established, using varieties such as R-134, R-162 and R-167, because of/due to their good organoleptic acceptance in the national and Central American markets. The experimental unit for each treatment consisted of ten trees planted mostly at 7 m x 7 m, for a density of 214 plants ha^{-1} .

The variables analyzed were nutrients: manganese, iron, copper, zinc, boron and sodium in leaves, fruit husk, branches and seeds. Composite samples were collected from the trees, identified and sent to the laboratory. The information obtained was subjected to analysis of variance ($p < 0.05$) and Tukey's mean test ($p < 0.05$), using SAS software version 9.1.3 (SAS, 2002).

3. Results

3.1 Nutrient distribution in rambutan vegetative organs

For the micronutrients Mn, Fe and Zn, ANOVA found significant differences ($p < 0.05$) among the organs analyzed throughout the developmental stages (Figure 1). Mn dynamics was dissimilar, being the highest concentration located in the leaf ($780.32 \text{ mg kg}^{-1}$), followed by the husk ($354.28 \text{ mg kg}^{-1}$), branch ($346.17 \text{ mg kg}^{-1}$) and, to a lesser extent, in the seed (90.73 mg kg^{-1}).

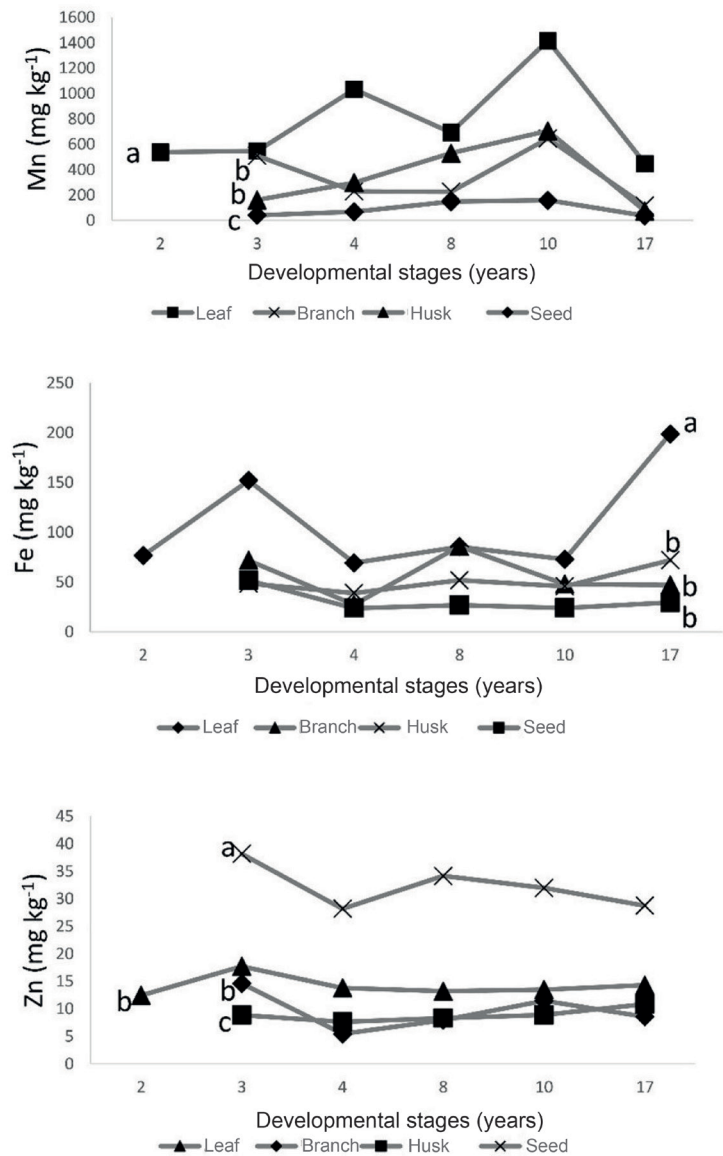


Figure 1. Mn, Fe and Zn content (mg kg^{-1}) in leaves, branch, husk and seed of the rambutan plant at different stages (years) of development. Atlántida, Honduras, 2017. Averages with the same letter do not differ significantly according to the Tukey test ($p < 0.05$).
Figura 1. Contenido de Mn, Fe y Zn (mg kg^{-1}) en hojas, rama, cáscara y semilla de la planta de rambután en diferentes etapas (años) de desarrollo. Atlántida, Honduras, 2017. Promedios con igual letra no difieren significativamente según Tukey ($p < 0,05$)

The highest amount of Fe in the plant was in the leaves ($109.16 \text{ mg kg}^{-1}$), the favorite organ for photoassimilate production, followed by the branches (55.99 mg kg^{-1}), husks (51.38 mg kg^{-1}) and finally the seed (31.15 mg kg^{-1}). Zn accumulated significantly more in the seed (32.25 mg kg^{-1}) among the organs, with a tendency to decrease in concentration as the plant grew during the years in production. Leaves (14.16 mg kg^{-1}) are also valuable reserve tissues, followed by branches (9.60 mg kg^{-1}) and husk (8.91 mg kg^{-1}).

For the micronutrients Cu, B and beneficial element Na, ANOVA found significant differences ($p < 0.05$) among plant organs (Figure 2). The largest reservoir of Cu was found significantly in the seeds (16.01 mg kg^{-1}), decreasing slightly in the husk (11.08 mg kg^{-1}), leaves (9.98 mg kg^{-1}) and, to a lesser extent, in the branches (6.40 mg kg^{-1}). During the development stages, the concentration of the nutrient increased slightly in the different organs up to year 10, decreasing in the oldest plant.

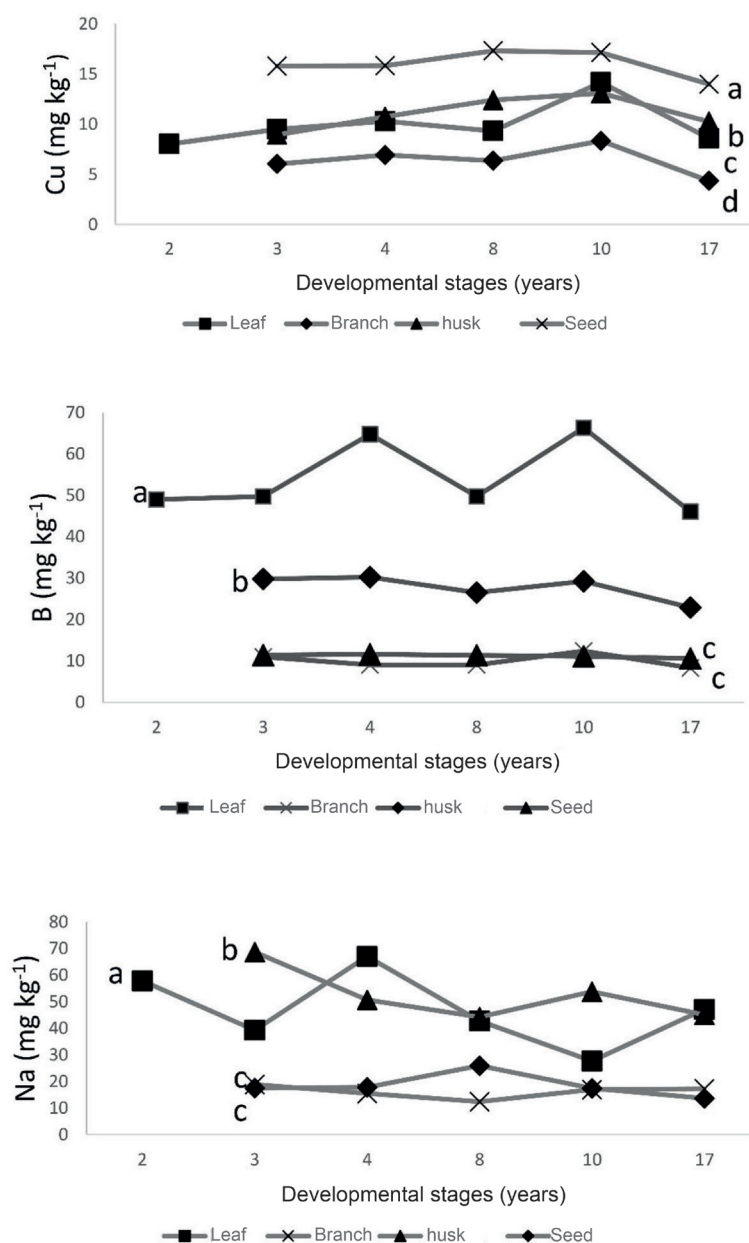


Figure 2. Cu, B and Na content (mg kg^{-1}) in leaves, bark, husk and seed of the rambutan plant at different stages (years) of development. Atlántida, Honduras, 2017. Averages with the same letter do not differ significantly according to the Tukey test ($p < 0.05$).

Figura 2. Contenido de Cu, B y Na (mg kg^{-1}) en hojas, corteza, cáscara y semilla de la planta de rambután en diferentes etapas (años) de desarrollo. Atlántida, Honduras, 2017. Promedios con igual letra no difieren significativamente según Tukey ($p < 0.05$).

Similarly to Mn and Fe, significantly higher concentrations of B were found in the leaves (54.26 mg kg^{-1}), where the highest photosynthetic activity occurs, followed by the lowest accumulation in the husk (27.74 mg kg^{-1}), seed (11.24 mg kg^{-1}) and finally in the branches (9.98 mg kg^{-1}). The behavior of Na among plant organs showed that the husks (52.51 mg kg^{-1}) and leaves (46.98 mg kg^{-1}) were the tissues with the highest accumulation compared to the branches (16.20 mg kg^{-1}) and seeds (18.48 mg kg^{-1}).

3.2. Nutrient dynamics at different stages of rambutan development

For the micronutrients Mn, Fe and Zn, ANOVA found significant differences ($p < 0.05$) between plant development stages (Figure 3). The highest manganese accumulation occurred in year 10 (732.40 mg kg⁻¹), decreasing in year 4 (408.11 mg kg⁻¹) and 8 (399.71 mg kg⁻¹) until reaching the lowest value (169.21 mg kg⁻¹) in the most adult plant.

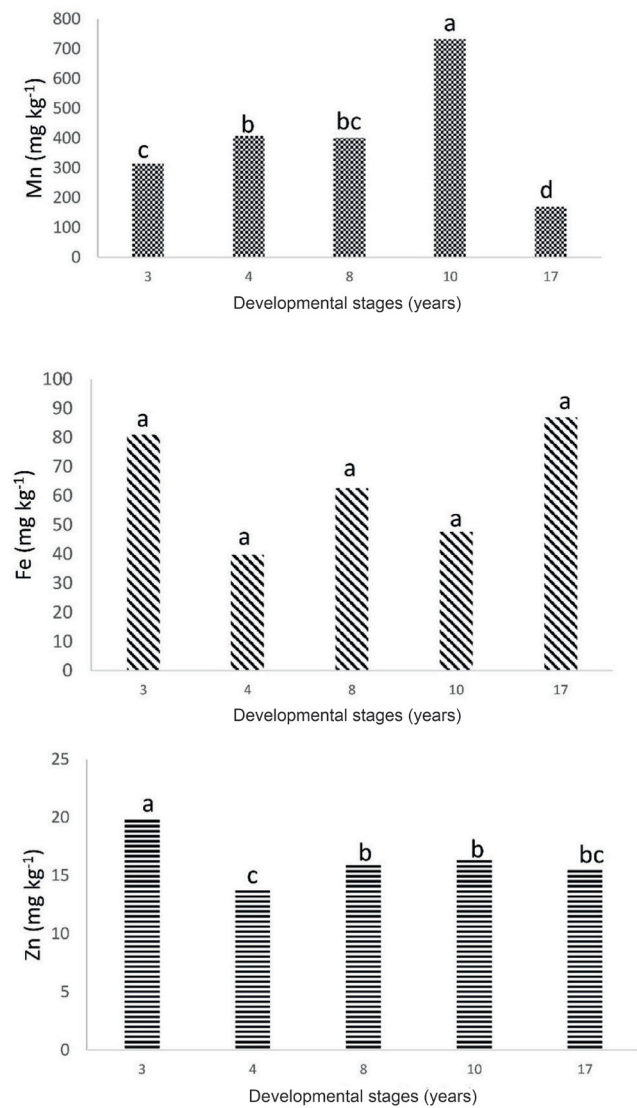


Figure 3. Mn, Fe and Zn content (mg kg⁻¹) in different ages (years) of the rambutan plant (leaves + husk+ branch + seed). Atlántida, Honduras, 2017. Averages with the same letter do not differ significantly according to the Tukey test ($p < 0,05$).
Figura 3. Contenido de Mn, Fe y Zn (mg kg⁻¹) en diferentes edades (años) de la planta (hojas+cáscara+rama+semilla) de rambután. Atlántida, Honduras, 2017. Promedios con igual letra no difieren significativamente según Tukey ($p < 0,05$).

The behavior of Fe was characterized by a constant variation of the concentration in the plant, even so, there were no significant differences between treatments. The highest concentrations were at the beginning of the productive stage (third year with 81 mg kg⁻¹) and at the end (17th year with 86.79 mg kg⁻¹).

The ranges of iron concentration in the leaves were higher than those reported by Arias and Calvo (2014), the high concentration found in the soil analysis (221.89 mg kg⁻¹) possibly facilitated the absorption and translocation to the leaves; similarly, in the Atlantic region, it is common to record in the soil analysis high amounts of Fe⁺² in the oxisols that characterize it.

The highest concentrations of Zn in the plant accumulated significantly at the beginning of the productive stage, year 3, with 19.85 mg kg⁻¹, while in the rest of the years, the highest concentrations of Fe⁺² were found

in the leaves. Demand was similar with 15.90 mg kg^{-1} in year 8, 16.45 mg kg^{-1} in year 10 and 15.62 mg kg^{-1} in year 17.

For the micronutrients Cu and B, as well as Na, the ANOVA also showed significant differences ($p < 0.05$) in the developmental stages (Figure 4). The plant gradually accumulated more Cu from the beginning (10.07 mg kg^{-1}) of its productive stage until year 10 (13.18 mg kg^{-1}), when it reached its highest accumulation, and then fell to the lowest level of concentration in the plant in year 17 (9.29 mg kg^{-1}).

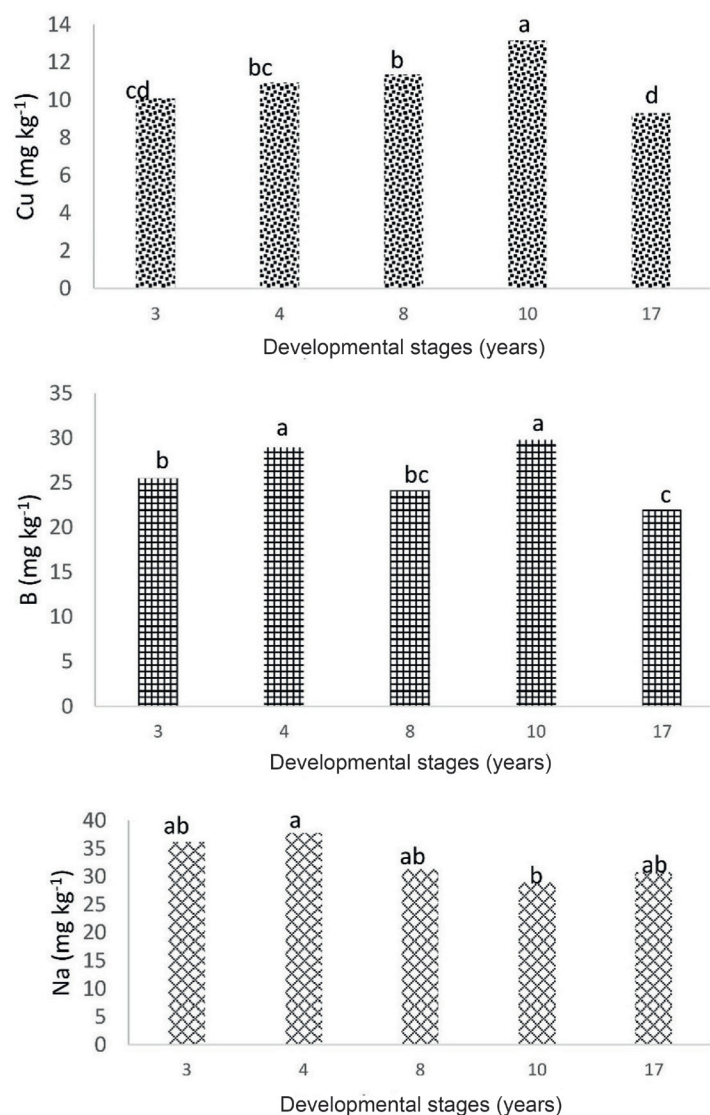


Figure 4. Cu, B and Na content (mg kg^{-1}) at different ages (years) of the rambutan plant (leaves + husk+ branch + seed). Atlántida, Honduras, 2017. Averages with the same letter do not differ significantly according to the Tukey test ($p < 0.05$).

Figura 4. Contenido de Cu, B y Na (mg kg^{-1}) en diferentes edades (años) de la planta (hojas + cáscara + rama + semilla) de rambutan. Atlántida, Honduras, 2017. Promedios con igual letra no difieren significativamente según Tukey ($p < 0.05$).

The concentrations of B accumulated in the plant were statistically different among the stages evaluated, ranging from 21.99 to 29.77 mg kg^{-1} , with the highest values in year 10 (29.77 mg kg^{-1}) and year 4 (28.92 mg kg^{-1}), while the lowest concentrations were in year 8 (24.17 mg kg^{-1}) and year 17 (21.99 mg kg^{-1}).

In the case of the beneficial element, significant changes were recorded, the highest levels were at the beginning of the productive stage with 36.12 mg kg^{-1} and fourth year with 37.78 mg kg^{-1} , from this point it began to decrease through the following stages of development, in year 8 (31.33 mg kg^{-1}), 10 (28.98 mg kg^{-1}) and 17 (30.78 mg kg^{-1}); even so, it is required in a constant and considerable way throughout the crop cycle.

The content of essential and beneficial nutrients in the plant over the years, expressed in relative percentage (Figure 5), shows that rambutan accumulates with great difference more manganese (73 %) than the rest

of the nutrients analyzed, followed by iron (11 %), sodium (6 %), boron (5 %), zinc (3 %) and copper (2 %). This allows to identify the contribution of each nutrient in field conditions in the northern part of the country, with Mn being of great preference in the productive cycle of the crop.

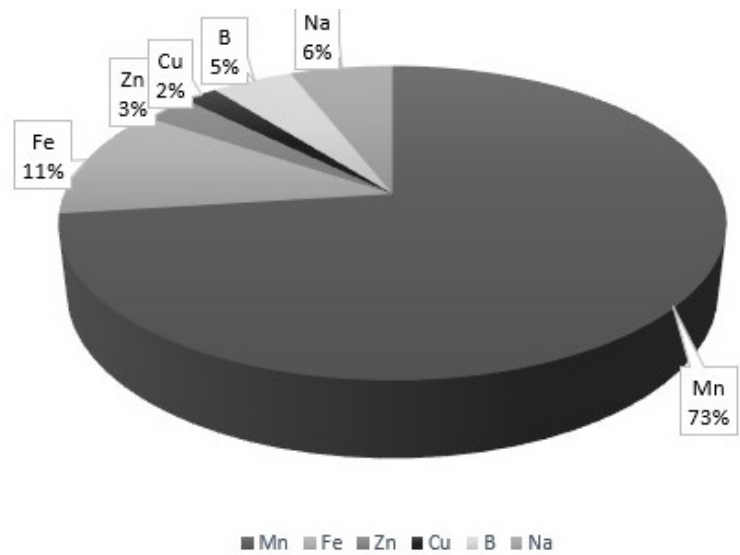


Figure 5. Concentration of essential and beneficial nutrients in the rambutan plant (leaves + husk + branch + seed) at the different stages of development (year 3 + 4 + 8 + 10 + 17). Atlántida, Honduras, 2017.

Figura 5. Concentración de los nutrientes esenciales y benéficos en la planta (hojas + cáscara + rama + semilla) de rambután en las diferentes etapas de desarrollo (año 3 + 4 + 8 + 10 + 17). Atlántida, Honduras, 2017.

In the present research the foliar analysis was carried out between October/November, at the harvest stage. While Molina , as cited in Arias and Calvo (2014), performed it in Costa Rica in 2013, between September/October, in the post-harvest period, when there is vegetative growth; whereas Lim et al. (1997) between May/June, before flowering. Although the edaphoclimatic conditions and varieties of rambutan differ between the productive zones of Honduras, Costa Rica and Australia, there are similarities in the concentration of the nutrients monitored (Table 3), with the exception of Mn and Fe, where the ranges proposed in local conditions are much higher than those referenced abroad. The results obtained contribute to consolidate optimal ranges of foliar analysis as a nutritional diagnostic tool.

Table 3. Ranges to interpret the foliar analyzes in rambutan. Atlántida, Honduras, 2017.
Tabla 3. Rangos para interpretar los análisis foliares en rambután. Atlántida, Honduras, 2017.

Elements	Sufficiency ranges (mg kg ⁻¹)		
		Molina (2013), as cited in Arias and Calvo (2014)	Lim <i>et al.</i> (1997)
Manganese	449-1034	50-200	104-150
Iron	69-199	40-100	77-98
Zinc	12-18	20-50	43-54
Copper	8-17	7-25	16-25
Boron	46-67	30-60	43-55
Sodium	27-58	-	100-200

Considering that rambutan plantations are mostly managed by small-scale producers on the Atlantic coast of Honduras, it is important to record the nutritional demand of the plant in the following order: Mn > Fe > Na > B > Zn > Cu, as this will serve as a parameter to formulate, or improve fertilization programs; and, consequently, increase productivity. Similarly, sufficiency ranges are proposed for the nutrients analyzed in the leaves, which will serve to evaluate the effect of fertilization and monitor the natural fertility of the soil.

4. Discussion

Variations were observed in the concentration of Mn in each of the organs; the highest accumulation occurred in the leaves and the lowest in the seed. At the beginning of the productive stage, the levels in the plant were similar -with the exception of the tenth year of production where/when the highest peak was recorded-, then they declined in year 17. This element takes part significantly in photosynthetic activity, where oxygen is produced from water (Marschner, 2003; Salisbury & Ross, 1994), therefore its concentrations rise when the plant demands it in large quantities during the productive stage; on the other hand, when there are deficiencies in the soil, interveinal chlorosis in old leaves may manifest as a symptom, depending on the species and growth (Taiz & Zeiger, 2006).

Mn concentrations are the highest in the rambutan plant. Azcón-Bieto and Talón (2008) state that Mn acts as a cofactor activating about 35 enzymatic reactions, some related to photosynthetic activity and others involved in plant defense.

Fe has low mobility in plant tissues due to high P and Mn concentrations, K deficiency and low light intensity (López, 1998). Although the conditions expressed by this author coincide to a large extent with the conditions of the experiment, the concentration varied from 40 to 90 mg kg⁻¹, with significant variations in each analyzed year in the whole plant; nevertheless, it was in the leaves where the greatest accumulation and mobility was observed, compared to the other organs. This dynamic in rambutan was/appears to be similar to that reported by Marschner (2003), where the concentration in leaves ranges between 50 and 150 mg kg⁻¹, while for Navarro Blaya and Navarro García (2003) the range varies from 25 to 250 mg kg⁻¹.

The accumulation of Zn, is located in the seeds, without exceeding 45 mg kg⁻¹, this element is absorbed from the soil by the plants as Zn²⁺, mainly as chelate, its concentration in the tissues ranges from 20 to 150 mg kg⁻¹ and, its mobility is low, with levels in the whole plant not higher than 20 mg kg⁻¹, according to this research. Apparently, the low level (0.82 mg kg⁻¹) in the soil could have affected its accumulation in the tissues, whose enzymatic function is valuable in the biosynthesis of indoleacetic acid, chlorophyll formation, or prevents its destruction and nitrogen metabolism (Navarro Blaya & Navarro García, 2003; Azcón-Bieto & Talón, 2008; Tisdale et al., 2005).

One of the primary functions of zinc is the synthesis of tryptophan, an amino acid precursor of indoleacetic acid (IAA), which is a growth hormone (Navarro Blaya & Navarro García, 2003).

The dynamics of B was quite similar among organs, except for the leaves, which apart from accumulating more of this nutrient, starting from the third year onwards, exhibited a rise and fall of the concentration. In the branches, husk and seeds the values were similar throughout the stages. Navarro Blaya and Navarro García (2003) express that B has little mobility in the plant, being the leaves and reproductive organs those that present the highest concentrations, proving that young plants absorb more than old ones, acting in the apical growth points, facilitating the transport of carbohydrates through the internal membranes (Bonilla et al., 1994). Despite the low level of boron in the soil, and its low mobility in the tissues, the values recorded in this experiment/research varied at all stages.

B is required in the productive stage of fruit crops and basic grains because of its role in multiple functions, such as flowering and pollen germination, fructification, synthesis of carbohydrates and hormones, regulate water absorption, among others (Mejía de Tafur, 2010; Rao, 2009).

The participation of Cu in higher plants is related to enzymes involved in photosynthesis, mitochondrial respiration, and cell wall metabolism, among others (Hänsch & Mendel, 2009; Mendel, 2013). Although leaves were the second organ that accumulated the most, after the seed, it is valuable to consider that it cannot be lacking in nutrition, since regardless of the organ, the plant accumulates it in a similar way through the years, being the tenth year the one with the highest peak recorded.

The higher concentrations of Na in leaves and shells suggest its high activity in osmotic control processes and turgor generation, capable of substituting K in many species due to its similar functions and concentrations in chloroplasts, hence the fact that Na exerts phosphorylation functions in photosynthesis (Marschner, 2003; Salisbury and Ross, 1994), to the point of being required for many halophytes and certain C4 as a micronutrient (Brownell, 1979; Malavolta et al., 1997).

Most of the plantations located on the Atlantic coast are established in Nitisols, characterized by low pH, high concentration of aluminum, manganese and iron. Apparently this crop has tolerance for these conditions, to the point of accumulating almost 75 % of the elements analyzed. Even so, the productivity seen in the field is moderate to good in the farms visited. There exists, however, an opportunity for nutritional management of

the soil through calcareous amendments, which will reflect the dynamics of these nutrients and their response in productive variables of the crop, understanding that macronutrients do not have their greatest availability under current conditions. The nutrient concentrations observed in this research, especially in the leaves as a monitoring organ, allow to contrast edaphoclimatic and nutritional conditions, and phytosanitary practices with/in other countries.

5. Conclusions

The concentration of essential and beneficial nutrients differed significantly among plant organs and different ages of the crop, finding the highest concentration of Mn, Fe, B, Na in leaves and Zn, Cu in the seed.

The order of the elements analyzed in the whole plant was as follows: Mn>Fe>Na>B>Zn>Cu; accumulating further at different times, Fe, Zn and Na at the beginning (3rd and 4th year) of production, while for B, Mn and Cu it was in the fourth and tenth year, allowing to identify the stage of greater demand, and the plant organ in which it accumulates.

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Contributor roles

- Breno Augusto Sosa Rodrigues: conceptualization, formal analysis, funding acquisition, investigation, project administration, visualization, writing - review & editing.
- Yuly Samanta García Vivas: formal analysis, investigation, project administration, supervision, visualization, validation, writing - review & editing.

Ethical implications

Ethics approval Not applicable..

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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