



DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v19n8p760-766>

Nutrient allocation among stem, leaf and inflorescence of jatropha plants

Rosiane L. S. de Lima¹, Hans R. Gheyi², Carlos A. V. de Azevedo³,
Valdinei Sofiatti⁴, Genelicio S. Carvalho Júnior⁵ & Jairo O. Cazetta⁶

¹ Fellow of the National Post-Doctoral Program (PNPD/UFCG)/CNPq. Campina Grande, PB. E-mail: limarosiane@yahoo.com.br (Autora correspondente)

² Water and Soil Engineering Nucleus/Federal University of Recôncavo of Bahia. Cruz das Almas, BA. E-mail: hans@pq.cnpq.br

³ Academic Unit of Agricultural Engineering/Federal University of Campina Grande. Campina Grande, PB. E-mail: cazevedo@deag.ufcg.edu.br

⁴ National Center for Research on Cotton/Embrapa Cotton. Campina Grande, PB. E-mail: nair@cnpa.embrapa.br

⁵ Master in Agricultural Sciences at the Paraíba State University (UEPB/Embrapa). E-mail: carvalhogenelicio@yahoo.com.br

⁶ Estadual University Paulista “Júlio de Mesquita Filho”. Jaboticabal, SP. E-mail: cazetta@unesp.br

Key words:

Jatropha curcas L.
flowering
nutrient translocation

ABSTRACT

Information on the partitioning of nutrients among various organs in jatropha plants, as a complementary tool for the recommendation of fertilization, is still not available. This study aimed to evaluate the contents of macro and micronutrients in stems, leaves and inflorescences of jatropha branches at the beginning of flowering. At the beginning of flowering, adult jatropha plants were sampled and divided into five compartments: inflorescences, leaves from vegetative branches, leaves from flowering branches, stems from vegetative branches and stems from flowering branches. Jatropha inflorescences are a drain of nutrients. Leaves are important sources of nutrients demanded by the inflorescences at the beginning of flowering. The higher allocation of nutrients in the inflorescences suggests the need for preventive/corrective fertilizations, which must be performed at least 30 days before flowering, providing plants with nutrients in adequate amounts for a good yield.

Palavras-chave:

Jatropha curcas L.
floração
translocação de nutrientes

Alocação de nutrientes entre caule, folha e inflorescência de pinhão-mansão

RESUMO

Ainda não se dispõe, para a cultura do pinhão-mansão, de informações concernentes à compartimentalização dos nutrientes nos diversos órgãos da planta; essas informações são importantes para subsidiar a recomendação de adubação. Objetivou-se, com este trabalho, avaliar os teores de macro e micronutrientes no caule, nas folhas e inflorescências dos ramos de pinhão-mansão por ocasião do início do florescimento. Plantas adultas de pinhão-mansão foram amostradas durante o início do florescimento dividindo-se a planta em cinco compartimentos (inflorescências, folhas colhidas de ramos vegetativos, folhas colhidas de ramos floríferos, caules de ramos floríferos e caules de ramos vegetativos). As inflorescências do pinhão-mansão são um forte dreno de nutrientes. As folhas são importantes fontes de nutrientes demandados pelas inflorescências por ocasião do início da floração. A maior compartimentalização de nutrientes nas inflorescências sugere a necessidade de adubações preventivas/corretivas que devem ser realizadas pelo menos 30 dias antes do florescimento disponibilizando, para as plantas, nutrientes em quantidades adequadas para a obtenção de boa produtividade.

INTRODUCTION

Jatropha (*Jatropha curcas* L.) is a plant species in *Euphorbiaceae* family, native to Central or South America (Suriharn et al., 2011; Schulz et al., 2012; Fernandes et al., 2013; Lima et al., 2014a). The capacity to adapt to different environments allows the presence of jatropha plants in a wide range of tropical and subtropical areas worldwide (Joshi et al., 2011).

For the formation of flowers and fruits, which results in yield, besides the genetic potential, adequate conditions of various environmental factors are necessary, such as temperature, water in the soil and nutrients (Laviola et al., 2011; Lima et al., 2014a). For this, the soil must provide nutrients in sufficient amounts, whether by natural fertility or fertilization (Lima et al., 2014b).

Jatropha plants accumulate 36.4, 3.31, 15.8, 22.3, 5.61 and 1.31 mg leaf⁻¹ and 53, 10.35, 37.5, 12, 9.7 and 1.75 mg fruit⁻¹ of N, P, K, Ca, Mg and S, respectively (Laviola & Dias, 2008); however, these authors do not present nutrient contents for either inflorescences or branches. Still according to this study, macronutrients are preferentially accumulated in fruits, except for Ca, which is preferentially accumulated in the leaves, and micronutrients show the same tendency, except for Fe and Mn. Despite the results for the accumulation and contents of macro and micronutrients in jatropha leaves and fruits, the participation of the accumulated reserves in comparison to the immediate absorption and assimilation is still not known.

In this context, this study aimed to evaluate the contents of macro and micronutrients in stems, leaves and inflorescences of the jatropha branches, before and at the beginning of the flowering period.

MATERIAL AND METHODS

Healthy 3.5-year-old jatropha plants, cultivated in a spacing of 3 x 2 m, were selected before and at the beginning of the flowering period in a homogeneous seed-producing area at the Estivas Farm, located in the municipality of Garanhuns-PE, Brazil (8° 56' S; 36° 27' W; 741 m). According to ITEP (2008), the historical mean rainfall in the region is 130 mm month⁻¹ and, according to the classification of Köppen, the climate is BS (dry, semiarid, megathermal, with four rainy months). Rainfall and temperature data during the year of evaluation are shown in Figure 1.

The soil of the experimental area is classified as Regolithic Neosol with sandy loam texture. For the chemical analysis, soil samples were collected in the layer of 0-0.20 m, under the canopy projection. Samples were homogenized and analysed at the Irrigation and Salinity Laboratory of the Federal University of Campina Grande (Table 1).

In the 2010 agricultural year, 6 t ha⁻¹ of cattle manure were applied in the entire area. Cultural practices were limited to

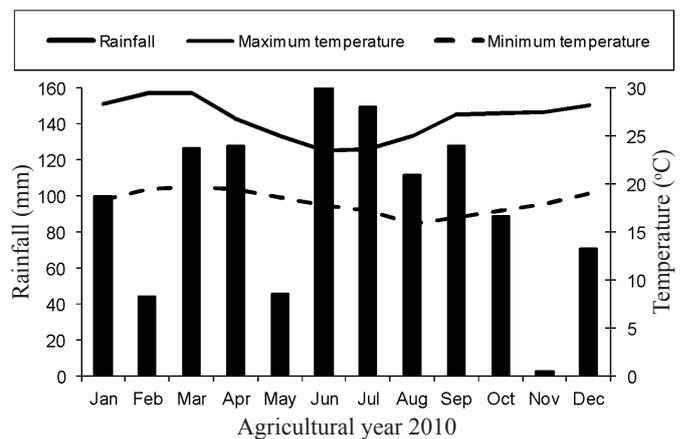


Figure 1. Rainfall and temperature data during the experiment conducted in 2010

weed control around the plants and mowing in the interrows, as a preventive measure against the erosive effects caused by the rains.

The experiment was set in a completely randomized design with five treatments, which corresponded to the plant compartments: stems from vegetative branches, stems from flowering branches, leaves from vegetative branches, leaves from flowering branches and inflorescences, with 4 replicates, totaling 20 plots.

Inflorescences, leaves and stems of each branch were separated, the number of branches per plant was counted and the material was dried at 65 °C. The collected plant material was subjected to nitric-perchloric digestion, in order to determine the contents of P, K, Ca, Mg and S (Malavolta et al., 1997), and to sulfuric acid digestion, for the determination of the N content (Jackson, 1965).

N was determined through the colorimetric Nessler method, P through the reduction of phosphomolybdic acid by the vitamin C, modified by Braga & Delfelipo (1974), and K through flame photometry. Ca, Mg, Cu, Fe, Mn and Zn were determined through atomic absorption spectrophotometry and S through the sulfate turbidimetric method (Malavolta et al., 1997).

The content of nutrients (C_N) in stems, leaves and inflorescences of each branch of jatropha plants was determined through the methodology proposed by Malavolta et al. (2002), according to Eq. 1:

$$C_N = (\text{Content in the organ} \times \text{Organ dry weight} \times n^\circ \text{ of branches plant}^{-1}) \times 1000 \quad (1)$$

where 1000 is a factor applied to convert the results of macronutrients into g plant⁻¹ and micronutrients into mg plant⁻¹. The values were extrapolated to 1 ha (C_{ha}) considering the planting density, according to Eq. 2:

Table 1. Characteristics of the soil in the experimental area of jatropha cultivation in the agricultural year of 2010

pH	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Sum	H + Al	Al ³⁺	Total	V	P	OM
1:2.5									%	mg dm ⁻³	g kg ⁻¹
6.2	25.7	14.3	1.47	2.3	43.7	14.0	0.5	57.7	76	11.4	14.7

pH in H₂O; T - cation exchange capacity; V - Base saturation, OM - Organic matter

$$C_{ha} = \frac{(C_N \times n^\circ \text{ of plants per hectare})}{1000} \quad (2)$$

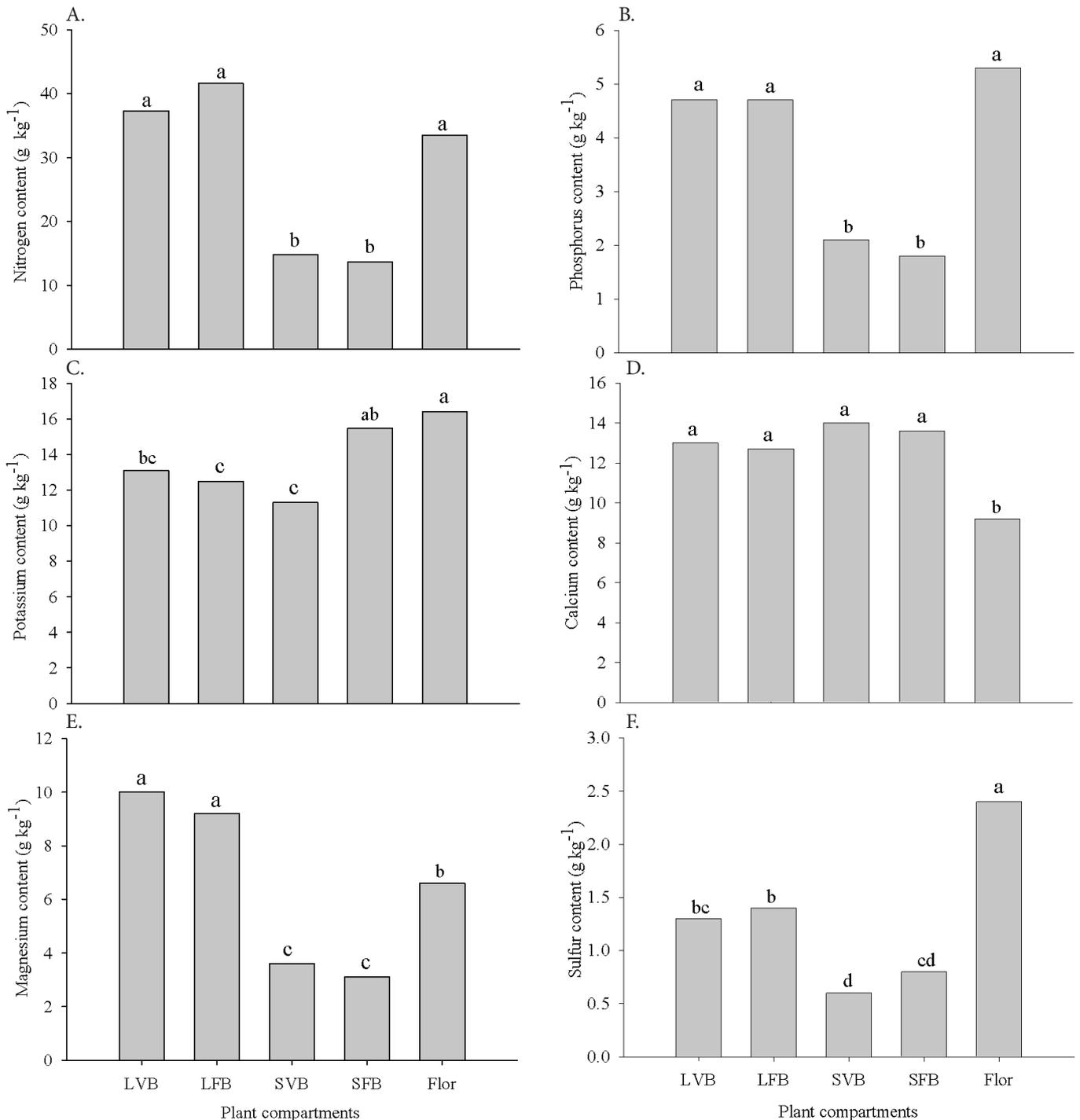
The factor 1000 was applied to convert the results of macronutrients into kg ha^{-1} and micronutrients into g ha^{-1} .

The data were subjected to the statistical analysis, using the software Sisvar, version 5.3. The analysis of variance and the comparison of the means were performed through the Tukey test at 0.05 probability level, according to the recommendations of Santos et al. (2008).

RESULTS AND DISCUSSION

The contents of nutrients in the different plant compartments suffered great variations (Figure 2). N and P contents of 41.6 and 4.7 g kg^{-1} , respectively, were observed in the leaves from flowering branches (LFB), while 33.5 and 5.3 g kg^{-1} were observed in the inflorescences (Flower), i.e., values higher than the ones observed in the stem (Figure 2A and B).

The contents of N and P in leaves from flowering branches (LFB) were slightly higher than those in leaves from vegetative



Means followed by the same lowercase letters in the row do not differ by Tukey test ($p \leq 0.05$)

Figure 2. Contents of nitrogen (A), phosphorus (B), potassium (C), calcium (D), magnesium (E) and sulfur (F) in leaves from vegetative branches (LVB), leaves from flowering branches (LFB), stems from vegetative branches (SVB), stems from flowering branches (SFB) and inflorescences (Flor) of jatropa plants, at the beginning of the flowering period

branches (LVB), but with no statistical difference (Figure 2A and B).

These two nutrients (N and P) have an important participation in the organs with higher metabolic activity (like leaves and inflorescences), because they constitute proteins and compounds related to the energy metabolism; however, they accumulate in lower amounts in the stem, which is a structural compartment of low metabolic activity. P has high mobility in the phloem and is a nutrient closely related to the physiological processes of energy flow (Marschner, 2002). The beginning of flowering did not change significantly the contents of N and P in the leaves and stems (Figure 2A and B) for both periods (beginning of flowering and vegetative phase), which suggests that the N and P accumulated in inflorescences were translocated from other plant parts or absorbed by the roots in order to meet the demand of the reproductive organs.

Potassium (K) is an element required in great amounts at the beginning and during the entire development of the fruits (Lima et al., 2014b). Probably, this is the reason why inflorescences showed high K content (16.4 g kg^{-1}) (Figure 2C). Stems from flowering branches (SFB) showed higher K content (15.5 g kg^{-1}) than stems from vegetative branches (SVB) (11.3 g kg^{-1}) (Figure 2C), possibly because the beginning of flowering causes a flow of K into the inflorescence or because it is accumulated closer to the seeds for a later moment, when the demand is intensified (Lima et al., 2014b). However, Lima et al. (2011b) mention that the presence or absence of inflorescences in the branches does not influence K contents in the leaf tissues of adult jatropha plants. K contents in the leaves did not change due to the flowering period, which suggests that this nutrient was translocated to the inflorescences from other plant parts, which can include older leaves (Lima et al., 2011a).

Calcium (Ca) contents in the stem ($13.6\text{-}14 \text{ g kg}^{-1}$) and leaves ($12.7\text{-}13 \text{ g kg}^{-1}$) were not influenced by the development stage of the branch, or by the presence or absence of inflorescence (Figure 2D). The Ca content in the inflorescences (9.2 g kg^{-1}) was lower than in stems and leaves of the same branch, probably because this nutrient has low mobility in the plant and accumulated in the tissue without being able to be redistributed to other plant parts (Marschner, 2002). According to the results, it is possible to infer that there was higher translocation of Ca from leaves to flowers, since this nutrient has structural function and low mobility in the phloem (Marschner, 2002; Lima et al., 2014b).

The magnesium (Mg) contents in the leaves ($9.2\text{-}10 \text{ g kg}^{-1}$) were higher than in stems ($3.1\text{-}3.6 \text{ g kg}^{-1}$) and inflorescences (6.6 g kg^{-1}) (Figure 2E). The literature does not mention the partitioning of this nutrient among the organs of jatropha, and is limited to the contents obtained only in leaves and fruits (Laviola & Dias, 2008; Lima et al., 2014b).

Similarly to Ca, Mg is an element with low mobility in the phloem and tends to concentrate in older tissues, such as mature and senescent leaves (Lima et al., 2011a). The beginning of the flowering period did not change Mg contents in stems and leaves, which evidences the low mobility of this element. Lima et al. (2014b) also verified that the contents

of these minerals are relatively low in the inflorescences and increase gradually, following fruit growth.

The highest sulfur (S) contents were observed in the inflorescences (2.4 g kg^{-1}), and the lowest ones in stems from vegetative and flowering branches (mean value of 0.7 g kg^{-1}) (Figure 2F). The beginning of flowering did not change the distribution of this nutrient between stems and leaves, but the demand for S is relatively high during the flowering period.

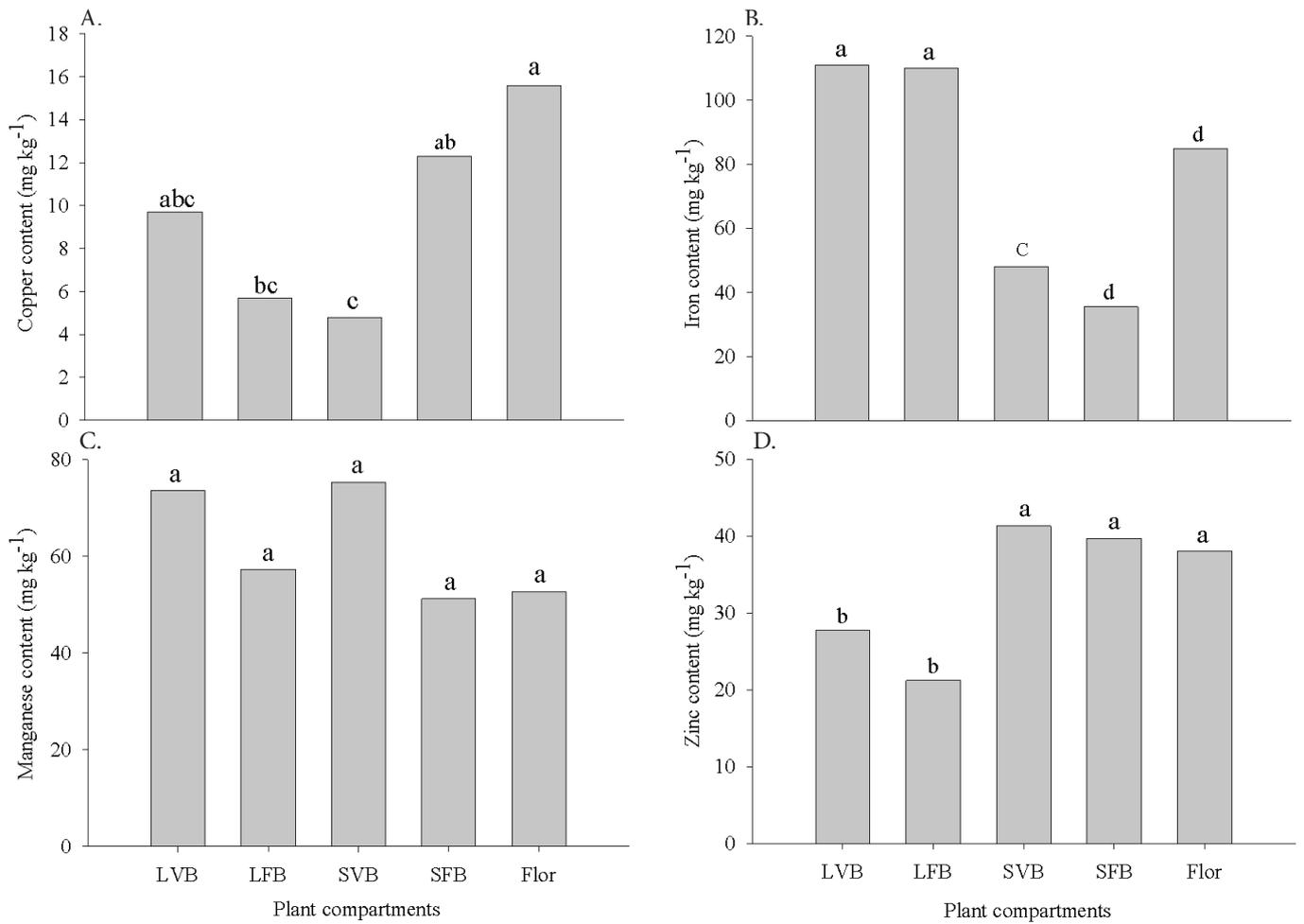
The inflorescences were the plant compartment with the highest copper (Cu) content (15.6 mg kg^{-1}), indicating that there is a high demand for this nutrient during the flowering period. According to Lima et al. (2014b), the nutritional requirement of jatropha plants during fruiting is very high. The contents of Cu in vegetative and flowering stems increased from 4.8 to 12.3 mg kg^{-1} , after the beginning of flowering, which indicates that this nutrient was translocated from other plant parts, as well as from leaves of the same branch (Figure 3A).

According to Lima et al. (2011b), Cu contents vary more depending on the position of the leaf in the branch in comparison to the phenology of the branch. These authors obtained Cu contents from 11.2 to 15.2 mg kg^{-1} in leaves between the first and fifth leaf positions. It should be pointed out that the leaves analysed in this study were collected only from the fifth position of the branch. The differences between the contents observed in this study and those cited in the literature may be attributed to climatic conditions and fertilization.

The highest iron (Fe) contents were observed in LFB (110 mg kg^{-1}) and LVB (110.8 mg kg^{-1}) (Figure 3B). Fe contents in the inflorescences (84.8 mg kg^{-1}) were intermediate between the aforementioned contents in the leaves and the contents in stems from flowering branches (SFB) (35.5 mg kg^{-1}) and stems from vegetative branches (SVB) (47.9 mg kg^{-1}), indicating that its demand by the inflorescences is not as high as the demand for Cu. Since the Fe contents decreased in the SFB with the beginning of flowering, the demand by the inflorescences was possibly supplied with the remobilization of Fe from the branches close to the inflorescences, but not from the leaves (Figure 3B). According to Marschner (2002), Cu and Zn are nutrients of low mobility with high contents in flowers and leaves and less variations in stem tissues.

Manganese (Mn) contents did not vary among the studied plant organs; however, Mn concentrated preferentially in the leaves from vegetative branches (71 mg kg^{-1}), indicating that the beginning of flowering caused a reduction in the Mn contents (Figure 3C). On the other hand, Mn content was lower in stems of flowering branches (51.2 mg kg^{-1}), followed by inflorescences (52.7 mg kg^{-1}) and stems from vegetative branches (54.8 mg kg^{-1}).

The demand of inflorescences for Mn is probably supplied by the translocation from the branches, where Mn seems to be stored. These results corroborate the claim that Mn demand is high in growing leaves, but is reduced after plants reach their final size and is little redistributed before leaf senescence (Lima et al., 2011a; Malavolta et al., 2002). In the inflorescences of jatropha, Mn also seems to concentrate at the beginning of the growth, being translocated from reserves or absorbed by the roots (Malavolta et al., 2002; 2006).



Means followed by the same lowercase letter in the row do not differ by Tukey test ($p \leq 0.05$)

Figure 3. Contents of copper (A), iron (B), manganese (C) and zinc (D) in leaves from vegetative branches (LVB), leaves from flowering branches (LFB), stems from vegetative branches (SVB), stems from flowering branches (SFB) and inflorescences (Flower) of jatropha plants at the beginning of the flowering period

The zinc (Zn) contents did not differ between the inflorescences and the stems from vegetative and flowering branches (Figure 3D), but were significantly different in the leaves. The highest Zn content was observed in the stems from vegetative branches (41.3 mg kg^{-1}) and the lowest ones in the leaves from flowering branches (21.2 mg kg^{-1}).

Zn is an element of low mobility in the phloem that decreases in the leaf tissue of jatropha plants as the leaf ages. In younger tissues, Zn contents in the leaves tend to be higher and can suffer occasional variations, with no defined tendency in the other growth phases (Lima et al., 2011a). During the stages of flowering and fruit formation, great amounts of Zn are translocated from the leaves to the reproductive structures, which explains the lower contents in

the leaves from flowering branches (Lima et al., 2014b).

The estimated amounts of macro and micronutrients in the different plant compartments are shown in Table 2. N was the nutrient allocated in the plant in the highest amount, followed by K, Ca, P and S. Among the studied micronutrients, Fe and Mn were the ones with the highest allocated amounts. The knowledge on the amounts of nutrients allocated in jatropha plants at the beginning of the flowering period is useful to determine the nutritional requirement of the plant during this phenological stage.

In the vegetative branches, the greatest part of the nutrients was allocated in the leaves, about 65.77 kg ha^{-1} of N, 7.7 kg ha^{-1} of P, 21.29 kg ha^{-1} of K, 21.32 kg ha^{-1} of Ca, 15.94 kg of Mg and 2.21 kg ha^{-1} of S, respectively (Table 2). After the

Table 2. Amounts of macro (kg ha^{-1}) and micronutrients (g ha^{-1}) in inflorescences (Flower), stems from vegetative branches (SVB), stems from flowering branches (SFB), leaves from flowering branches (LFB) and leaves from vegetative branches (LVB) of jatropha plants at the beginning of the flowering period

Plant compartment	Amount of nutrients										
	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	
			kg ha^{-1}					g ha^{-1}			
Flower	55.84	8.79	27.26	15.25	11.00	3.92	25.88	141.29	87.91	63.27	
SVB	24.67	3.38	18.80	23.21	5.96	0.96	7.89	79.71	91.35	68.73	
SFB	22.80	3.00	25.76	22.67	5.13	1.33	20.38	59.05	85.27	66.13	
LFB	69.35	7.71	20.84	21.05	15.21	2.29	9.47	183.23	95.54	35.41	
LVB	62.18	7.83	21.75	21.59	16.67	2.13	16.05	184.74	122.52	46.07	

Table 3. Percent allocation of macro and micronutrients between leaves, stems and inflorescences of vegetative and flowering branches of jatropha plants

Plant compartment	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
	%									
Vegetative branch										
Leaves	62.0	63.9	78.0	81.5	59.5	64.9	66.9	63.9	80.8	86.0
Stems	38.0	36.1	22.0	18.5	40.5	35.1	33.1	36.1	19.2	14.0
Flowering branch										
Leaves	35.4	34.8	60.9	65.5	37.2	38.1	61.6	35.5	58.1	65.7
Stems	31.3	26.0	14.3	17.6	32.1	19.0	8.3	31.9	18.9	10.2
Inflorescences	33.3	39.2	24.8	16.9	30.7	42.9	30.1	32.6	23.0	24.1

beginning of the flowering period, the allocation of nutrients in the leaves decreased; part of this reduction is due to the increase in the biomass of the entire branch, and another part is due to the translocation of nutrients from the leaves. Ultimately, the allocation of P (8.79 kg ha⁻¹) and S (3.92 kg ha⁻¹) in the inflorescences stands out, since these nutrients are found in higher amounts in the reproductive structures, compared with the leaves.

The percent allocation of macro and micronutrients among stems, leaves and inflorescences is shown in Table 3. The highest percentage of macro and micronutrients occurred in the leaves, regardless of the type of branch, and the lowest ones were observed in the stems of both vegetative and flowering branches. It is noteworthy to observe that the stems from flowering branches were the plant compartment with the lowest accumulation of Cu and Zn, with values much lower than those observed in the other compartments (Table 3).

The highest Cu accumulation was observed in the leaves, corresponding to 64.25%, on average, for the two types of leaves (Table 3). On the other hand, the stems from flowering branches were the organ with the lowest Cu accumulation (8.3%), evidencing a probable translocation of Cu to the inflorescences, while the other organs accumulated more balanced amounts. The accumulation of Fe was also higher in the leaves from vegetative branches (63.9%); however, Fe was well distributed in the organs from the flowering branches, without great variations among inflorescences, stems and leaves (Table 3). The micronutrient Mn was mainly accumulated in the leaves, regardless of the type of branch, with nearly 80.8% of its content allocated in leaves from vegetative branches (Table 3). The same tendency was observed for Cu and Fe, except for leaves from flowering branches. On the other hand, the inflorescences allocated, on average, 23% of the Mn content. Zn contents showed great variations among leaves, stems and inflorescences, preferentially concentrating in the leaves, a specific organ that showed the highest Zn accumulation in vegetative and flowering branches (86 and 65.7%) and, in lower proportions, stems (mean value of 12.1%) and inflorescences (24.1%).

CONCLUSIONS

1. *Jatropha* inflorescences are a drain of nutrients and leaves are important sources of nutrients demanded by the inflorescences at the beginning of the flowering period.

2. The higher allocation of nutrients in the inflorescences suggests the need for preventive/corrective fertilizations,

which must be performed at least 30 days before flowering, providing plants with nutrients in adequate amounts for a good yield.

ACKNOWLEDGMENTS

To the National Council for Scientific and Technological Development (CNPq) for the PNPd scholarship granted for the first author, through the Edicts MEC/CAPES and MCT/CNPq/FINEP N° 28/2010 – PNPd/CNPq/UFCG.

LITERATURE CITED

- Braga, J. M.; Defelipo, B. V. Determinação espectrofotométrica de P em extratos de solo e material vegetal. *Revista Ceres*, v.21, p.73-85, 1974.
- Fernandes, J. D.; Chaves, L. H. G.; Dantas, J. P.; Silva, J. R. P. Fenologia e produção do pinhão-mansão cultivado com diferentes fontes de adubação. *Revista Ciência Agronômica*, v.44, p.339-346, 2013. <http://dx.doi.org/10.1590/S1806-66902013000200017>
- ITEP - Instituto de Tecnologia de Pernambuco. Médias históricas da chuva (mm) de janeiro a dezembro para o estado de Pernambuco. 2008. <http://www.itep.br/meteorologia/climatologia.htm>. 2 Fev. 2014.
- Jackson, M. L. Soil chemical analysis. New Jersey: Prentice Hall, 1965. 498p.
- Joshi, G.; Shukla, A.; Shukla, A. Synergistic response of auxin and ethylene on physiology of *Jatropha curcas* L. *Brazilian Society of Plant Physiology*, v.23, p.67-77, 2011. <http://dx.doi.org/10.1590/S1677-04202011000100009>
- Laviola, B. G.; Bhering, L. L.; Mendonça, S.; Rosado, T. B.; Albrecht, J. C. Caracterização morfo-agronômica do banco de germoplasma de pinhão manso na fase jovem. *Bioscience Journal*, v.27, p.371-379, 2011.
- Laviola, B. G.; Dias, L. A. S. Teor e acúmulo de nutrientes em folhas e frutos de pinhão manso. *Revista Brasileira de Ciência do Solo*, v.32, p.1969-1975, 2008. <http://dx.doi.org/10.1590/S0100-06832008000500018>
- Lima, R. L. S. de; Azevedo, C. A. V. de; Gheyi, H. R.; Sofiatti, V.; Cazetta, J. O.; Carvalho Júnior, G. S.; Arriel, N. H. C. Seasonal variation of nutrient content in the foliage of *Jatropha curcas*. *Semina: Ciências Agrárias*, v.35, p.3031-3042, 2014a. <http://dx.doi.org/10.5433/1679-0359.2014v35n6p3031>
- Lima, R. L. S. de; Severino, L. S.; Cazetta, J. O.; Azevedo, C. A. V. de; Sofiatti, V.; Arriel, N. H. C. Posição da folha e estágio fenológico do ramo para análise foliar do pinhão-mansão. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.15, p.1068-1072, 2011a. <http://dx.doi.org/10.1590/S1415-43662011001000011>

- Lima, R. L. S. de; Severino, L. S.; Cazetta, J. O.; Azevedo, C. A. V. de; Sofiatti, V.; Arriel, N.H.C. Redistribuição de nutrientes em folhas de pinhão-mansão entre estádios fenológicos. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.15, p.1175-1179, 2011b. <http://dx.doi.org/10.1590/S1415-43662011001100010>
- Lima, R. L. S. de; Sofiatti, V.; Azevedo, C. A. V. de; Cazetta, J. O.; Carvalho Júnior, G. S.; Arriel, N. H. C. Nutrient accumulation curves in fruits and nutrient export by seeds and hull harvesting of physic nut (*Jathopa curcas* L.). *Semina: Ciências Agrárias*, v.35, p.3003-3014, 2014b. <http://dx.doi.org/10.5433/1679-0359.2014v35n6p3003>
- Malavolta, E.; Kavarin, J. L.; Malavolta, M.; Cabral, C. P.; Heinrichs, R.; Silveira, J. S. M. Repartição de nutrientes nos ramos, folhas e flores do cafeeiro. *Pesquisa Agropecuária Brasileira*, v.37, p.1017-1022, 2002. <http://dx.doi.org/10.1590/S0100-204X2002000700016>
- Malavolta, E.; Leão, H. C. de; Oliveira, S. C.; Lavres Júnior, J.; Malavolta, E.; Vitti, G. C.; Oliveira, S. A. Avaliação do estado nutricional das plantas: princípios e aplicações. Piracicaba: Potafos. 1997. 319p.
- Malavolta, E.; Leão, H. C. de; Oliveira, S. C.; Lavres Júnior, J.; Moraes, M. F.; Cabral, C. P.; Malavolta, M. Repartição de nutrientes nas flores, folhas e ramos da laranjeira cultivar natal. *Revista Brasileira de Fruticultura*, v.28, p.506-511, 2006. <http://dx.doi.org/10.1590/S0100-29452006000300036>
- Marschner, H. Mineral nutrition of higher plants. London: Academic, 2002. 889p.
- Santos, J. W. dos; Almeida, F. de A. C.; Beltrão, N. E. de M.; Cavalcante, F. B. Estatística experimental aplicada. 2.ed. Campina Grande: Embrapa Algodão/UFCG, 2008. 461p.
- Schulz, D. G.; Fey, R.; Ruppenthal, V.; Malavasi, M. M.; Malavasi, U. C. Initial growth of physic nut as a function of sources and doses of organic fertilizers. *Ciência e Agrotecnologia*, v.36, p.615-623, 2012. <http://dx.doi.org/10.1590/S1413-70542012000600003>
- Suriharn, B.; Sanitchon, J.; Songsr, P.; Kesmla, T. Effects of pruning levels and fertilizer rates on yield of physic nut (*Jathopa curcas* L.). *Asian Journal of Plant Sciences*, v.10, p.52-59, 2011. <http://dx.doi.org/10.3923/ajps.2011.52.59>