

## LEAF CONTENTS AND BIOCHEMICAL CYCLING OF NUTRIENTS IN ACCESSIONS OF UMBU AND UMBU-CAJA<sup>1</sup>

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**ABSTRACT** - Information is needed on the characteristics of potential accessions of *Spondias tuberosa* Arruda Câmara (umbu) and *Spondias* sp.(umbu-caja) for commercial planting and preservation. Thus, the objective was to evaluate the leaf contents and cycling of nutrients of 15 accessions of umbu and one of umbu-caja. The treatments consisted of 16 accessions: BGU-44, BGU-45, BGU-47, BGU-48, BGU-50, BGU-75, EPAMIG-01, EPAMIG-03, EPAMIG-04, EPAMIG-05, EPAMIG-06, EPAMIG-07, EPAMIG-09, EPAMIG-13, umbu of unknown origin and the umbu-caja Princesa. A completely randomized experimental design was adopted, with three replicates, consisting of one plant each. Nutrient contents in the leaves were measured in the leaf flushing and leaf senescence phases in the 2015/2016 and 2016/2017 seasons, and the N, P, K and Mg retranslocation rates were determined. The accessions showed average leaf nutrient contents of 28.6, 27.6, 9.5, 4.20, 2.5 and 2.0 g kg<sup>-1</sup> with the descending order N>Ca>K>Mg>S>P, respectively, and 103.61, 86.22, 82.12, 60.2, 16.0 and 3.52 mg kg<sup>-1</sup> of Fe>B>Na>Mn>Zn>Cu, respectively. The accession BGU-48 had higher N and P retranslocation efficiency in the leaves and BGU-50 showed recycling efficiency for K and Mg. The order of retranslocation rates is K>P>N>Mg, being higher in the 2015/2016 season.

**Keywords:** *Spondias* spp.. Genetic resources. Variability. Nutrients.

## TEOR FOLIAR E CICLAGEM BIOQUÍMICA DE NUTRIENTES EM ACESSOS DE UMBUZEIRO E UMBUCAJAZEIRA

**RESUMO** - O umbuzeiro e umbu-cajazeira demandam informações sobre as características de acessos potenciais para implantação comercial e preservação. Assim, objetivou-se avaliar o teor foliar e ciclagem dos nutrientes de 15 acessos de umbuzeiro e um de umbucajazeira. Os tratamentos constaram de 16 acessos: BGU-44, BGU-45, BGU-47, BGU-48, BGU-50, BGU-75, EPAMIG-01, EPAMIG-03, EPAMIG-04, EPAMIG-05, EPAMIG-06, EPAMIG-07, EPAMIG-09, EPAMIG-13, umbuzeiro de origem desconhecida e umbu-cajazeira Princesa. Adotou-se o delineamento experimental inteiramente casualizado, com três repetições, constituídas de uma planta cada. Foram mensurados os teores de nutrientes nas folhas, nas fases de emissão de fluxo foliar e senescência das folhas, nas safras de 2015/2016 e 2016/2017, e determinou-se a taxa de retranslocação de N, P, K e Mg. Verificou-se que os acessos denotaram teores médios de nutrientes na folha de 28,6; 27,6; 9,5; 4,20; 2,5 e 2,0 g kg<sup>-1</sup> com ordem decrescente N>Ca>K>Mg>S>P, respectivamente, e 103,61; 86,22; 82,12; 60,2; 16,0 e 3,52 mg kg<sup>-1</sup> de Fe>B>Na>Mn>Zn>Cu, respectivamente. O acesso BGU-48 revelou maior eficiência de retranslocação de N e P nas folhas e o BGU-50 expressou eficiência de reciclagem para K e Mg. A ordem das taxas de retranslocação é K>P>N>Mg sendo maior na safra 2015/2016.

**Palavras-Chave:** *Spondias* spp.. Recursos genéticos. Variabilidade. Nutrientes.

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## INTRODUCTION

*Spondias tuberosa* Arruda Câmara (Umbu) and *Spondias* sp. (umbu-caja) are fruit plants of the Anacardiaceae family, native to Northeastern Brazil (MERTENS et al., 2017), with mechanisms of survival to the water scarcity and irregular rainfall distribution that prevail in the Brazilian semi-arid region, such as leaf abscission, roots with structures called tubers or xylopodia, popularly known as 'umbu potatoes' with the function of storing water and nutrients (MITCHELL; DALY, 2015), in addition to efficient control of leaf transpiration (LIMA FILHO; AIDAR, 2016).

Due to the characteristics of adaptation to the edaphoclimatic conditions of the semi-arid region, these species have environmental and socioeconomic importance for the region, because their fruits are commercialized in an extractive way, with great expansion capacity for commercial plantations destined for the markets of fresh products and products processed from pulp and peel. Fruit collection is directly affected, in order of importance, by flavor, size, and quantity of fruit pulp (LINS NETO; PERONI; ALBUQUERQUE, 2010).

In this context, despite the advances of research in the field of fruit characterization (BASTOS; MARTINEZ; SOUZA, 2016; CAMPOS et al., 2018), definition of suitable rootstocks (LIMA FILHO; SANTOS, 2009), seedling production by cuttings (MENDES et al., 2019) and physiological characterization (ANTUNES et al., 2016), umbu and umbu-caja currently have no recommended accessions for use on a productive scale or for a specific destination market, either for fresh consumption or for agroindustry, so studies need to be conducted (FREITAS et al., 2015).

Thus, the creation of Germplasm Banks and Collections are an important source of information in this selection process because, besides the preservation of species variability, reducing the effects of genetic erosion under natural conditions, they enable the characterization and documentation of different accessions for use in breeding programs or identification of insertion in a potential market (OLIVEIRA et al., 2016).

Studies with the different accessions in Germplasm Banks and Collections are still incipient and are necessary, mainly the nutritional evaluation in leaves of umbu and umbu-caja under field conditions, because the studies with nutritional characterization were carried out in the initial phase of seedling production with native umbu (GONÇALVES; NEVES; CARVALHO, 2006; SILVA; GONÇALVES; PINHO, 2005) or umbu in Caatinga forest system (ALBUQUERQUE et al., 2018).

Leaf contents are important to indicate the deficiency in quantity or absorption of nutrients in the plant. However, the nutrient absorption process is

regulated by genetic control, in which selectivity and speed of absorption depend on genotype characteristics (FAQUIN, 2005). Thus, in addition to the supply of nutrients in the soil, the genetic characteristics of each accession can interfere in the leaf contents of nutrients. In this context, the objective was to evaluate the leaf contents and cycling of nutrients of 15 accessions of umbu and one of umbu-caja.

## MATERIAL AND METHODS

The plants used in this study make up the Collection of Umbu and Umbu-caja Accessions of the Federal Institute of Education, Science and Technology of Bahia, *Guanambi* Campus, located in the municipality of Guanambi, BA, Ceraíma District, with the coordinates of 14°17'38.50"S and 42°41'35.94"W and altitude of 545 m.

The umbu accessions used come from the municipalities of Lontra-MG (EPAMIG-01), Porteirinha-MG (EPAMIG-03 and EPAMIG-05), Janaúba-MG (EPAMIG-04), Mamonas-MG (EPAMIG-06) and Januária-MG (EPAMIG-07, EPAMIG-09 and EPAMIG-13), produced and provided by the EPAMIG North Collection in Nova Porteirinha, MG. Accessions from Anagé-BA (BGU-44), Brumado-BA (BGU-45), São Gabriel-BA (BGU-47), América Dourada-BA (BGU-48), Santana-BA (BGU-50) and Macaúbas-BA (BGU-75) come from the Active Germplasm Bank of Umbu of Embrapa Semiárid, Petrolina, PE, and were provided by Embrapa Cassava and Tropical Fruits, Cruz das Almas, BA.

The umbu accession called unknown refers to a plant with no identification of origin, but considered of sweet fruit, provided by Embrapa Cassava and Tropical Fruits, Cruz das Almas, BA. The umbu-caja Princesa from Iaçu-BA was produced and provided by Embrapa Cassava and Tropical Fruits, Cruz das Almas, BA. The accession EPAMIG-01 (SATURNINO; GONÇALVES; SILVA, 2000) used in the study was provided by the EPAMIG North Accession Collection in Nova Porteirinha, MG. This accession comes from the municipality of Lontra, MG, Gangorra Community, at coordinates 15°48'27.23"S Latitude and 44°18'27.21"W Longitude, at altitude of 692 m, and corresponds to the same accession BGU-68 identified by Santos, Nascimento and Oliveira (1999), registered in the Umbu Germplasm Bank of EMBRAPA. The fruits have a high value of fruit mass and are popularly called 'umbu Gigante' (giant umbu, in Portuguese), as well as the accession BGU-75, from the municipality of Macaúbas, BA.

The planting of grafted seedlings, provided by Embrapa Cassava and Tropical Fruits and the Agricultural Research Company of Minas Gerais - EPAMIG North, was carried out on October 5 and

December 5, 2007, respectively, at the quincunx spacing of 8 x 8 x 8 m. The seedlings were planted in soil classified as *Latosolo Vermelho-Amarelo* (Oxisol), with typic, weak A horizon and medium texture, and the chemical characterization for each accession is described in Table 1. The pits were opened with diameter of 50 cm and depth of 60 cm,

using a soil auger. Basal fertilization was carried out with 500 g of single superphosphate, which supplies 90 g of P<sub>2</sub>O<sub>5</sub>, and 20 L of bovine manure. Top-dressing fertilization, weed control, pruning to open the crown, removal of unwanted plants around the stem were performed according to Donato et al. (2019b).

**Table 1.** Chemical attributes of the soil for the evaluated accessions.

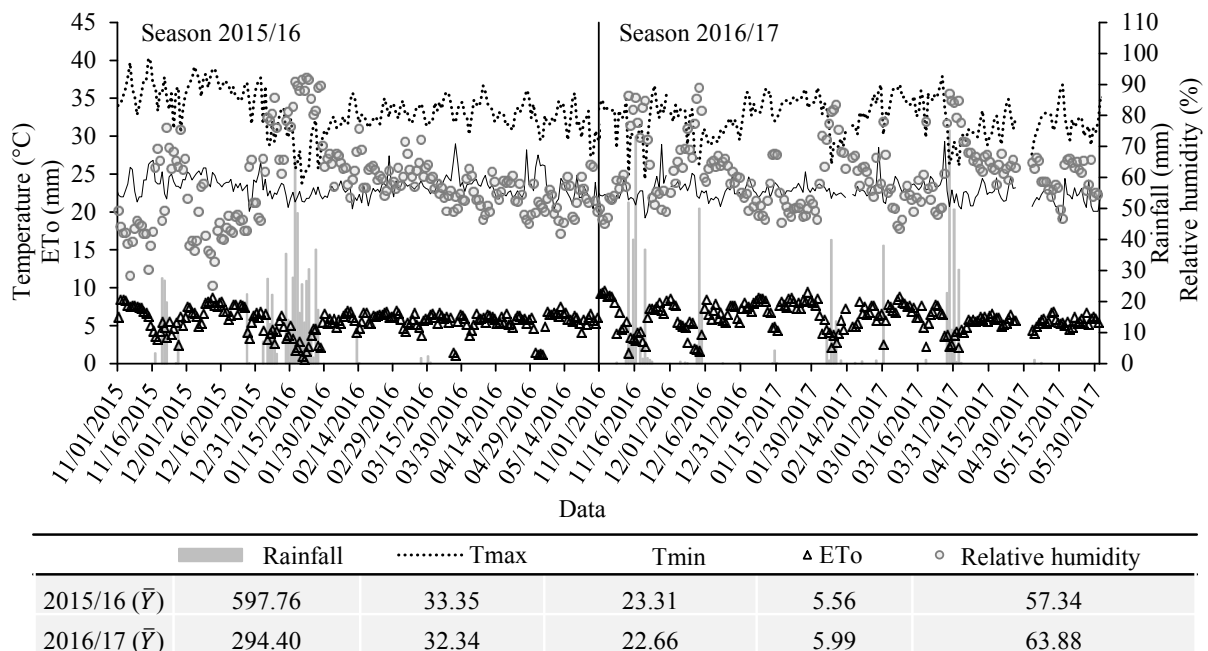
Attributes	EPAMIG-01	EPAMIG-05	Princesa	BGU-75	BGU-47	BGU-48	BGU-50	BGU-45	BGU-44	Unknown	EPAMIG-07	EPAMIG-09	EPAMIG-13	EPAMIG-06	EPAMIG-04	EPAMIG-03
pH	7.2	7.3	7.3	7.1	7.2	7.0	7.3	7.3	7.1	6.8	7.2	7.0	7.5	7.7	7.4	7.3
SOM (dag kg <sup>-1</sup> )	1.7	1.3	1.2	1.1	1.7	1.2	1.2	1.3	1.4	1.3	1.8	1.2	1.7	2.5	1.8	1.5
P (mg dm <sup>-3</sup> )	42.2	35.6	43.4	41.8	50.5	68.8	67.8	75.4	80.7	36.0	34.8	51.9	94.5	120.7	69.8	28.4
K <sup>+</sup> (mg dm <sup>-3</sup> )	196	207	200	200	291	198	226	268	222	194	177	199	255	269	218	198
Ca <sup>2+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	3.4	3.3	3.3	3.4	3.6	2.9	3.3	3.2	2.8	2.9	3.2	2.9	3.9	3.8	3.3	3.7
Mg <sup>2+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	1.1	1.0	0.9	1.2	1.2	1.0	1.1	1.1	1.1	0.9	0.9	0.9	1.1	1.1	1.1	1.0
Al <sup>3+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H+Al (cmol <sub>c</sub> dm <sup>-3</sup> )	1.2	1.0	1.0	1.1	1.0	1.1	1.1	1.2	1.0	1.5	1.1	1.0	1.0	1.0	1.0	1.1
SB (cmol <sub>c</sub> dm <sup>-3</sup> )	5.0	5.0	4.9	5.1	5.6	4.6	5.1	5.1	4.6	4.4	4.6	4.4	5.7	5.7	5.0	5.3
t (cmol <sub>c</sub> dm <sup>-3</sup> )	5.0	5.0	4.9	5.1	5.6	4.6	5.1	5.1	4.6	4.4	4.6	4.4	5.7	5.7	5.0	5.3
T (cmol <sub>c</sub> dm <sup>-3</sup> )	6.2	6.1	5.9	6.3	6.7	5.7	6.1	6.3	5.6	5.9	5.7	5.5	6.8	6.7	6.0	6.5
V (%)	81.3	83.0	82.7	81.7	84.0	80.3	81.3	81.3	81.3	74.7	80.0	81.0	84.7	84.7	83.3	82.7
B <sup>3-</sup> (mg dm <sup>-3</sup> )	0.4	0.4	0.4	0.7	0.4	0.4	0.5	0.5	0.4	0.4	0.3	0.5	0.5	0.4	0.3	0.3
Cu <sup>2+</sup> (mg dm <sup>-3</sup> )	0.6	0.6	0.5	0.6	0.4	0.4	1.8	1.1	0.6	0.4	0.4	0.5	0.7	1.6	0.6	0.3
Fe <sup>2+</sup> (mg dm <sup>-3</sup> )	23.4	16.7	16.6	45.0	19.4	22.6	34.0	39.8	49.6	21.1	23.4	29.4	39.4	53.6	21.7	24.9
Mn <sup>2+</sup> (mg dm <sup>-3</sup> )	70.2	77.8	75.2	58.9	86.8	67.6	57.1	64.9	78.4	85.9	92.8	72.4	80.1	87.0	87.5	95.1
Zn <sup>2+</sup> (mg dm <sup>-3</sup> )	3.2	3.1	2.7	2.9	3.6	4.2	7.1	3.9	4.3	4.3	5.4	4.1	3.2	-	-	-
P <sub>rem</sub> (mg L <sup>-1</sup> )	40.5	41.3	41.9	41.8	41.7	42.1	42.7	42.5	41.9	38.9	41.0	42.4	43.9	42.7	41.8	38.1
EC (dS m <sup>-1</sup> )	0.7	1.0	1.4	1.4	1.6	1.4	0.8	0.8	1.1	1.0	0.7	1.0	0.8	0.9	0.9	0.8

Note: pH in water; Soil organic matter (SOM)/Colorimetry; P, K<sup>+</sup>, Na<sup>+</sup>, Cu<sup>2+</sup>, Fe<sup>2+</sup>, Mn<sup>2+</sup>, Zn<sup>2+</sup>/Extractant: Mehlich-1; Ca<sup>2+</sup>, Mg<sup>2+</sup>, Al<sup>3+</sup>/Extractant: 1 mol/L KCl; H+Al/pH SMP; B<sup>3-</sup>/Extractant: CaCl<sub>2</sub>; P<sub>rem</sub>/P equilibrium solution; SB, Sum of bases; t, effective CEC; T, CEC at pH 7; V, Base saturation; m, Aluminum saturation; P-rem, Remaining phosphorus; EC, Electrical conductivity.

The first top-dressing fertilization, in February 2008, consisted of the application of 100 g of ammonia sulfate, which provides 20 g of N, and 20 L of bovine manure per plant. In November 2008, the second top-dressing fertilization was carried out with 500 g of 04-14-08 (NPK) and 36 L of bovine manure per plant. The third top-dressing fertilization occurred in March 2009, with 100 g of urea, 50 g of potassium chloride and 36 L of bovine manure. At the beginning of the rainy season, in October 2009, the area was fertilized with one bag of bovine manure, 300 g of MAP and 50 g of urea per plant. In March 2010, the plants were fertilized with 200 g of 14-07-28 (NPK) and 100 g of urea for each tree. In the rainy season of October 2010, plants were fertilized with 300 g of MAP, 70 g of urea, 70 g of potassium chloride and 36 L of bovine manure per plant. Subsequently, in March 2011, fertilization was carried out with 36 L of sheep manure per plant. In December 2011, 800 g of single superphosphate, 50 g of urea, 100 g of potassium chloride and 36 L of

bovine manure were applied per plant. In January 2013, fertilization was performed with 1 kg of single superphosphate, 150 g of potassium chloride, 100 g of urea and 72 L of bovine manure per plant. In March 2014, the trees were fertilized with 200 g of MAP, 100 g of potassium chloride and 60 L of bovine manure mixed with grass. In May 2015, 36 L of bovine manure were applied per plant. After this period, a new fertilization was carried out with 500 g of 04-30-10 (NPK) and 36 L of bovine manure for each plant only in February 2017.

The values of maximum and minimum temperatures, relative humidity, rainfall and evapotranspiration along the experimental periods are shown in Figure 1. Rainfall occurred in the months of November/2015 to February/2016 (597.76 mm), supporting the flowering of the 2015/2016 season, and from November 2016 to May 2017 (294.40 mm), which influenced fruit growth in the 2016/2017 season.



Source: Meteorological data: Federal Institute of Education, Science and Technology of Bahia - Automatic Meteorological Station - Guanambi *Campus*.

**Figure 1.** Maximum temperature (Tmax), minimum temperature (Tmin), relative humidity, rainfall and evapotranspiration (ETo) with respective mean values referring to the 2015/16 and 2016/17 seasons.

The treatments consisted of 15 umbu accessions (BGU-44, BGU-45, BGU-47, BGU-48, BGU-50, BGU-75, EPAMIG-01, EPAMIG-03, EPAMIG-04, EPAMIG-05, EPAMIG-06, EPAMIG-07, EPAMIG-09, EPAMIG-13, umbu of unknown origin) and one umbu-caja accession (Princesa). A completely randomized experimental design with three replicates was used, consisting of one plant each. The arrangement was in split-plot-in-time: 16 x 2 x 2 for nutrient contents in leaves (accessions x cycle x phase).

The evaluations were carried out in the 2015/16 and 2016/17 seasons, i.e., in plants at eight and nine years after planting. Sampling consisted in collecting leaves, without petiole, in four quadrants of the crown. Twenty units of the second or third leaflet of the developed leaf were collected from each plant. The collection period occurred at two distinct phenological stages: phase I, period of complete formation of the crown (leaf flushing), occurred on December 18, 2015 (cycle I) and December 22, 2016 (cycle II); and phase II, period of color change of leaves from green to yellow and fall of leaves or senescence, sampled on April 14, 2016 (cycle I) and March 21, 2017 (cycle II). Cycle I was considered the 2015/2016 season and cycle II was considered the 2016/2017 season.

After field collection, samples of umbu and umbu-caja leaves were dried in a ventilation oven at 60 °C (Temperature accuracy:  $\pm 0.2$  °C) until they reached constant weight, and then sent to the Soil Laboratory of EPAMIG North, Nova Porteirinha, MG, and evaluated for the contents of the

macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), expressed in  $\text{g kg}^{-1}$ , and boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and sodium (Na), expressed in  $\text{mg kg}^{-1}$ . The analytical determinations were performed according to Malavolta, Vitti and Oliveira (1989): N, sulfuric digestion with the Kjeldahl method; P, K, S, Ca, Mg, Cu, Fe, Mn, Zn and Na, nitric-perchloric digestion and B, dry digestion.

The retranslocation rate or magnitude of biochemical cycling of nutrients in umbu and umbu-caja leaves was estimated for the nutrients of high mobility in the plant, namely N, P, K and Mg. Therefore, Ca was used as a marker and the rates were estimated using Equation 1, adapted by Chuyong, Newbery and Songwe (2000).

$$\% \text{Re Nut} = 1 - \frac{\left[ \frac{\text{Mobile nut. (senescent leaves)}}{\text{Ca (senescent leaves)}} \right]}{\left[ \frac{\text{Mobile nut. (young leaves)}}{\text{Ca (young leaves)}} \right]} \times 100 \quad (1)$$

Where:

%ReNut = percentage of the retranslocated nutrient.

Mobile Nut. (senescent leaves)/Ca(senescent leaves) = relationship between the contents of mobile nutrients and Ca content in senescent leaves;

Mobile Nut. (young leaves)/Ca(young leaves) = relationship between the contents of mobile nutrients and Ca content in young leaves.

The data of leaf contents of nutrients were subjected to analysis of variance, and the means of the cycle and phase factors were compared by F test ( $P \leq 0.05$ ), while those referring to the accessions and significant interactions were grouped by the Scott-Knott criterion ( $P \leq 0.05$ ).

## RESULTS AND DISCUSSION

The contents of N, P, S and Ca in the leaves of umbu and umbu-caja were affected by the interaction between the factors accessions, cycles and evaluation phases. The K and Mg contents were affected by the interactions between accessions and cycles and between accessions and phases (Table 2). The leaf contents of N in the cycles varied between accessions, with formation of two groups by the Scott-Knott criterion. In the 2015/16 cycle, the accessions EPAMIG-01, EPAMIG-04, EPAMIG-06, EPAMIG-09, EPAMIG-13, BGU-44, BGU-48 and BGU-50 showed higher N content in leaf flushing. The accessions 06, EPAMIG-09, EPAMIG-13, BGU-44, BGU-48 and BGU-50 had higher N content in the leaf flushing of the 2016/17 cycle.

Nitrogen contents for the accessions EPAMIG-07 and umbu of unknown origin as well as boron contents for EPAMIG-01, BGU-48, BGU-50, EPAMIG-07, EPAMIG-09, EPAMIG-06, Princesa umbu-caja and umbu of unknown origin were not determined because the number of 20 sampled units was not sufficient to perform leaf analysis. The number of leaflet units was pre-established in this study since there is no reference for sampling aimed at complete nutrient analysis in umbu and umbu-caja.

In general, higher leaf N contents were observed in the leaf flushing phase of the 2015/2016 season. The accessions BGU-45 and Princesa umbu-caja in the 2015/2016 cycle and the accessions EPAMIG-01, EPAMIG-06 and Princesa umbu-caja in the 2016/2017 cycle maintained constant leaf N contents between leaf flushing and senescence, while the other accessions reduced their N contents in the senescent phase. The accessions, evaluated in two production cycles and in two evaluation phases, had average N contents of  $28.6 \text{ g kg}^{-1}$ , consistent with the chemical composition of leaves of adult umbu plants, which have an average N content of  $29.0 \text{ g kg}^{-1}$  (MEDEIROS; SANTOS; TERTULIANO, 2008), and with another species of *Spondias* (ISAH; OMOROGIUA; OKUNADE, 2013).

The leaf contents of P differed between accessions, only in the leaf flushing phase of the

2015/2016 season, forming four groups. In addition, the highest P contents were observed, in general, in the leaf flushing phase of the 2015/2016 season. The accessions showed a reduction in P contents in the senescent leaves of the two evaluated seasons, except for EPAMIG-01, EPAMIG-05, BGU-44, BGU-47, BGU-48 and Princesa umbu-caja, in the 2016/2017 season. The average P content among the accessions, for the two production cycles and the two evaluation phases, was  $2.0 \text{ g kg}^{-1}$ .

Leaf contents of S varied between accessions in the leaf flushing phase of the 2015/16 season, with three groups being formed. In general, the accessions had higher S contents in the leaf flushing phase compared to the senescence, verified in the 2015/2016 season. In the 2016/17 season, the S contents varied in two groups between accessions in the senescence phase. The contents remained constant between leaf flushing and senescence, except for the accessions BGU-47 and EPAMIG-09, which reduced their S contents in the senescence, in the 2016/17 cycle. The accessions were characterized by average S content of  $2.5 \text{ g kg}^{-1}$ , in the two production cycles and in the two evaluation phases. These contents were close to those reported by Medeiros, Santos and Tertuliano (2008), who observed  $2.4 \text{ g kg}^{-1}$  in leaves of adult umbu tree.

S participates in the structure of proteins, being necessary to reduce sulfate (VITTI et al., 2018). According to the authors, during leaf expansion, the evolution of sulfate reduction is maximum, but decreases dramatically after leaf maturity, which could be one of the justifications for the reduction in the S contents of senescent leaves in the 2015/2016 season. The constant S content in the phases of leaf flushing and senescence in the 2016/2017 season can be explained by the low mobility of this nutrient in the plant, which reduces the influence of the sink on its translocation. Considering that sulfate is transported mainly in the root-leaf direction, the plant has little capacity to translocate sulfur via phloem in the leaf-root direction (MARSCHNER, 2012).

Another hypothesis for the higher contents of nutrients, including S, in the leaf flushing phase of the 2015/2016 season, and subsequent reduction, would be climate interference. In 2015, the low levels of rainfall (Figure 1) led to lower nutrient storage in the xylopodia, due to lower root absorption. The following rains must have enabled more efficient absorption of the nutrients available in the soil, which resulted in an initial accumulation in young leaves and then dilution of the nutrient concentration, later observed in the senescent leaves.

**Table 2.** Leaf contents of nitrogen (N), phosphorus (P), sulfur (S), calcium (Ca), potassium (K) and magnesium (Mg) of fifteen accessions of umbu and one of umbu-caja in the phases of leaf flushing (phase I) and senescence (phase II) in two production cycles represented by the seasons of 2015/16 (cycle I) and 2016/17 (cycle II).

Accessions	-----N (g kg <sup>-1</sup> )-----				-----P (g kg <sup>-1</sup> )-----			
	Cycle I		Cycle II		Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	35.9 Aa	26.3 Bb	27.5 Ba	24.7 Aa	3.0 Ca	1.4 Ab	1.6 Aa	1.4 Aa
EPAMIG-05	30.9 Ba	27.2 Bb	26.5 Ba	23.7 Ab	2.4 Da	1.4 Ab	1.5 Aa	1.3 Aa
BGU-75	30.7 Ba	24.1 Bb	27.4 Ba	22.5 Bb	3.2 Ca	1.4 Ab	1.8 Aa	1.1 Ab
BGU-47	33.1 Ba	27.7 Bb	25.7 Ba	19.8 Bb	3.3 Ca	1.4 Ab	1.6 Aa	1.1 Aa
BGU-48	38.7 Aa	26.8 Bb	28.9 Aa	25.7 Ab	3.8 Ba	1.3 Ab	1.8 Aa	1.4 Aa
BGU-50	39.4 Aa	26.5 Bb	33.1 Aa	24.8 Ab	4.4 Aa	1.5 Ab	1.8 Aa	1.2 Ab
BGU-45	33.1 Ba	33.1 Aa	26.9 Ba	19.9 Bb	3.1 Ca	1.3 Ab	1.6 Aa	1.0 Ab
BGU-44	39.1 Aa	26.7 Bb	30.6 Aa	26.4 Ab	4.1 Ba	1.5 Ab	1.8 Aa	1.2 Aa
EPAMIG-07	-	-	-	-	3.0 Ca	1.5 Ab	1.8 Aa	1.1 Ab
EPAMIG-09	35.1 Aa	28.1 Bb	32.6 Aa	23.6 Ab	4.5 Aa	1.6 Ab	2.1 Aa	1.3 Ab
EPAMIG-13	34.7 Aa	27.0 Bb	30.6 Aa	22.4 Bb	3.4 Ca	1.6 Ab	1.9 Aa	1.2 Ab
EPAMIG-06	36.4 Aa	25.9 Bb	29.7 Aa	27.3 Aa	3.9 Ba	1.4 Ab	2.0 Aa	1.3 Ab
EPAMIG-04	36.2 Aa	30.3 Ab	31.1 Aa	20.9 Bb	3.4 Ca	1.5 Ab	1.9 Aa	1.0 Ab
EPAMIG-03	32.7 Ba	26.8 Bb	27.2 Ba	22.2 Bb	2.4 Da	1.3 Ab	1.6 Aa	1.1 Ab
Princesa	28.9 Ba	29.0 Aa	23.5 Ba	24.8 Aa	3.4 Ca	1.7 Ab	1.8 Aa	1.7 Aa
Unknown	-	-	-	-	3.9 Ba	1.6 Ab	1.9 Aa	1.3 Ab
Mean		28.6				2.0		
CV (%)		9.90				16.61		
Accessions	-----S (g kg <sup>-1</sup> )-----				-----Ca (g kg <sup>-1</sup> )-----			
	Cycle I		Cycle II		Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	2.2 Ca	2.0 Ba	2.7 Aa	2.2 Aa	8.1 Bb	33.2 Ba	20.2 Cb	40.0 Ca
EPAMIG-05	2.7 Ba	2.5 Aa	2.7 Aa	2.5 Aa	15.1 Ab	38.8 Aa	25.5 Bb	42.1 Ca
BGU-75	3.3 Aa	2.0 Bb	2.6 Aa	2.2 Aa	10.9 Bb	42.6 Aa	26.5 Bb	54.2 Aa
BGU-47	4.1 Aa	2.2 Ab	2.6 Aa	1.7 Bb	17.1 Ab	45.0 Aa	36.0 Ab	57.2 Aa
BGU-48	3.6 Aa	1.8 Bb	2.6 Aa	2.4 Aa	7.6 Bb	43.7 Aa	20.2 Cb	40.6 Ca
BGU-50	3.5 Aa	1.9 Bb	2.7 Aa	2.4 Aa	9.4 Bb	31.6 Ba	22.1 Cb	46.9 Ba
BGU-45	3.3 Aa	2.3 Ab	2.8 Aa	2.5 Aa	10.1 Bb	33.0 Ba	23.9 Bb	51.5 Ba
BGU-44	3.8 Aa	2.1 Ab	2.5 Aa	2.1 Aa	6.8 Bb	34.2 Ba	20.9 Cb	34.0 Da
EPAMIG-07	1.9 Ca	2.1 Aa	2.3 Aa	1.8 Ba	11.2 Bb	35.1 Ba	25.7 Bb	37.5 Da
EPAMIG-09	3.5 Aa	2.1 Ab	2.7 Aa	2.0 Ab	8.9 Bb	35.3 Ba	20.4 Cb	35.2 Da
EPAMIG-13	3.6 Aa	1.9 Bb	2.3 Aa	1.9 Ba	12.0 Ab	26.6 Ba	23.5 Bb	43.3 Ca
EPAMIG-06	2.9 Ba	2.0 Bb	2.5 Aa	2.2 Aa	6.5 Bb	38.1 Aa	24.3 Bb	38.0 Da
EPAMIG-04	2.8 Ba	2.1 Ab	2.3 Aa	1.9 Ba	5.6 Bb	31.6 Ba	17.6 Cb	37.5 Da
EPAMIG-03	2.7 Ba	1.8 Bb	2.6 Aa	2.2 Aa	13.2 Ab	33.7 Ba	20.9 Bb	32.9 Da
Princesa	3.0 Ba	2.4 Ab	2.1 Aa	2.3 Aa	17.7 Ab	33.6 Ba	19.9 Cb	35.4 Da
Unknown	3.1 Ba	2.0 Bb	2.4 Aa	2.1 Aa	7.8 Bb	35.9 Ba	21.1 Bb	33.6 Da
Mean		2.5				27.6		
CV (%)		13.15				15.69		
Accessions	-----K (g kg <sup>-1</sup> )-----				-----Mg (g kg <sup>-1</sup> )-----			
	Cycle I		Cycle II		Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	13.2 Aa	8.1 Ab	12.9 Aa	8.3 Ab	3.4 Ba	4.1 Ba	3.8 Ca	3.8 Ba
EPAMIG-05	11.1 Ba	8.1 Ab	10.2 Ba	9.0 Aa	4.0 Ba	3.8 Ba	4.2 Ca	3.6 Ba
BGU-75	12.4 Aa	5.3 Bb	11.2 Aa	6.4 Ab	3.3 Ba	4.0 Ba	3.6 Ca	3.6 Ba
BGU-47	10.8 Ba	5.2 Bb	9.5 Ba	6.6 Ab	6.1 Aa	5.9 Aa	6.8 Aa	5.2 Ab
BGU-48	13.7 Aa	5.7 Bb	11.6 Aa	7.8 Ab	3.2 Bb	4.3 Ba	3.7 Ca	3.8 Ba
BGU-50	14.8 Aa	5.7 Bb	13.3 Aa	7.1 Ab	3.4 Ba	3.9 Ba	3.2 Ca	4.1 Ba
BGU-45	12.7 Aa	5.0 Bb	11.3 Aa	6.5 Ab	3.3 Ba	4.0 Ba	3.4 Ca	3.8 Ba
BGU-44	13.7 Aa	6.3 Bb	12.0 Aa	7.8 Ab	3.3 Bb	4.8 Ba	3.5 Cb	4.6 Aa
EPAMIG-07	12.9 Aa	6.5 Bb	11.5 Aa	7.9 Ab	4.0 Bb	6.2 Aa	4.6 Ca	5.5 Aa
EPAMIG-09	14.0 Aa	5.5 Bb	12.0 Aa	7.5 Ab	3.3 Bb	4.7 Ba	3.5 Cb	4.5 Aa
EPAMIG-13	12.6 Aa	6.0 Bb	11.5 Aa	7.2 Ab	4.0 Ba	4.2 Ba	3.7 Ca	4.4 Ba
EPAMIG-06	13.7 Aa	7.1 Ab	12.1 Aa	8.7 Ab	3.5 Bb	4.7 Ba	3.6 Ca	4.5 Aa
EPAMIG-04	13.5 Aa	7.9 Ab	12.4 Aa	9.0 Ab	3.0 Bb	4.1 Ba	3.1 Ca	3.9 Ba
EPAMIG-03	10.8 Ba	6.4 Bb	9.7 Ba	7.4 Ab	4.1 Bb	5.3 Ba	4.4 Ca	5.0 Aa
Princesa	11.7 Ba	6.4 Bb	10.2 Ba	7.9 Ab	5.4 Aa	4.6 Ba	5.6 Ba	4.4 Bb
Unknown	12.4 Aa	5.6 Bb	10.7 Ba	7.3 Ab	3.6 Bb	5.8 Aa	4.0 Cb	5.4 Aa
Mean		9.5				4.20		
CV (%)		16.7				21.8		

Nitrogen contents not presented (-) were not determined because the number of 20 sampled units was not sufficient to perform leaf analysis. Means followed by equal uppercase letters in columns, for accessions, belong to the same grouping by the Scott-Knott criterion ( $P \leq 0.05$ ). Means followed by equal lowercase letters in rows, for phases in the same cycle, do not differ by the F test ( $P \leq 0.05$ ). CV = coefficient of variation.

The leaf contents of Ca in the cycles and phases varied between accessions, with the formation of at least two and at most four groups by the Scott-Knott criterion. The accessions had lower Ca contents in the leaf flushing phase in both seasons. Ca accumulation was observed in the senescent leaves. It is understood that part of the Ca from cell walls is degraded with the processes that occur in the leaf senescence, while another residual part remains in the cell wall. As Ca is little mobile in the plant, once in the tissue, it is no longer remobilized to another part of the plant (LIMA et al., 2018). Then, its biogeochemical recycling returns the nutrient from the phytomass to the environment. The accessions had an average Ca content of 27.6 g kg<sup>-1</sup>, for the two production cycles and the two evaluation phases, which is consistent with values close to 30 g kg<sup>-1</sup> found in an adult native umbu tree (MEDEIROS; SANTOS; TERTULIANO, 2008).

The leaf contents of K and Mg varied in the cycles between accessions, with the formation of at least two and at most four groups, except for K in the 2016/2017 season, which did not form a group by the Scott-Knott criterion. The accessions had higher K contents in the 2015/2016 season. For the two production cycles evaluated, accessions with an average K content of 9.5 g kg<sup>-1</sup> were observed, which corroborates the characteristics of the leaf contents described for the crop (MEDEIROS; SANTOS; TERTULIANO, 2008). The highest K contents observed in the 2015/2016 season may be related to fertilizations performed until 2015. The

absence of fertilization in the experimental area in 2016 led to lower K contents in the 2016/2017 season.

For most accessions, there was no significant difference between Mg contents in 2015/2016 and 2016/2017. The accessions had an average Mg content of 4.20 g kg<sup>-1</sup> regardless of the season. In both production seasons and between phases, it was verified that the accession BGU-47 had the highest Mg contents. The function of Mg is involved in pH regulation and enzyme activation in the energy metabolism. The element is quite mobile in the phloem, being remobilized from the older leaves to the new ones or to the growth points (LIMA et al., 2018). However, higher Mg contents were observed in the senescent leaves. Also according to these authors, in most plants, the Mg contents in the young parts are higher than in the old parts, although the reverse may also occur.

It was observed that the accessions BGU-48 and EPAMIG-06 had higher percentage values of nutrient retranslocation rate for N compared to the other accessions in cycle I and lower percentage in Princesa umbu-caja (Table 3). The accession EPAMIG-04 had higher efficiency in the biochemical cycling of N in cycle II and Princesa umbu-caja had lower efficiency. Higher efficiency in the biochemical cycling of a nutrient by a given accession may mean greater nutritional saving, because the deposition of senescent leaves influences soil fertility at first and plant development in the long term (VARGAS et al., 2018).

**Table 3.** Retranslocation rate (RR) or magnitude of biochemical cycling of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) in fifteen accessions of umbu and one of umbu-caja.

Accessions	RR – N (%)		RR – P (%)		RR – K (%)		RR – Mg (%)	
	Cycle I	Cycle II	Cycle I	Cycle II	Cycle I	Cycle II	Cycle I	Cycle II
EPAMIG-01	82.13	54.64	88.61	55.81	88.71	53.55	70.98	38.71
EPAMIG-05	65.74	45.83	77.30	47.51	81.61	30.26	65.69	36.03
BGU-75	79.91	59.85	88.81	70.12	91.34	70.05	72.71	32.71
BGU-47	68.20	51.51	83.88	56.73	86.18	56.35	64.69	35.84
BGU-48	87.96	55.76	94.05	61.30	94.41	69.94	76.38	34.82
BGU-50	79.99	64.69	89.86	68.59	91.47	70.95	70.56	40.57
BGU-45	69.39	65.67	87.17	71.00	90.10	74.59	68.49	35.41
BGU-44	86.42	46.97	92.73	59.02	92.11	64.61	76.84	-2.74
EPAMIG-07	-	-	84.05	58.12	87.80	50.16	53.54	-12.05
EPAMIG-09	79.82	58.05	91.04	64.12	92.21	67.70	71.73	-0.34
EPAMIG-13	64.90	60.27	78.77	65.72	83.02	63.33	65.81	25.56
EPAMIG-06	87.86	41.22	93.88	58.43	93.49	50.69	78.76	6.93
EPAMIG-04	85.17	68.46	92.18	75.30	92.02	61.41	80.31	23.34
EPAMIG-03	67.90	48.15	78.78	56.33	78.65	57.88	59.94	-2.96
Princesa	47.14	40.68	73.66	46.91	79.78	53.74	59.12	46.28
Unknown	-	-	91.09	57.03	91.92	63.18	64.96	0.12

Nitrogen contents not presented (-) were not determined because the number of 20 sampled units was not sufficient to perform leaf analysis.

Although N is considered of high mobility (SOUZA; FERNANDES, 2018), for deciduous plants such as umbu, the source-sink ratio and the remobilization have lower cycling efficiency. N is probably poorly remobilized from the senescent leaves to the main sink after the fruits, leaves and branches. Soon after the beginning of leaf senescence and beginning of dormancy of the branches, the xylopodium becomes the main sink in the plant, so that possibly the phytomass of fallen leaves on the soil surface contributes to N cycling in the soil-plant relationship.

The accessions had a lower N and P retranslocation rate percentage in cycle II compared to the percentage of the accessions in cycle I. This may be a consequence of the lower leaf contents in the leaf flushing phase of cycle II. It was verified that the accession BGU-48 had higher efficiency of biochemical cycling of P and the accession of umbu-caja had lower efficiency in cycle I. In cycle II, the accession EPAMIG-04 obtained higher P retranslocation P rate and Princesa umbu-caja obtained lower rate. The lower retranslocation of N and P in the two seasons by the Princesa umbu-caja compared to the umbu accessions is justified by its lower degree and speed of senescence (DONATO et al., 2019a).

In plants with P deficiency, the supplement is mobilized from the senescent leaves to the young ones and to the roots, because this nutrient has high mobility and the distribution pattern is apparently related to the source-sink ratio, and its movement is determined by the demand of carbohydrate within the plant (MARSCHNER, 2012). In the case of umbu, which loses its leaves in the dry season, it can be considered that P is remobilized to the strongest sink of carbohydrates in the leaf senescence period, the xylopodia, for storage, and that will support the production of new leaves and flowering, in the subsequent season.

The accessions BGU-50 and BGU-45 had higher K retranslocation rate and the accession EPAMIG-05 showed lower rate. The accession BGU-50 also had a higher percentage of Mg retranslocation, while EPAMIG-07 showed a lower percentage. The genetic characteristic of the accession is one of the main factors for higher efficiency of biochemical recycling, enabling these accessions of higher percentage in the nutrient retranslocation rate to be possibly more efficient and less demanding in terms of nutritional supply and an option for cultivation under poorer soil conditions or aiming at reduction of costs in fertilization.

The accessions had higher leaf K contents in the leaf flushing phase. This can be justified by the need for supply from the phloem to the young leaves, meristematic tissues and fresh fruits

(MARSCHNER, 2012). On the other hand, it should also be considered, in senescence, that there is a reduction in the K content in the leaves, when there is no or reduced requirement for young leaves, fruits and/or growth of branches, and K is easily translocated between cells and tissues (MARSCHNER, 2012). Possibly, K should be transported to the xylopodia, understood as a sink, due to the adaptive need of umbu and umbu-caja to store nutrients and water in the tuberous roots, for the supply that will be used in flowering, in the next season. In addition to the biogeochemical cycling of K with the allocation from leaf tissues to xylopodium, the influence of this cycling was also verified, with loss of the nutrient from the leaves by leaching from the end of 2016 to January 2017, by the precipitations shown in Figure 1.

K is a nutrient of high mobility, with an important function in osmotic control, in favoring of the transport and storage of carbohydrates, and in the participation in starch synthesis in the leaf (MEURER; TIECHER; MATTIELLO, 2018). In addition, when the soil provides adequate amount of K for the plant, it affects the starch contents in fruits and xylopodia, color and aroma of the fruit, vitamin C content, and contents of soluble solids can be increased.

The higher translocation rate observed in the year of greater stress by drought and heat, 2015 (Figure 1), accelerates senescence, contributes to increasing the nutritional and photosynthetic efficiency of the plant (TAIZ et al., 2017), and ensures the accumulation of reserves of nutrients and photoassimilates for the subsequent season. Nutrients such as K and Mg play an essential role in the loading and transport of sugars via phloem. The speed of transport of carbon from leaves to other organs depends on the adequate supply of these nutrients (CAKMAK; KIRKBY, 2008; CAKMAK, 2013). This capacity for storing carbohydrates in reserve organs, such as the tubers, and subsequent translocation contribute significantly to the stability of high yield under stress conditions.

Leaf contents of B formed from two to three groups for accessions in the evaluated phases and cycles (Table 4). Only the leaf flushing of the 2015/2016 season did not form distinct groups. In general, there was accumulation of B content in the senescent leaves of the 2015/2016 season, while in the 2016/2017 season, the young leaves had high values of B, which stabilized in the senescence, except for the accessions EPAMIG-05 and BGU-44, which increased B contents in the senescence. The accessions had, in both production cycles and evaluation phases, an average B content of 86.22 mg kg<sup>-1</sup>.



**Table 4.** Leaf contents of boron (B), copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) of fifteen accessions of umbu and one of umbu-caja in two sampling phases, leaf flushing (I) and leaf senescence (II) in two production cycles, 2015-2016 (I) and 2016-2017 (II).

Accessions	B (mg kg <sup>-1</sup> )				Cu (mg kg <sup>-1</sup> )			
	Cycle I		Cycle II		Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	-	-	-	-	5.4 Aa	2.6 Ab	4.2 Aa	4.7 Aa
EPAMIG-05	41.4 Ab	70.7 Ca	65.9 Bb	85.9 Ba	4.6 Aa	1.6 Ab	2.7 Ba	2.1 Ba
BGU-75	50.0 Ab	117.5 Aa	97.5 Aa	97.4 Ba	5.7 Aa	2.2 Ab	3.1 Ba	4.0 Aa
BGU-47	-	-	-	-	4.9 Aa	3.1 Aa	3.2 Aa	1.3 Bb
BGU48	-	-	-	-	5.6 Aa	1.8 Ab	2.1 Ba	3.0 Ba
BGU-50	-	-	-	-	5.7 Aa	4.2 Aa	5.0 Aa	2.7 Bb
BGU-45	51.7 Ab	108.2 Ba	107.5 Aa	113.9 Aa	4.1 Ba	1.5 Ab	3.8 Aa	1.8 Bb
BGU-44	43.6 Ab	107.4 Ba	71.4 Bb	107.7 Aa	5.7 Aa	3.4 Ab	3.7 Aa	1.1 Bb
EPAMIG-07	-	-	-	-	5.2 Aa	2.8 Ab	3.1 Ba	0.8 Bb
EPAMIG-09	-	-	-	-	7.3 Aa	2.6 Ab	4.4 Aa	1.3 Bb
EPAMIG-13	61.5 Ab	127.1 Aa	117.5 Aa	117.8 Aa	5.0 Aa	2.7 Ab	3.1 Aa	0.6 Bb
EPAMIG-06	-	-	-	-	4.2 Ba	2.9 Aa	1.4 Bb	4.6 Aa
EPAMIG-04	49.0 Ab	96.1 Ba	93.5 Aa	99.8 Ba	5.0 Aa	0.9 Ab	2.0 Ab	5.4 Aa
EPAMIG-03	53.9 Ab	78.5 Ca	97.5 Aa	83.0 Ba	4.4 Ba	1.9 Ab	2.6 Bb	5.8 Aa
Princesa	-	-	-	-	4.9 Aa	3.7 Aa	2.8 Bb	5.3 Aa
Unknown	-	-	-	-	3.9 Ba	2.2 Ab	3.8 Aa	5.6 Aa
Mean		86.22				3.52		
CV (%)		13.11				37.50		

Accessions	Zn (mg kg <sup>-1</sup> )			
	Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	24.17 Ba	14.98 Bb	9.66 Ba	10.40 Ba
EPAMIG-05	17.89 Ba	17.11 Ba	11.88 Aa	10.81 Ba
BGU-75	21.16 Ba	21.67 Aa	13.30 Aa	6.49 Bb
BGU-47	23.51 Ba	12.41 Bb	13.46 Aa	10.50 Ba
BGU48	23.12 Ba	18.72 Aa	11.86 Ab	16.76 Aa
BGU-50	21.45 Ba	19.83 Aa	12.45 Aa	11.59 Ba
BGU-45	22.73 Ba	18.83 Aa	11.95 Aa	11.05 Ba
BGU-44	20.38 Ba	24.25 Aa	11.72 Aa	13.06 Ba
EPAMIG-07	21.27 Ba	14.55 Bb	13.74 Aa	13.06 Ba
EPAMIG-09	23.12 Ba	14.54 Bb	13.29 Aa	13.06 Ba
EPAMIG-13	23.21 Ba	16.15 Bb	12.95 Aa	9.47 Ba
EPAMIG-06	30.46 Aa	10.70 Bb	10.98 Ba	11.85 Ba
EPAMIG-04	31.91 Aa	18.83 Ab	13.06 Aa	10.13 Ba
EPAMIG-03	21.27 Ba	14.55 Bb	11.22 Aa	12.36 Ba
Princesa	18.42 Ba	15.4 Ba	11.83 Ab	20.56 Aa
Unknown	18.81 Ba	14.55 Ba	13.39 Aa	15.28 Aa
Mean		16.00		
CV (%)		18.99		

Accessions	----- Fe (mg kg <sup>-1</sup> ) -----		----- Mn (mg kg <sup>-1</sup> ) -----			
			Cycle I		Cycle II	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
EPAMIG-01	88.5 Ba	92.0 Ba	31.75 Ca	45.47 Da	25.1 Cb	52.1 Da
EPAMIG-05	128.7Aa	101.4 Ba	54.31 Ca	54.13 Ca	40.1 Cb	68.2 Ca
BGU-75	95.9 Aa	100.3 Ba	36.17 Ca	39.18 Da	32.9 Cb	76.6 Ca
BGU-47	102.4Aa	105.9 Ba	48.20 Ca	61.29 Ca	44.8 Cb	85.1 Ca
BGU-48	73.6 Bb	129.3 Aa	65.63 Ba	64.28 Ca	36.9 Cb	83.5 Ca
BGU-50	101.0Aa	111.7 Aa	54.64 Ca	65.89 Ca	36.8 Cb	62.2 Da
BGU-45	89.2 Ba	86.6 Ba	41.56 Ca	57.48 Ca	31.0 Ca	50.4 Da
BGU-44	96.4 Aa	115.9 Aa	34.76 Ca	46.73 Da	54.7 Bb	116.2 Ba
EPAMIG-07	127.9Aa	107.8 Aa	81.99 Ba	89.00 Ba	80.2 Ab	161.9 Aa
EPAMIG-09	83.1 Bb	126.9 Aa	67.89 Bb	97.96 Ba	36.0 Cb	88.9 Ca
EPAMIG-13	103.7Aa	122.2 Aa	104.73Ab	137.42Aa	23.3 Cb	89.5 Ca
EPAMIG-06	91.9 Ba	93.1 Ba	54.65 Ca	70.31 Ca	27.2 Ca	48.8 Da
EPAMIG-04	97.5 Aa	127.8 Aa	78.01 Ba	34.86 Db	33.3 Cb	83.6 Ca
EPAMIG-03	111.4Aa	124.3 Aa	39.44 Ca	36.63 Da	40.1 Cb	76.6 Ca
Princesa	76.8 Ba	91.6 Ba	58.96 Ca	57.96 Ca	27.2 Ca	48.1 Da
Unknown	91.1 Ba	118.4 Aa	52.89 Ca	63.91 Ca	49.8 Bb	116.0 Ba
Mean		103.6			60.2	
CV (%)		26.5			33.4	

Boron contents not presented (-) were not determined because the number of 20 sampled units was not sufficient to perform leaf analysis. Means followed by equal uppercase letters in columns, for accessions, belong to the same grouping by the Scott-Knott criterion ( $P \leq 0.05$ ). Means followed by equal lowercase letters in the rows, for phases in the same cycle, do not differ by the F test ( $P \leq 0.05$ ), CV = coefficient of variation.

Cu contents formed two groups between accessions, except for the leaf senescence phase of the 2015/2016 season, with one group. In turn, the leaf contents of Zn formed two groups between the accessions in the cycles and phases evaluated.

The accessions showed variations in Cu and Zn contents between phases and cycles evaluated. The Cu content decreased in the senescence of the 2015/2016 season, except for the accessions EPAMIG-06, BGU-47, BGU-50 and Princesa umbu-caja, which did not differentiate between phases. The accessions showed average Cu and Zn contents of 3.52 mg kg<sup>-1</sup> and 16 mg kg<sup>-1</sup>, respectively, considering two production cycles and two evaluation phases.

Cu is a constituent of oxidation-reduction enzymes and is part of other enzymes, such as polyphenol oxidase, which catalyzes phenolic compounds to ketones while forming cuticle lignin. This element is not considered readily mobile in the plant, but there are reports of Cu translocation from old leaves to young leaves. Conversely, Zn, which is considered highly or intermediately mobile in the plant, is present at higher concentrations in the root, plays the role of enzymatic cofactor, and regulates and stabilizes the protein structure (DECHEN et al., 2018).

There was a significant difference between Mn contents in 2015/2016 and 2016/2017. The accession EPAMIG-13 showed higher Mn contents in both cycles compared to the other accessions, with an average content of 60.20 mg kg<sup>-1</sup> regardless of the season.

The variation in Mn contents between accessions was higher, forming three and four groups, in the phases of leaf flushing and leaf

senescence, respectively. The accessions BGU-47, EPAMIG-07, Princesa umbu-caja and umbu of unknown origin stood out from the others in the evaluated phases. Half of the accessions had higher Mn contents in the leaf senescence phase, which was observed in BGU-48, BGU-44, EPAMIG-07, EPAMIG-09, EPAMIG-06, EPAMIG-04, EPAMIG-03 and umbu of unknown origin. For Fe, there was no difference between leaf flushing and leaf senescence. The Mn considered immobile, in some cases of low mobility, is fundamental for chlorophyll synthesis and plays the role of activation of enzymes (DECHEN et al., 2018).

The accessions showed, for the two collection phases, an average Fe content of 103.61 mg kg<sup>-1</sup>, which is consistent with the values described for umbu (MEDEIROS; SANTOS; TERTULIANO, 2008). Fe plays a role in the activation of enzymes, catalyzes chlorophyll formation, and is considered immobile in plant tissues (DECHEN et al., 2018). This explains its stability in leaf flushing and leaf senescence.

The leaf contents of K, Mg, Fe, Mn and Na varied between phases in the two cycles evaluated, forming two groups, except for the leaf contents of Mg and Fe, in cycle I, and Na, in the 2016/2017 season (Table 5). The highest leaf content of K was observed in the leaf flushing phase of the 2015/2016 season, regardless of accession. In the senescent leaves of the plants, the content of this nutrient was higher in 2016/2017. In turn, the average Fe content was lower in the leaf flushing phase of the 2016/2017 season. There was a lower Mn content in the leaf flushing phase in 2015/2016. The highest leaf content of Na was observed in the leaf flushing phase in 2015/2016, equal to 130.9 00 mg kg<sup>-1</sup>.

**Table 5.** Average leaf contents of potassium (K), magnesium (Mg), iron (Fe), manganese (Mn) and sodium (Na) in phases of leaf flushing (I) and leaf senescence (II) in two production cycles, 2015-2016 (I) and 2016-2017 (II).

Phases	K (g kg <sup>-1</sup> )		Mg (g kg <sup>-1</sup> )		Fe (mg kg <sup>-1</sup> )		Mn (mg kg <sup>-1</sup> )		Na (mg kg <sup>-1</sup> )	
	Cycle I	Cycle II	Cycle I	Cycle II	Cycle I	Cycle II	Cycle I	Cycle II	Cycle I	Cycle II
I	16.5 Aa	9.0Ab	3.9 Aa	3.7 Ba	112.4 Aa	82.5 Bb	28.9 Bb	48.5 Ba	130.9Aa	56.1 Ab
II	6.3 Ba	6.3 Ba	4.2 Ab	5.1 Aa	108.1 Aa	111.4 Aa	84.2 Aa	79.2 Aa	48.8 Ba	92.6 Aa
Mean	9.5		4.2		103.6		60.2		82.1	
CV (%)	16.7		21.8		26.5		33.4		143.0	

\*Means followed by equal uppercase letters in columns, for phases, and lowercase letters in rows, for cycles, do not differ by the F test ( $P \leq 0.05$ ). CV= coefficient of variation.

According to Neves, Sá and Carvalho (2004), who evaluated the omission of micronutrients in umbu seedlings, there was a higher requirement of B, Fe and Zn in the initial growth phase compared to Mn and Cu. On the other hand, Gonçalves, Neves and Carvalho (2006), evaluating the omission of macronutrients, observed greater requirement of N, K, Ca and Mg in the initial growth phase of umbu

seedlings.

Also to understand the variation that occurs in leaf contents of nutrients between accessions, Faquin (2005) stated that the process of nutrient absorption is regulated by genetic control. Thus, the selectivity and speed of absorption depend on the absorption characteristics of the genotype. Thus, in addition to the supply of nutrients in the soil, the genetic

characteristics of each accession can interfere in the leaf contents of nutrients. The leaf contents of nutrients in plants influence the availability of elements for their physiological processes and, consequently, the development of the accession.

## CONCLUSIONS

The accession BGU-48 has higher efficiency of nitrogen and phosphorus retranslocation in the leaves, while BGU-50 showed recycling efficiency for potassium and magnesium.

The order of the retranslocation rates is  $K > P > N > Mg$ , being higher in the 2015/2016 season.

The accessions show the following decreasing order of accumulation of macronutrients:  $N > Ca > K > Mg > S > P$ ; and micronutrients:  $Fe > B > Na > Mn > Zn > Cu$ .

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