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Productive and physiological performance of jambu genotypes cultivated in hydroponics

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ABSTRACT

Jambu is a condiment herb used in the preparation of typical and herbal dishes in the Amazon Region. The inflorescences, leaves, and stems of the plant are used. In addition, jambu has numerous applications in the cosmetics and food industries due to the presence of the bioactive compound spilanthol. The objective of this study was to evaluate the productive and physiological performance of jambu genotypes of *Acmella oleracea,* and *Acmella ciliata* species grown in hydroponics. The experiment used was a completely randomized design with eight treatments and four replicates. The treatments consisted of jambu genotypes (UFR-1, UFR-2, UFR-3, UFR-4, UFR-5, UFR-6, UFR-7 and UFR-8) collected in different locations in the state of Pará. We evaluated the beginning of flowering, length of the main branch, diameter of the main branch, leaf area, shoot fresh mass, inflorescence fresh mass, root fresh mass, total fresh mass, net photosynthetic rate, stomatal conductance, internal CO_2 concentration, and instant carboxylation efficiency. The genotypes presented different behaviors about the productive and physiological growth characteristics. The genotypes UFR-1, UFR-2, UFR-3, UFR-4 and UFR-7 exhibited greater precocity of flowering. In general, genotypes of the species *A. oleracea* presented lower rate of net photosynthesis when compared to those of the species *A. ciliata*. The genotypes of *A. oleracea* showed total fresh mass accumulation capacity, in addition to a high potential for inflorescence production. The genotypes UFR-2 and UFR-4 stood out because they presented higher yields of shoots fresh mass and inflorescences, respectively. Therefore, these genotypes should be considered in crop improvement programs.

Keywords: *Acmella oleracea*, *Acmella ciliata*, soilless cultivation, yield, gas exchange.

RESUMO

Desempenho produtivo e fisiológico de genótipos de jambu cultivados em hidroponia

O jambu é uma erva condimentar usada no preparo de pratos típicos e fitoterápicos na região Amazônica. São utilizados as inflorescências, as folhas e os caules da planta. Além disso, o jambu possui inúmeras aplicações nas indústrias de cosméticos e alimentícia devido à presença do composto bioativo espilantol. Objetivou-se com este estudo avaliar o desempenho produtivo e fisiológico de genótipos de jambu, das espécies *Acmella oleracea* e *Acmella ciliata*, cultivados em hidroponia. O delineamento utilizado foi inteiramente casualizado com oito tratamentos e quatro repetições. Os tratamentos foram constituídos por genótipos de jambu (UFR-1, UFR-2, UFR-3, UFR-4, UFR-5, UFR-6, UFR-7 e UFR-8) coletados em diferentes localidades do estado do Pará. Foram avaliados o início do pendoamento, comprimento da rama principal, diâmetro da rama principal, área foliar, massa fresca da parte aérea, massa fresca das inflorescências, massa fresca das raízes, massa fresca total, taxa de fotossíntese líquida, condutância estomática, concentração interna de CO_2 e eficiência instantânea de carboxilação. Os genótipos apresentaram comportamentos distintos em relação às características de crescimento, produtivas e fisiológicas. Os genótipos UFR-1, UFR-2, UFR-3, UFR-4 e UFR-7 exibiram maior precocidade de floração. Em geral, genótipos da espécie *A. oleracea* apresentaram menor taxa de fotossíntese líquida se comparados aos da espécie *A. ciliata*. Os genótipos da *A. oleracea* apresentaram capacidade de acúmulo de massa fresca total, além de elevado potencial para produção de inflorescências. Destacaram-se os genótipos UFR-2 e UFR-4, pois apresentaram maiores produções de massa fresca da parte aérea e inflorescências, respectivamente. Portanto devem ser considerados em programas de melhoramento da cultura.

Palavras-chave: *Acmella oleracea*, *Acmella ciliata*, cultivo sem solo, produtividade, trocas gasosas.

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Jambu belongs to the Asteraceae family, is an unconventional food plant from the Amazon region and has great economical potential (Gusmão & Gusmão, 2013; Homma, 2017; Silva *et al.*, 2020), due to the presence of spilanthol, a bioactive compound with several applications in the cosmetics and food industries (Bae *et al.*, 2010; Barbosa *et al.*, 2016). Two species of the genus are popularly known as jambu in the Northern Region of Brazil, and they are used for medicinal and cuisine purposes, *Acmella oleracea* and *Acmella ciliata* (Silva & Santos, 2011;

Martins *et al.*, 2012).

Considering the potential use of jambu (Santos *et al.*, 2021), studies on the adaptability of different species and/or genotypes of the crop, in different environments and cultivation systems, may be useful to increase its productive and qualitative potential, as well as its expansion to other Brazilian regions (Silva *et al.*, 2020). Thus, although numerous studies on the cultivation of this vegetable can be found in literature (Sampaio *et al.*, 2018, 2021), data on the productive and qualitative ability of the genotypes and/or varieties of species of jambu, under different cultivation systems, mainly for a hydroponic system, are scarce.

The hydroponic system is quite efficient in managing biotic and abiotic factors which affect plant growth and development (Nascimento *et al.*, 2020). It is mainly characterized by the use of aqueous solutions, instead of soil, to supply nutrients to plants. Under this system, we can notice higher productivity and quality of the plants, longer useful life after harvesting, as well as lower consumption of fertilizers, pesticides, and water, absence of soil pathogens, year-round production, and reduced labor costs (Sambo *et al.*, 2019).

The cultivation system adopted can influence the characteristics of the physiological and biochemical trait as well as the development cycle, which results in alterations in the productivity and quality of plants (Costa *et al.*, 2020; Nascimento *et al.*, 2020). Therefore, the analysis of the adaptation of genotypes in a certain cultivation system shall be based not only on productive traits but also on the physiological behavior of the crop under this system (Souza *et al.*, 2019).

Given the above, it appears necessary to identify promising genotypes to be used in the hydroponic cultivation system. That's why we aimed to evaluate the productive and physiological performance of the genotypes of two jambu species.

MATERIAL AND METHODS

The experiment was carried out from September to December 2018, in a chapel-type greenhouse, with a roof lantern, covered with low-density polyethylene film (PEBD), 100 microns, 15 m long, 8 m wide, 3.5 m ceiling height, sides covered with 40 mm galvanized wire mesh, located in the Soil Science Department, of Agrarian Science Institute, at Federal Rural University of Amazon, Belém campus. According to Köppen, the climate is 'Afi', with rainfall above 60 mm year-round (Alvares *et al.*, 2013). During the experiment, the temperature and relative air humidity were measured daily using a thermo-hygrometer installed in the greenhouse, being 35.3°C the maximum average temperature, 28.1°C the minimum, and 77.1% the average relative humidity.

The experimental design was completely randomized, with eight treatments and four replicates. The treatments consisted of jambu genotypes harvested in different locations of Pará state. Four genotypes belong to *A. oleracea* (UFR-1, UFR-2, UFR-3, UFR-4) and four to *A. ciliata* (UFR-5, UFR-6, UFR-7, UFR-8) (Table 1).

The seedlings of the genotypes were grown in 128-cell expanded polystyrene trays, using coconut fiber as a filling substrate, and a sowing density of six seeds per cell. Seven days after sowing (DAS), plants were thinned, keeping one seedling per cell. After thinning, the trays were transferred to nursery benches. The trays were filled with Hoagland & Arnon (1950) nutrient solution, at 25% ionic concentration.

After 21 DAS, the seedlings were transplanted to the cultivation hydroponic system using sterilized ground silica as substrate. The authors used 2-L plastic pots, covered with aluminum foil. Replacement and drainage of the nutrient solution (aeration) were performed in the early morning and late afternoon, manually and daily.

Hoagland & Arnon (1950) nutrient solution was used, prepared with pure salts for analysis. Each pot was filled with 600 mL of the solution. The solution was renewed weekly, and the pH was checked daily with the aid of a field peagameter. When necessary, the correction was performed by applying 1N NaOH or 1N citric acid solutions, keeping the pH between 5.5 and 6.5. Daily replacement of water lost by the evapotranspiration process was performed to maintain the volume of 600 mL per vessel, using distilled water.

Plants were harvested at 60 DAS, when all the genotypes were in the reproductive phase and, according to Gusmão & Gusmão (2013), higher biomass content for commercialization can be verified. The evaluated traits were: a) beginning of flowering (days), counting the days since the sowing; b) length of the main branch (cm), measured with the aid of a graduated ruler; c) diameter of the main branch (mm), measured using a caliper; d) leaf area (cm^2 $plant^{-1}$) using an area integrator device, LICOR® model LI-3100; e) shoot fresh mass (g $plant^{-1}$); f) inflorescence fresh mass (g $plant^{-1}$); g) root fresh mass (g $plant^{-1}$), and h) total fresh mass (g $plant^{-1}$), determined by the sum of the shoot, inflorescence, and root fresh masses. The masses were weighed with a precision scale (0.001 g).

One day before harvesting, between 9 and 11 AM, the authors analyzed the gas exchanges in the second leaf of the main tip branch of the plant (Sampaio *et al.*, 2021). We evaluated the net photosynthesis rate (A, μmol CO_2 m^{-2} s^{-1}), stomatal conductance (gs, mol H_2O m^{-2} s^{-1}), internal concentration of CO_2 (C_i, μmol CO_2 mol^{-1}), and instant carboxylation efficiency (A/Ci), obtained by the ratio between A and C_i; internal CO_2 concentration, and stomatal conductance were obtained using a portable infrared gas analyzer (IRGA, model LI6400XT, LICOR®) under an external CO_2 concentration of 400 μmol mol^{-1} of air and artificial PAR of 1,000 μmol of $m^{-2}s^{-1}$ photons.

The obtained results were submitted to the Kolmogorov-Smirnov test for normality and Bartlett's test for homogeneity. Using assumptions of normality and homogeneity of variances, we performed an analysis of variance by the F test ($p<0.05$) and, when significant, the Scott-Knott test was applied. To analyze the data obtained in this study, we used the statistical software Sisvar version 5.6 (Ferreira, 2011).

RESULTS AND DISCUSSION

The tested jambu genotypes, in general, showed significant differences ($p<0.05$) in growth, productivity, and physiological traits under the hydroponic system. At beginning of flowering, we verified that UFR-1, UFR-2, UFR-3, UFR-4, and UFR-7 were the earliest genotypes and UFR-6 was the latest one (Table 2).

When jambu is cultivated in soil, the flowering begins between 45 and 50 days after emergence, considering that the greatest precocity for each species and/or genotype depends on the cultivation conditions to which the materials will be submitted (Gusmão & Gusmão, 2013). Given the above, the earliness shown by jambu plants cultivated under a hydroponic system (Table 2) occurred, probably, due to the system, which has an expressive capacity to manage biotic and abiotic factors compared to soil cultivation (Nascimento *et al.*, 2020), highlighting the nutrient supply through the balanced nutrient solution which presents rigorous monitoring of pH control and electrical conductivity; these factors, when well adjusted, promote greater growth and development of plants. Thus, for producers who aim to produce inflorescences, *A. oleracea* genotypes are more promising materials due to its greater precocity demonstrated under the hydroponic system.

For number of inflorescences, we verified that the studied genotypes showed differentiated behaviors, comprising three distinct groups. The two first groups were formed by the genotypes belonging to *A. ciliata,* standing out the genotypes UFR-7 and UFR-8, which showed a greater number of inflorescences emitted, whereas the third group was formed by materials of *A. oleracea* (UFR-1, UFR-2, UFR-3, and UFR-4), which produced the lowest number of inflorescences, showing no differences among them (Table 1).

The differences found among *A. ciliata* genotypes about the emission of inflorescences may be related to the transition from vegetative to reproductive phase, verifying that genotypes UFR-7 and UFR-8 were earlier than UFR-5 and UFR-6; therefore, they had more time to release flower buds until harvest (60 DAS). Concerning variations found between *A. oleracea* and *A. ciliata,* they are probably due to the genetic differences between each species, as observed by Martins *et al.* (2012). These cited authors verified differences about the floral morphology of these species (Figure 1): the inflorescences of *A. ciliata* are simple globoids and those of *A. oleracea* are simply elongated, showing occasionally elongated and/or globoid twin inflorescences.

About the length of the main branch, UFR-5 (58.2 cm) stood out, followed by UFR-6 (35.9 cm) and UFR-8 (39.3 cm) (Table 2). In general, *A. oleracea* genotypes (UFR-1, UFR-2, UFR-3, and UFR-4) showed the shortest length of the main branch. For diameter of the main branch, we verified that two groups were formed, considering that the first group was formed by *A. oleracea* genotypes (UFR-1, UFR-2, UFR-3, and UFR-4), which stood out for this trait, whereas the second group was formed by *A. ciliata* genotypes (Table 2).

Table 1. Jambu genotypes from the UFRA germplasm bank, collected in different locations in Pará state, 2017. Belem, UFRA, 2018.

Genotype	Location	Species	Coordinates
UFR-1	Belem	*A. oleracea*	01°27’19”S, 48°26’20”W
UFR-2	Abaetetuba	*A. oleracea*	01°43’04”S, 48°52’58”W
UFR-3	Igarape-Açu	*A. oleracea*	01°07’44”S, 47°37’12”W
UFR-4	Santa Izabel	*A. oleracea*	01°17’58”S, 48°09’40”W
UFR-5	Cameta	*A. ciliata*	02°14’54”S, 49°30’12”W
UFR-6	Salvaterra	*A. ciliata*	00°45’21”S, 48°45’54”W
UFR-7	Bragança	*A. ciliata*	01°03’46”S, 46°46’22”W
UFR-8	Ananindeua	*A. ciliata*	01°21’57”S, 48°22’19”W

Borges *et al.* (2013), studying the effect of fertilization in jambu under a conventional system in São Manuel-SP, found averages of main branch length of *A. oleracea* of 25.6 cm, and 43.6 cm in plants submitted to organic and mineral fertilization, respectively. These variations were higher than those observed in this study among the genotypes of *A. oleracea*, which were from 21.3 to 28.0 cm. Such differences can be attributed to cultivation and management systems adopted for the studies, considering that the low variation of the stalk length of plants cultivated under hydroponics can be related to greater availability and balance of nutrients and water offered by the system when compared to soil cultivation (Sambo *et al.*, 2019).

The variations observed for main branch length for *A. ciliata* genotypes, from 28.6 to 58.2 cm, suggest greater instability for these traits among the tested genotypes when compared to *A. oleracea* genotypes. Thus, the results obtained both for the length and diameter of the main branch in this study suggest that the photoassimilate distribution for primary and secondary branch growth is regulated by factors intrinsic to each jambu species and within each genotype, especially *A. ciliata,* as well as the cultivation conditions in which the genotypes were submitted to (Oliveira *et al.*, 2011; Yuri *et al.*, 2017).

The leaf area ranged from 1570.6 to 2265.9 cm plant^{-1} among the genotypes tested in this study. UFR-6 showed the highest total leaf area, forming a group separate from the other genotypes which did not differ from each other (Table 1). This suggests little genetic variation among materials related to this trait. Moreover, the greatest response in the leaf area showed by UFR-6 to the detriment of the other genotypes may be related to the longer time of this material in the vegetative phase, which favored the destination of photoassimilates for the emission and expansion of the leaf blade (Taiz *et al.*, 2017).

For shoot fresh mass, the averages ranged from 91 to 108 g plant^{-1}, being UFR-4 the one which showed the best performance in relation to the others which did not differ from each other (Table 3).

The shoot fresh mass of jambu, considering leaves and stalk, is the part which shows the greatest commercial importance, being used, mainly, to prepare typical dishes of the Northern part of Brazil, such as "tacacá". This dish is prepared with the leaves and stalks of jambu (Silva *et al.*, 2020). Thus, although the genotype UFR-4 has shown potential for greater accumulation of shoot fresh mass, the other genotypes of both species have the potential for commercialization, as observed by Martins *et al.* (2012).

Martins *et al.* (2012), evaluating the agronomic and morphological traits of *A. oleracea* and *A. ciliata* genotypes, under conventional cultivation in the conditions of North Minas Gerais, did not observe differences between the genotypes for producing shoot fresh mass which ranged from 40.1 to 53.3 g plant^{-1}. These results were lower than the ones found in this study which ranged from 90.6 to 105.7 g plant^{-1} among the tested genotypes. These differences probably occurred due to genetic divergences and interaction of these genotypes with the environment and/or cultivation system (Yuri *et al.*, 2017).

For inflorescence fresh mass, the authors observed that the genotypes in this study showed different behaviors among themselves and within the same species, which resulted in three distinct groups, standing out the group formed by UFR-2 which obtained the highest response (Table 2).

Thus, the good performance showed by UFR-2 in this study, as well as the flowering precocity under a hydroponic system, is evidence of material for inflorescence production. This jambu organ has been gaining prominence for being an ingredient of differentiated dishes in exotic food restaurants, and also in the production of a drink called “cachaça” and artisanal liqueurs (Homma, 2017; Balieiro *et al.*, 2020).

For root fresh mass, we verified differences among the genotypes, which allowed us to form three groups (Table 2). UFR-1 and UFR-3 formed groups different from the others, considering that UFR-1 obtained greater root mass. Although the whole plant is commercialized (leaves, branch, inflorescence, and root) (Sampaio *et al.*, 2018), the leaves and stalks (shoot part) are the parts which are the most used to prepare typical dishes, and the inflorescences are commercialized for producing, mainly, liqueur and “cachaça” (Homma, 2017); the roots are discarded, though.

Comparing the performance of the genotypes, about total fresh mass, the authors verified that *A. oleracea* showed, in general, higher productions in relation to *A. ciliata* (Table 3). The differences observed between the species can be explained by the morphological traits of each species, as verified by Martins *et al.* (2012).

According to Preczenhak *et al.* (2014), the genetic diversity, considering mass accumulation in plants, may be related to the genetic potential of the genotype, as well as the cultivation conditions to which the plants are submitted. Thus, the highest performance obtained by some genotypes of *A. oleracea* species in terms of shoot, inflorescence, and total fresh mass, as well as the greatest precocity in flowering, shows the potential of these genotypes to be used in a hydroponic system and this crop breeding program. However, although genotypes of *A. ciliata* in general produced lower yields for inflorescence, root, and total fresh mass, both genotypes have the potential to be commercialized (Martins *et al.*, 2012).

About physiological performance of the genotypes, we observed differences

Table 2. Beginning of flowering (BF, days), number of inflorescences (NI), main branch length (MBL, cm), main branch diameter (MBD, mm), and leaf area (LA, cm^2 plant^{-1}) of *A. oleracea* and *A. ciliata* genotypes cultivated in a hydroponic system. Belem, UFRA, 2018.

Genotype	BF	NI	MBL	MBD	LA
UFR-1	30.0 d	24.0 c	21.3 c	7.2 a	1715.2 b
UFR-2	30.0 d	28.3 c	25.3 c	6.3 a	1584.6 b
UFR-3	30.0 d	28.5 c	29.0 c	7.4 a	1619.8 b
UFR-4	30.0 d	35.8 c	28.0 c	6.5 a	1570.6 b
UFR-5	43.5 b	44.0 b	58.2 a	5.2 b	1719.9 b
UFR-6	47.5 a	49.5 b	35.9 b	4.6 b	2265.9 a
UFR-7	30.0 d	110.0 a	28.6 c	4.8 b	1813.9 b
UFR-8	38.0 c	117.5 a	39.3 b	4.9 b	1863.3 b
CV (%)	4.5	21.0	23.5	12.0	10.5

Averages followed by the same lowercase letter in the column do not differ by the Scott-Knott test at 5% probability showing similarities in the formed groups.

Table 3. Shoot fresh mass (SFM, g/plant), inflorescence fresh mass (IFM, g/plant), root fresh mass (RFM, g/plant), and total fresh mass (TFM, g/plant) of *A. oleracea* and *A. ciliata* genotypes cultivated in a hydroponic system. Belem, UFRA, 2018.

Genotype	SFM	IFM	RFM	TFM
UFR-1	95.4 b	15.2 b	57.1 a	167.7 a
UFR-2	90.6 b	33.8 a	42.8 c	167.1 a
UFR-3	97.5 b	21.4 b	50.0 b	168.9 a
UFR-4	105.7 a	17.4 b	46.9 c	170.0 a
UFR-5	91.0 b	4.2 c	46.0 c	141.2 c
UFR-6	93.0 b	3.0 c	41.5 c	137.5 c
UFR-7	94.3 b	16.4 b	48.2 c	158.9 b
UFR-8	92.4 b	18.1 b	40.9 c	151.3 c
CV (%)	4.2	19.2	9.5	3.7

Averages followed by the same lowercase letter in the column do not differ by the Scott-Knott test at 5% probability, showing similarities in the formed groups.

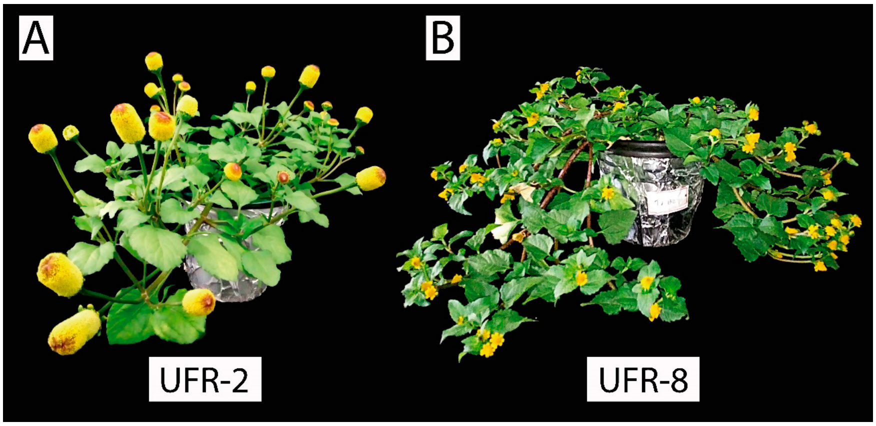

Figure 1. Morphological differences between the inflorescences of genotypes of the species *A. oleracea* (A) and *A. ciliata* (B) cultivated in a hydroponic system. Belem, UFRA, 2018.

Table 4. Net photosynthesis (*A*, µmol CO_2 m^{-2} s^{-1}), stomatal conductance (*gs*, mol H_2O m^{-2} s^{-1}), internal CO_2 concentration (*Ci*, µmol CO_2 mol^{-1}), and instantaneous carboxylation efficiency (*A/Ci*) of *A. oleracea* and *A. ciliata* genotypes cultivated in hydroponic system. Belem, UFRA, 2018.

Genotype	*A*	*gs*	*Ci*	*A/Ci*
UFR-1	17.6 c	0.19 a	367.1 a	0.05 c
UFR-2	15.7 c	0.17 b	369.3 a	0.04 c
UFR-3	23.0 b	0.24 a	358.9 a	0.06 c
UFR-4	22.9 b	0.23 a	356.9 a	0.06 c
UFR-5	30.9 a	0.14 b	342.6 b	0.09 a
UFR-6	31.0 a	0.14 b	340.3 b	0.09 a
UFR-7	21.1 b	0.15 b	361.9 a	0.06 c
UFR-8	27.0 a	0.23 a	348.1 b	0.08 b
CV (%)	11.6	22.6	3.8	12.8

Averages followed by the same lowercase letter in the column do not differ by the Scott-Knott test at 5% probability, showing similarities in the formed groups.

($p<0.05$) in net photosynthesis, stomatal conductance, internal CO_2 concentration, and instantaneous carboxylation efficiency (Table 4).

The highest rates of net photosynthesis (*A*), ranged from 15.7 to 31.0 µmol CO_2 m^{-2} s^{-1}. These values were observed in genotypes UFR-5, UFR-6, and UFR-8 of *A. ciliata*, whereas the genotypes *A. oleracea* showed the lowest rates. Stomatal conductance (*gs)* ranged from 0.14 to 0.24 mol H_2O m^{-2} s^{-1} among the genotypes tested in this study. We observed that the genotypes of *A. ciliata*, in general, showed the lowest stomatal pore opening, whereas the results observed for *A. oleracea* were higher. Such behavior suggests that the reductions observed for *A* among the genotypes of *A. oleracea* were not led by limitations related to stomata, since the genotypes which showed the highest *A* were the ones that showed the lowest *gs*, except genotype UFR-8 (Table 4), being the possible cause the biochemical limitations which may occur throughout the process of net CO_2 assimilation (Taiz *et al.*, 2017).

Changes from vegetative to reproductive stages caused changes in flow and partition of plant photoassimilates, consequently remobilization of nutrients from the leaves to the fruits, thus promoting changes (additions and/or reductions) in the growth and development of different organs, considering that flowering and fruiting represent drain organs with high demand for photoassimilates to reach maturation (Taiz *et al.*, 2017). Costa *et al.* (2020) observed higher photosynthetic capacity of cowpea genotypes (*Vigna unguiculata*) in vegetative than in the reproductive stage.

Thus, by the time we analyzed gas exchanges, the genotypes of jambu were in different stages of the reproductive phase, being these rates higher in the genotypes of *A. oleracea* (Table 2), which may have caused different degrees of nutrient remobilization from leaves to jambu inflorescences, as verified by Peçanha *et al.* (2019), resulting in negative effects about net CO_2 assimilation capacity in the leaves. Therefore, the remobilization of nutrients can explain, to a certain degree, the changes in the photosynthetic performance of the tested genotypes. According to Taiz *et al.* (2017), the mineral composition of plants is a factor that promotes significant changes in the photosynthetic capacity of plants.

The higher photosynthetic rates for the genotypes of *A. ciliata* resulted in higher consumption of the internal CO_2 concentration (*Ci*), and consequently higher *A/Ci*, except for genotype UFR-7. On the other hand, the genotypes of *A. oleracea* showed higher *Ci*, consequently lower *A/Ci* (Table 4), which means that the CO_2 arriving in leaf mesophyll cells is not being assimilated in the carboxylate phase, possibly because of biochemical limitations due to factors intrinsic and/or extrinsic to the plant, since the CO_2 accumulation in the stomatal chamber indicates and/or causes metabolic imbalances, such as Rubisco regeneration limitation (ribulose-1,5 bi-phosphate), which promotes a reduction in net photosynthesis (Fernandes *et al.*, 2015; Taiz *et al.*, 2017).

The photosynthetic performance of plants is a trait that undergoes alteration due to genetic, morphological, and environmental traits (Taiz *et al.*, 2017), therefore, we believe that the photosynthetic capacity of the genotypes tested in this study was influenced by the phenological age of the plants since the lowest rates of photosynthesis were obtained in genotypes which showed earlier flowering. Such a hypothesis is also reinforced by the lowest photosynthesis showed by UFR-7, considering that this material, among

A. ciliata species, was the only one that flowered early and obtained the lowest photosynthesis rate (Table 4).

The responses for growth and production can be related to physiological changes observed in the genetic materials. However, we highlight that in this study, in addition to the intrinsic capacity of each species and/or genotype to adapt to the hydroponic system, we verified strong indications that phenological differences governed the magnitude of these alterations, which is justified by the greater photosynthetic capacity showed by genotypes of *A. ciliata* which flowered late (Table 4). Nevertheless, these genotypes did not show a greater capacity to accumulate total biomass compared to *A. oleracea*, which means that these can be harvested after 60 DAS, if the aim is supposed to be total biomass production. Considering the genotypes of *A. oleracea*, although a lower photosynthetic capacity of plants was observed at the time of analysis, we verified that throughout their vegetative and reproductive cycle these materials sent a substantial photoassimilate supply for the growth and development of their organs, which promoted greater accumulation of total fresh mass (Table 4).

Given the above, this study showed genetic differences in relation to growth, production, and physiological responses between *A. oleracea* and *A. ciliata* species, as well as a variation in terms of the commercial part of genotypes of the same species grown in hydroponics.

We concluded that *A. ciliata* and *A. oleracea* genotypes can be used in the hydroponic system for producing shoot fresh mass. The genotypes of *A. oleracea*, in addition to the ability to accumulate total fresh mass, showed high potential for inflorescence production, mainly UFR-2 and UFR-4 for presenting greater production of shoot fresh mass and inflorescences, respectively. Therefore, they shall be considered in this crop breeding program.

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