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PROPORÇÕES DE NITRATO E AMÔNIO NO CRESCIMENTO INICIAL DE PLANTAS DE BERTALHA

NITRATE AND AMMONIUM PROPORTIONS IN THE INITIAL GROWTH OF BERTALHA PLANTS

PROPORCIONES DE NITRATO Y AMONIO EN EL CRECIMIENTO INICIAL DE PLANTAS DE BERTALHA

Gildeon Santos Brito[1]
Alfredo Teles de Jesus Neto[2]
Cristian Martins de Souza[3]
Girlene Santos de Souza[4]

Resumo: Objetivou-se avaliar o efeito de proporções de NO_3^- e NH_4^+ em solução nutritiva no crescimento inicial de plantas de bertalha. O experimento foi conduzido em casa de vegetação em delineamento inteiramente casualizado com parcelas constituídas por uma planta útil e cinco repetições. As proporções NO_3^-:NH_4^+ afetaram de forma significativa o crescimento inicial da bertalha, assim como nos aspectos fisiológicos e na produção de fitomassa, com exceção das variáveis massa da matéria seca total e altura. O equilíbrio entre as proporções de NO_3^- e NH_4^+ potencializam aos parâmetros de maior interesse econômico em plantas de bertalha.
.**Palavras-chave:** *Basella alba L.* Nitrogênio. Solução nutritiva. Fitomassa

Abstract: The objective was to evaluate tehe effect of NO_3^- and NH_4^+ proportions in nutrient solution on the initial growth of Bertalha plants. The experiment was carried out in a greenhouse, in a completely randomized design, with plots consisting of one useful plant and five replications. The NO_3^-:NH_4^+ proportions significantly affected the initial growth of bertalha, as well as the physiological aspects and phytomass production, except for the total dry matter mass and height variables. The balance between the proportions of NO_3^- and NH_4^+ leverage the parameters of greater economic interest in Bertalha plants.
Keywords: *Basella alba L.* Nitrogen. Nutrient solution. Phytomass

[1]Graduando em Agronomia pela Universidade Federal do Recôncavo da Bahia (UFRB), bolsista PIBIC FAPESB. ORCID: https://orcid.org/0000-0002-6165-0408. E-mail: gildeon1997@outlook.com
[2] Graduando em Agronomia pela Universidade Federal do Recôncavo da Bahia (UFRB), bolsista PIBIC CNPq. ORCID: https://orcid.org/0000-0002-9855-978X. E-mail: alfredotelles008@gmail.com
[3] Graduando em Agronomia pela Universidade Federal do Recôncavo da Bahia (UFRB), bolsista PIBIC FAPESB. ORCID: https://orcid.org/0000-0002-4167-7590. E-mail: cr-tiam@hotmail.com
[4] Doutora em Agronomia. Docente Titular do Centro de Ciências Agrárias, Ambientais e Biológicas da Universidade Federal do Recôncavo da Bahia. Orcid: https://orcid.org/0000-0003-1526-7966. Email: girlene@ufrb.edu.br

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Resumen: El objetivo fue evalar el efecto de las proporciones de NO3- y NH4+ en la solución nutritiva sobre el crecimiento inicial de las plantas de bertalha. El experimento se llevó a cabo en un invernadero en un diseño completamente al azar con parcelas compuestas por una planta útil y cinco repeticiones.. Las proporciones NO3-:NH4+ afectaron significativamente el crecimiento inicial de la bertalha, así como los aspectos fisiológicos y la producción de fitomasa, con excepción de las variables masa seca total y altura. El equilibrio entre las proporciones de NO3- y NH4+ potencian los parámetros de mayor interés económico en las plantas de bertalha
Palabras-clave:. Basella alba L. Nitrógeno. Solución nutritiva. fitomasa

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Introduction

Bertalha *(Basella alba L.)* is a leafy vegetable belonging to the Baselaceae family, and its consumption is constantly expanding. It is characterized by being an unconventional edible plant (PANC), with tender and tasty leaves. It is used in food in the form of salads, breads, cakes, and stir-fried in soups, containing high levels of vitamins A and C (TOBELEM, 2018). This species originates from India and Brazil, it is cultivated and sold in some regions, on a small scale, mainly in vegetable gardens (KINUPP and LORENZI, 2014).

The Bertalhaplant is a source of several compounds of nutritional and medicinal interest, such as carotenoids, polysaccharides, mucilages, organic acids, flavonoids, anthocyanins, tannins, triterpenes, steroids, and pigments, such as betacyanin (DESHMUKH and GAIKWAD, 2014; TONGCO, AÑIS and TAMAYO, 2015). Also, it has high levels of vitamins "A," "B9," and "C", mineral salts (calcium, iron, phosphorus, and magnesium), and several amino acids, such as arginine, isoleucine, leucine, lysine, threonine, and tryptophan (KHARE, 2012). According to Gondim (2010), the species has medicinal use, with emollient and astringent properties.

Therefore, it is clear that PANCs, rich in nutrients, are becoming a new option to optimize human food quality, in addition to emerging as a cheap alternative. Regarding Bertalha, this species has a vast nutritional potential, even so it is still little cultivated and studied, making investigations valuing and improving cultivation methods necessary.

Thus, developing appropriate cultivation and exploitation technologies are essential, especially on those related to mineral nutrition, in particular nitrogen (N) metabolism, a nutrient required in greater quantity by plants, as it acts directly influencing plant growth and is related to metabolism, being present in the composition of the most important biomolecules, such as ATP, NADH, NADPH, chlorophyll, proteins, coenzymes and enzymes, in addition to participating in the synthesis of vitamins and hormones (BREDEMEIER & MUNDSTOCK, 2009).

Nitrogen fertilization is one of the agronomic practices that most interfere with plant productivity (STEFEN et al., 2015); however, the correct choice of its source is one of the main topics of studies, as plants can respond in different ways to different forms of N, being absorbed by the roots, preferentially in the forms of nitrate (NO_3^-) or ammonium (NH_4^+) (MARTINEZ-ANDÚJAR et al., 2013).

The adequate amounts and sources of nitrogen are determining factors for the plant good performance, in addition to making it possible to avoid losses and environmental damage due to the incorrect use of these fertilizers. Thus, both nitrogen excess and deficiency can affect plant development, making it crucial to provide adequate dosages (OLIVEIRA *et al.,* 2019).

N assimilation, when absorbed in the form of $N\text{-}NH_4^+$, requires less energy, as it spares the reduction phases, which are required when $N\text{-}NO_3^-$ is absorbed (HACHIYA et al., 2012). However, NH4+ can be cytotoxic at high concentrations, causing chlorosis, in addition to reduced growth, compared to NO_3^- at the same concentration (MILLER & CRAMER, 2005).

In general, the negative effects of NH_4^+ are associated with acidification of the rhizosphere, less absorption of other cations, hormonal imbalance, and depletion of organic acids required for the synthesis of amino acids (HACHIYA et al., 2012). NH_4^+ toxicity in plants is also due to the high energy consumption for the efflux of this ion, keeping its concentration low in the cell cytosol (BRITTO & KRONZUCKER, 2002; GARNICA et al., 2009; HACHIYA et al., 2012).

According to Esteban et al. (2016), ammonium can limit plant growth, as its use as the only N source can cause morphological and physiological problems, reducing growth and causing toxicity to plants. However, ammonium consumes less energy due to its direct insertion in the carbon chain of N assimilation. Thus, the reduction phases by enzymatic action with energy expenditure are not necessary, as occurs for the nitrate ion that is not directly incorporated into an organic compound.

The limit amount of NO_3^- and NH_4^+ in the nutrient solution for the full development of the bertalha culture is unknown. Thus, this study aimed at evaluating the effect of different proportions of NH_3^- and NO_4^+ in nutrient solution on the vegetative growth of bertalha.

Material and Methods

The experiment was carried out between February and May 2021, in a greenhouse at the Center for Agricultural, Environmental, and Biological Sciences (CCAAB) of Universidade Federal do Recôncavo da Bahia (UFRB), in the city of Cruz das Almas, located in the South Recôncavo of Bahia, 200 m above sea level, latitude 12°40'0" S and longitude 39°06'0" W of Greenwich. According to the Köppen classification, it has an Aw to Am climate, tropical hot and humid, with 1,224 mm average annual rainfall, with greater rainfall between March and June.

The production of seedlings was carried out by means of cuttings taken from a matrix plant, originating from a rural property, located in the municipality of Sapeaçu, Bahia. Cuttings from the intermediate parts of the stem containing two axillary buds were selected. Then they were planted in disposable and perforated 400-mL cups containing soil and earthworm humus as substrate, in a 3:1 ratio.

The cuttings were daily irrigated with 100 mL of water. Subsequently, they were placed in a greenhouse for 35 days, when their definitive transplant into pots with a 3 dm³ capacity and containing a mixture of sand (previously sieved and washed) and vermiculite, in a 2:1 ratio, respectively, took place.

The experiment was conducted in a completely randomized design (DIC), with five replications, and the treatments consisted of five proportions of nitrate and ammonium ions (NO_3^-:NH_4^+): T1=100:0, T2=75:25, T3=50:50, T4=25:75, and T5=0:100. Treatments were adjusted according to the standard solution established by Hoagland and Arnon (1950), in which during its cycle each plant received macronutrients in the mg L^{-1} concentration: N = 210, P = 31, K = 234, Ca = 200, Mg = 48, and S = 64 (Table 1). Treatments were applied eight days after transplanting, a period for the seedlings to adapt.

Table 1 – Table of stock solution with volume (mL) to form 1L of modified nutrient solution that is suitable for the respective treatments.

Stock solution (1M)	Proportions of (NO_3^-:NH_4^+)				
	0:100	25:75	50:50	75:25	100:0
	------------------------------- (mL L^{-1}) -----------------------------------				
KH_2PO_4	1.0	1.0	1.0	1.0	1.0
NH_4Cl	15.0	11.25	7.50	3.75	-
KCl	5.0	1.25	5.0	3.75	-
$CaCl_2$	5.0	5.0	1.25	-	-
$MgSO_4$	2.0	2.0	2.0	2.0	2.0

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KNO_3	-	3.75	-	1.25	5.0
$Ca(NO_3)_2$	-	-	3.75	5.0	5.0
Micronutrients **	1.0	1.0	1.0	1.0	1.0
Iron – EDTA *	1.0	1.0	1.0	1.0	1.0

**Micronutrient solution (g/L): H_3B0_3 = 2.86; $MnCl_2$ $4H_20$ = 1.81; $ZnCl_2$ = 0.10; $CuCl_2$ = 0.04; H_2Mo0_4 H20 = 0.02. *Iron-EDTA solution: 26.1 g of disodium EDTA were dissolved in 286 mL of NaOH 1N + 24.9 g of $FeS0_4$.7H20 and aerated overnight.

Fonte: Hoagland and Arnon (1950)

Fifty-six days after transplanting, the following parameters were quantified: Plant height (AL) with a measuring tape graduated in millimeters, from the collar to the apex of the terminal bud. Chlorophyll A (CLA), chlorophyll B (CLB), chlorophyll A/B ratio (CLA/CLB), and total chlorophyll (CLT) (ICF – Folker Chlorophyll Index) indices. Such measuring was carried out between 6:00 and 8:00 AM, using the Falker electronic meter, model CFL1030, with readings performed on three leaves of each plant's middle third. The number of leaves (NF) was determined by simple count. The plant collar diameter (DC) was measured with an analog caliper, measuring the collar region, with results expressed in millimeters. To measure root length (CR), a tape measure was used, and data was also expressed in millimeters.

To evaluate production, the fresh mass of the leaf and dry matter of all harvested material was determined, where plants were partitioned into root, stem, and leaf. To determine the fresh matter mass, the leaves were weighed on a digital scale. Then, the fresh plant material (root, stem, and leaf) was packed in kraft paper bags, identified, and dried at 65°C in an oven with air circulation for 72 hours until dry matter stability was achieved, with results being expressed in grams.

The leaf area was obtained using a perforator with a known diameter (6 mm), collecting 10 leaf discs from each plant, with randomly chosen leaves and avoiding the midrib regions. Subsequently, the disks were dried under the same conditions mentioned above and weighed on a 10^{-4} precision analytical balance. Knowing the dry matter mass and the area of the 10 disks, leaf area (AF) was estimated. The leaf area ratio (RAF), leaf mass ratio (RMF), and specific leaf area (AFE) were determined from mathematical formulas described by Peixoto et al. (2011).

After these analyses, the material was destined for measuring plant phytomass nutrients, nitrogen in the leaves (N leaf), in the root (N root), phosphorus in the leaves (P leaf), in the root (P root), and protein content in the leaves.

To perform the mineral analysis, samples were ground in a Wiley-type mill and packed in plastic bags. From this material, approximately 0.1 g of the dry mass of leaves and roots were submitted to acid digestion, in a mixture containing 3.5 mL of concentrated sulfuric acid (H_2SO_4) and 3 mL of hydrogen peroxide (H_2O_2) at 30%, as proposed by Jones (2001). The digested material was diluted to 100 mL with distilled water, thus obtaining the extract for carrying out the analyzes of nitrogen in the leaves (NF) and in the root (NR) and phosphorus in the leaves (PF) and in the root (PR). The N contents were determined by the phenol-hypochlorite spectrophotometric method (Weatherburn, 1967); the P contents were determined by the molybdo-vanadate spectrophotometric method. Crude protein content in the leaves was calculated using the conversion factor for vegetables, 5.75, as determined by RDC No. 360 (Anvisa, 2003).

Data was subjected to analysis of variance with the aid of the "R" computational statistical program (R Development Core Team, 2018). Depending on the significance level, Tukey's test was applied at 5% error probability to compare means.

Results and Discussions

Bertalha plants responded significantly ($P<0.05$) to the different $NO_3^-:NH_4^+$ ratios, both in the physiological aspects of growth and in the production of phytomass, except for the total dry matter mass and height variables.

Plants grown with nitrate dosages above 50% showed the highest levels of CLA, CLB, and CLT, not differing from each other, and being statistically superior to the other proportions (Table 2). The results are in line with studies by Silva et al. (2010), who, when working with sunflower plants grown only with the ammonium ion, observed that they had lower levels of chlorophyll. This occurrence is explained by Raab & Terry (1994), who state that the efflux of hydrogen ions from the roots increases the acidity of the environment around them; so, the absorption of nutrients ceases, and plants can suffer from nitrogen deprivation, which is the main constituent of chlorophyll molecules.

Table 2 – Chlorophyll a (CLA), b (CLB), and total (CLT) indices of *Basella alba L.* plants cultivated under different proportions of nitrate and ammonium. Cruz das Almas, BA, 2021.

NO_3^-:NH_4^+	CLA	CLB	CLT
100:0	34.52 a	10.65 a	45.17 a
75:25	33.49 a	10.16 ab	43.65 a
50:50	32.86 ab	10.14 ab	43.00 ab
25:75	30.89 b	9.36 b	40.25 b
0:100	30.73 b	9.34 b	40.07 b
CV (%)	3.85	4.66	3.91

*Equal letters do not differ from each other in the columns, according to Tukey's test at 5% probability.

Fonte: Dados da Pesquisa (2023)

Furthermore, during rapid vegetative growth, nitrate reduction rates are high, as well as amino acid synthesis in the leaves; therefore, most of the amino acids are used in the leaves themselves for the synthesis of chlorophyll, rubisco, and other proteins (BREDEMEIER & MUNDSTOCK, 2009).

This nitrate preference for the assimilation of chlorophyll molecules can also be evidenced in this study.

It is noteworthy that the increase in chlorophyll is due to the greater uptake and incorporation of N in the form of nitrate; thus, we can infer that the N supply in the form of ammonium may have impaired the assimilation of this nutrient, thus reducing the chlorophyll content. Contradictory results were found by Yang et al. (2020). These authors observed that CLA levels and the CLA/B ratio were higher in the 75:25 NH_4^+:NO_3^- ratio in *Brassica rapa* plants.

The tested proportions of NO_3^- and NH_4^+ significantly influenced the analyzed MSR, MSC, and MSF, except for the MST mass (Table 3). Plants grown with a balanced ratio between

NO_3^-:NH_4^+ ions showed better performance for MSF, even though they did not differ statistically from other treatments containing ammonium as a nitrogen source, this is in agreement with Taiz et al. (2017), who state that “nitrogen supply in a balanced mixture of cations and anions tends to reduce the rapid increase in the medium pH, which is commonly observed when nitrogen is supplied only as a nitrate anion.”

Table 3 – Dry matter mass of the leaf (MSF), stem (MSC), root (MSR), total (MST), and root/shoot dry mass ratio (MSR/MSPA) of *Basella alba L.* plants cultivated under different proportions of nitrate and ammonium. Cruz das Almas, BA, 2021.

NO_3^- : NH_4^+	MSF	MSC	MSR	MST	MSR/MSPA
	....	.... (g)	....	....	
100:0	10.39 b	12.04 a	7.12 a	29.55 a	0.32 a
75:25	11.30 ab	10.30 b	6.78 a	28.38 a	0.32 a
50:50	11.73 a	11.68 ab	5.89 ab	29.30 a	0.25 ab
25:75	10.59 ab	10.71 ab	4.89 ab	26.20 a	0.23 ab
0:100	11.14 ab	10.30 b	4.03 b	26.54 a	0.18 b
CV (%)	6.04	7.97	20.76	6.37	21.80

*Equal letters do not differ from each other in the columns, according to Tukey's test at 5% probability.

Fonte: Dados da Pesquisa (2023)

We observed that nitrate as the exclusive source of N resulted in the lowest accumulation of MSF (Table 3). One of the factors associated with this result is the higher energy cost for nitrate absorption, as occurred with the cassava crop, where Cruz et al. (2006) observed this behavior. Likewise, Shan et al. (2011) state that ammonium absorption occurs via a uniport system, occurring through a passive process and, unlike nitrate absorption, ammonium is readily available for incorporation without the need to use energy.

The NO_3^-:NH_4^+ ratios in the proportions 100:0, 50:50, and 25:75 showed significant results for the MSC variable (Table 3). The supply of NO_3^- to the plants or even associated with low proportions of NH_4^+ are the best forms of N supply, due to the toxic effect of N nutrition based on high proportions of NH_4^+ (MENDOZA- VILLARREAL *et al.,* 2015). This is observed in this study, occurring with the root dry matter mass and root dry matter mass/shoot dry matter mass variables, revealing that the species has a preference for supplying N in the nitric form.

Reports in the literature state that ammonium toxicity is related to attributes linked to the reduction or inhibition of cation absorption as a consequence of ion imbalance (KOTSIRAS *et al.,* 2002), such as the observed negative results for the MSC, MSR, and MSR/MSPA variables, which were possibly affected by the toxic effect of this ion.

As the proportion of ammonium increased, the CR was gradually impaired (limited) (Table 4), reiterating the result obtained by Silva et al. (2010), who, working with the sunflower crop, observed that the 100% ammonium proportion caused reductions in root growth in relation to the proportion with nitrate application only, indicating a possible preference for absorption by the nitric form.

There are several physiological reasons that may have led to such a limitation in CR, such as ammonium toxicity, that causes biochemical and physiological changes in the plant, such as: changes in intracellular pH, in osmotic balance, in the metabolism of phytohormones and polyamines that can induce nutrient deficiency (GERENDAS *et al*., 1997).

Table 4 – Root length (CR), number of leaves (NF), stem diameter (DC), height (AL), leaf area (AF), leaf area ratio (RAF), specific leaf area (AFE), and leaf mass ratio (RMF) of *Basella alba L.* plants grown under different proportions of nitrate and ammonium. Cruz das Almas, BA, 2021.

NO_3^- : NH_4^+	CR (cm)	NF (un)	DC (mm)	AL (m)	AF (cm^2)	RAF ($cm^2\ g^{-1}$)	AFE ($cm^2\ g^{-1}$)	RMF ($g\ g^{-1}$)
100:00.	37.00 a	84.20 a	9.06 a	2.14 a	17.95 b	0.61 b	1.73 a	0.35 b
75:25.	33.20 ab	73.20 b	8.15 ab	2.44 a	18.69 ab	0.66 ab	1.66 a	0.40 a
50:50.	30.80 b	83.60 a	8.25 ab	2.60 a	23.54 a	0.81 a	2.01 a	0.40 a
25:75.	29.67 b	67.20 b	7.77 b	2.60 a	21.22 ab	0.81 a	1.99 a	0.40 a
0:100.	28.50 b	68.80 b	7.43 b	2.54 a	20.96 ab	0.79 a	1.88 a	0.42 a

CV (%)	8.8	7.08	7.76	21.8	13.99	12.97	11.46	3.87

* Equal letters do not differ from each other in the columns, according to Tukey's test at 5% probability.

Fonte: Dados da Pesquisa (2023)

Plants cultivated with 100% and 50% NO_3^- showed a significant effect on the NF of Bertalha (Table 4). On the other hand, high concentrations of NH_4^+ did not allow for an increase in this variable, which probably occurred due to the reduction in the photosynthetic rate and the internal concentration of CO_2, possibly causing stomatal closure, since, according to Cramer *et al.* (1993), these are consequences of ammonium high concentrations in the medium.

In addition, high concentrations of nitrate were also favorable for the increase in DC, more specifically when concentrations of this ion greater than or equal to 50% were used (Table 4). This result differs from that found by Mendoza-Villarreal *et al.* (2015), who, working with the lysianthus crop, observed a significant behavior for treatments containing high levels of ammonium, following a linearity parameter. However, Tanan (2019) working with *Physalis angulata L.* plants confirmed that the use of ammonium as the sole source of nitrogen considerably reduces the DC of these plants.

Regarding the AL variable, we verified that there was no statistical difference between the proportions of NO_3^-:NH_4^+ (Table 4). The same behavior was observed in the study by Oliveira et al. (2008), who, when studying the initial growth of popcorn, did not observe significant differences in the AL of plants with different NO_3^-:NH_4^+ ratios.

As for AF, we observed results different from the other variables, and increasing dosages of NH_4^+ ion positively benefited this parameter, which was even significantly higher than the proportion with 100% ammonium (Table 4). For Marschner (2012), N is the main nutrient that influences AF, and, consequently, the photosynthetic rate, being able to promote greater accumulation of dry mass in plants. However, Carvalho *et al.* (2020) reiterate that when the nitrogen source is not adequate, plants compromise absorption, presenting a performance similar to the deficit of this element.

For AFE, a mean of 2,01 cm2 g-1 was observed in the 50:50 (NH4+:NO3-) ratio, not statistically differing from means obtained in the other ratios and being superior to the other ratios (Table 4). Thus, the 50:50 (NH4+:NO3-) ratio increased leaf blade growth. For Peixoto et al. (2020), AFE increases are relevant, as they point to morphological adaptations that allow the plant to form a more efficient leaf area.

According to Maças *et al.* (2008) some plants can eventually metabolize significant amounts released by photorespiration, without showing signs of toxicity. A similar result was obtained for RAF, which showed better performance with ammonium concentrations from 25%.

Regarding RMF, supplying only nitrate to the plants became harmful, with preference being given when there is ammonium in solution (Table 4).

Analyzing the results on nutritional diagnosis, we observed that few treatments interfered for the variable N in the leaves, with no significant difference between them (Table 5). Even by being available in concentrations favorable to their growth, according to Furlani (2004), the nitrogen contents for an optimal production for most plants are between 20 and 50 g N kg^{-1} of dry matter. This result differs from that found by Alves et al. (2013), who, working with sunflower, obtained better performances with plants grown only with NO_3^-. Thus, the non-significance between treatments for this variable may be linked to genetic issues, proving that each species responds differently.

On the other hand, the most concentrated proportions of ammonium favored significant N accumulation in the roots (Table 5), especially the treatment with 75% of this ion with approximately 66.4 g. Kg^{-1}, this was probably due to the harmful nature of NH_4^+, which requires its rapid assimilation to avoid its accumulation in tissues. For this reason, the highest concentrations of N were observed in the roots of Bertalha.

Table 5 – Nitrogen content in leaves (N leaves), roots (N roots), phosphorus content in leaves (P leaves), roots (P roots), crude protein content in leaves (PB) of *Basella alba L.* plants cultured under different proportions of nitrate and ammonium. Cruz das Almas, BA, 2021.

NO_3^- : NH_4^+	N leaves	N roots	P leaves	P roots	PB
	.... g Kg^{-1}				(%)
100:00.	23.15 a	43.78 c	0.32 b	0.68 a	13.31 a
75:25.	24.84 a	46.80 c	0.44 ab	0.72 a	14.28 a

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50:50.	28.70 a	51.37 bc	0.55 a	0.91 a	16.50 a
25:75.	27.05 a	66.35 a	0.48 a	0.94 a	15.55 a
0:100.	27.06 a	59.36 ab	0.48 a	0.74 a	15.55 a
CV (%)	11.89	9.04	13.46	16.2	11.89

*Equal letters do not differ from each other in the columns, according to Tukey's test at 5% probability.

Fonte: Dados da Pesquisa (2023)

Regarding the concentration of phosphorus in leaves (P leaves) there was no significant difference between treatments with the presence of NH_4^+ ion, but higher than the condition with 100% nitrate (Table 5). The NO_3^- supply from 75% was disadvantageous to the increase of the P concentration in the leaves, a performance similar to that obtained by Tanan et al. (2019), who, working with *P. angulata* plants, found that high concentrations of NH_4^+ were conducive to the absorption of this macronutrient, to the detriment of NO_3^-.

This negative effect of nitrate may be related to its greater energy expenditure for absorption and reduction, as it needs to be reduced to nitrite and then to ammonium, requiring large amounts of reducing equivalents (HACHIYA *et al*., 2007). However, it requires energy, and according to Taiz et al. (2017), P is one of the main components of nucleotides used in the energy metabolism of plants (such as ATP), DNA, and RNA, in addition to other important compounds in plant cells, including phosphate sugars, intermediaries of respiration and photosynthesis, as well as the phospholipids that make up plant membranes.

Analyzing the concentration of P in the roots and PB in the leaves, no significant difference was observed between the proportions of NH_4^+:NO_3^- (Table 5). Lima et al. (2017), in a factorial study between light environments and proportions similar to those studied in this work, also did not find significance in an isolated effect for this variable. Thus, these same authors point out that plants with reduced P absorption have their development compromised, as this nutrient is a component of phosphate sugars, nucleic acids, coenzymes, etc., plays a central role in the reactions involving the ATP molecule, which is essential for the functioning of plant metabolism.

The protein importance is related to their presence in living cells, linked to vital biological activities. According to Botrel et al. (2019), this variable followed the same pattern as the nitrogen content, probably because this element participates in the composition of amino acids, which has a direct effect on the protein content as it is the main constituent of the structure, considering that all proteins of all living organisms are made up of a varied combination of just 20 different types of amino acids.

According to studies carried out by Martinevski et al. (2013), it was found that Bertalhais an excellent source of protein and fiber; however, the nutritional quality of this protein is of low biological value due to its digestibility, amino acid composition, and the presence of antinutritional factors.

Conclusions

After analyzing the results, it was concluded that the lowest amounts of total dry mass were obtained for Bertalha plants cultivated with only nitrate or ammonium as a nitrogen source. In this aspect, ammonium was less harmful to growth than the nitric source.

Nitrogen uptake efficiency was higher for Bertalha plants grown under higher NH4+ proportions.

NO_3^- and NH_4^+ proportions significantly influence chlorophyll indices, with better performance for increasing doses from 50% N-NO_3^-.

The balance between the proportions of NO_3^- and NH_4^+ leverage the parameters of greater economic interest in Bertalha plants, such as leaf area, dry mass, and number of leaves.

The N supply at 75% or above in the ammoniacal form induces the accumulation of this nutrient in the roots.

The results showed that the Bertalha culture grows better when a mixture of NO3- and NH4+ occurs in the growth solution, mainly in the proportions of 50:50 (NO3-:NH4+), being the best option for the nutrition of Betalha plants in initial phase of growth.

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