Jambu varieties performance under shading screens[1]

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ABSTRACT

Shading screens have been extensively used in leafy-vegetables production system. Nevertheless, there is still a substantial lack of knowledge regarding the effects of this technology on the performance of non-conventional vegetables such as jambu, a typical staple food with social and economic importance for the Amazon region. This study thus aimed to evaluate the effects of shading screens on the agronomic performance of two jambu varieties. The experiment was performed in a randomized block design, in a 4 x 2 factorial scheme (shading screens and varieties), with four replications. Plants were then evaluated for morphophysiological and yield parameters. As an outcome, there was no significant interaction between shading screens and varieties for assessed variables. On the other hand, the shading screen itself affected significantly jambu varieties yield. The 50%-shading screen for instance provided both higher fresh weight accumulation and higher shoot water content. Moreover, 50%-shading screen led to an increase in both productivity (Kg m^{-2}) and yield (bunch m^{-2}) by 46%, respectively. The use of 50%-shading screen improves the agronomic performance of jambu, hence being a suitable technological alternative available for the farmers.

Keywords: *Acmella oleracea* (L.) R.K Jansen; non-conventional vegetables; luminosity.

INTRODUCTION

The species *Acmella oleracea* (L.) R.K Jansen, known as jambu, is one of the most popular non-conventional vegetables in the Amazon (Gusmão & Gusmão, 2013). According to Borges *et al*. (2013), jambu is traditionally used for both regional cuisine and medicinal purposes, such as to treat anaemias, aches, and colds (Lorenzi & Matos, 2008). Due to its wide applicability, the economic importance of jambu has increased considerably in recent years (Sampaio *et al*., 2018). However, the scarcity of studies concerning cultural practices for this species is notorious, and this is a limiting factor for its fitness and yield improvement.

According to Menezes Júnior & Vieira Neto (2012), the performance of jambu depends on its adaptation to the environment and cultural practices adopted in the field. Belonging to the genus *Acmella* and it being a C3-metabolism-plant (Gusmão & Gusmão, 2013), jambu grows well in partially shaded environments (Sampaio, 2017). Nonetheless, jambu is also adapted to full sun, justifying thus more studies addressing the performance of this specie under different bright quality and intensities.

According to Queiroga *et al*. (2001), several techniques have been developed seeking to obtain both higher yield and quality of vegetable supply throughout the year. The cultivation of vegetables under shading screens has been widely used seeking to manipulate the radiation intensity on the vegetables' surface, affecting plant's physiology, yield and quality. It is worth noting that the light intensity management not only reduces the radiation on these environments, but also increases the fraction of diffused light, thereby altering the spectrum quality. In other words, the increase in shading intensity increases blue light fraction (400-500 nm) and decreases red light fraction (600-700 nm) (Li *et al*., 2010). Among physiological aspects,

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leaf anatomy, chloroplast structure and photo-assimilates distribution at the whole plant appear as the most influenced by the luminosity management (Gondim *et al*., 2018).

Studies concerning the influence of shading screens have been performed for several leafy vegetable species. In lettuce, for instance, Ramos (1995) observed the use of shading nets increases plant height, biomass accumulation, yield, and nutritional leaf quality. Costa *et al*. (2011) likewise demonstrated that the cultivation under 50%-shading screen may increase arugula yield by 43%, concomitantly higher both leaf area and biomass accumulation. However, for non-conventional vegetables such as jambu, studies exploiting shading screens and plant yield are quite limited. Therefore, this work aimed to evaluate the effect of shading screens on the agronomic performance of jambu varieties.

MATERIAL AND METHODS

The experimental was carried out at Experimental School Farm from Universidade Federal Rural da Amazônia (UFRA), Igarapé-Açú, Pará's northeast (01° 07' 48,47'' S, 47° 36' 45,31'' W, e 54 m above sea level), in September-October (2018) timeframe. The region climate is classified as Ami according to Köppen's classification system, with a maximum annual average of temperature about 32.2°C and a minimum of 21.4°C (Bastos & Pacheco, 1999).

Plants were grown in Dystrophic Yellow Argisol. The soil chemical analysis from samples collected to a depth of 0-20 cm is described as follows: pH in $CaCl_2$ of 4.8; 16.0 O.M.; 8.0 g dm^{-3} P_{resin}; 0.7; 15.0 and 4.0 mmolc dm^{-3} K, Ca and Mg, respectively. A randomized block design was used, in a 4 x 2 factorial scheme (shading screens x varieties), with four replications - 25 plants per plot - with six plants as a useful area. The first factor was composed by black polypropylene shading screens (30%-shading screen; 50%-shading screen; 70%-shading screen and open field) and the second factor as jambu varieties (purple flower and yellow flower).

Beds with 1.0 m wide by 1.0 m long and 0.20 m high were built. The shading screens system was structured in a low tunnel model with 1.0 m high. The arch structure was made of bamboo attached to the soil. Subsequently, the screens were stretched and tied on both sides of the arches, leaving a gap of approximately 50 cm (to not affect the irrigation system).

Jambú seeds were obtained from producers located in Igarapé-Açu municipality, state of Pará. The seeds (five seeds per cell) were sown in a polystyrene tray containing 200 cells filled with commercial substrate Tropstrato®. At 12 days after germination, single one seedling per cell remained after thinning. During this timeframe, the trays were placed on a bench under a covered environment with a 50%-shading screen. The irrigation was performed manually, three times a day (07:00, 12:30 and 17:00) at the substrate saturation capacity (minimum drainage). The seedlings were then transplanted at 25 days after emergence (showing four definitive leaves). The spacing adopted was 0.20 m between lines and 0.20 m between plants.

Both soil liming and fertilization were performed based on the soil chemical analysis and Cravo *et al*. (2007) recommendations for leafy vegetables as follows: 20 g m^{-2} urea; 20 g m^{-2} potassium chloride and 150 g m^{-2} simple superphosphate. Phosphorus was applied once only at the beginning of the experiment, and nitrogen, as well as potassium, were otherwise applied at every 10 days.

The irrigation was performed by a micro-sprinkler system, containing eight micro-sprinklers distributed over the area, manually activated everyday morning (08:00 am) and afternoon (4:00 pm), with an operating time of 30 min.

Manual control of invasive plants was conducted periodically. There was no application of phytosanitary products, since there was no significant occurrence of pests. Only one harvest was performed after 40 days after transplanting (DAT).

Six plants per plot were evaluated for main branch length, by measuring along the neck to the main branch apex (expressed in centimeters); the number of inflorescences, by counting the total of inflorescence per plant; dry inflorescence weight, by drying the inflorescence in an oven at 65 ° C for 48 hours before being weighted; the number of secondary branches, by counting the total of secondary branches per plant; shoot fresh weight, by weighing the shoot (stems, leaves, and inflorescences); shoot dry weight, by drying the shoot in an oven at 65 ° C for 48 hours before being weighted; dry leaf weight, by drying the leaves in an oven at 65 ° C for 48 hours before being weighted; and shoot water content, estimated by the difference between shoot fresh weight and shoot dry weight.

Leaf area was assessed on a sample composed of two plants per plot and estimated by the leaf discs dry weight method adapted from Hinnah *et al*. (2014); specific leaf area, estimated using the ratio between leaf area and leaf dry weight; leaf area index (LAI), obtained by the ratio between leaf area and soil area available for each plant. Productivity was estimated by the ratio between shoot fresh weight and area (Kg m^{-2}). The yield of bunches (bunches m^{-2}) was estimated by the ratio between productivity and the average weight of a commercial jambu bunch (300 g) produced by the conventional system.

The data were submitted to the verification of assumptions of the analysis of variance (ANOVA). Data normality was verified by Liliefors' test at 5% significance level. Once given the assumptions, ANOVA was performed. If ANOVA showed significant effects, Tukey test $p > 0.05$ was applied seeking to determine differences between treatments. To examine the individual effect of plants within the plot, analysis of variance among and within families was performed using GENES software (Cruz, 2013).

RESULTS AND DISCUSSION

There was no significant interaction between shading and jambu varieties for , so the factors were examined separately. For shading screens, main branch length, number of secondary branches, shoot fresh weight, shoot water content, productivity and yield were statistically different. On the other hand, only main branch length, number of inflorescences and inflorescence dry weight showed a significant difference when jambu varieties were compared (Table 1).

For main branch length (Table 1), both 50% and 70%-shading screens displayed the highest values on average. Whilst for variety factor, the main branch length was higher in purple flower variety (30.50 cm) as compared to the yellow one. These results indicate thus jambu plants submitted to higher shade levels develop mechanisms to overcome sub-optimal light conditions, maximizing the radiation capture for their fundamental development, by allocating more resources towards the main branch elongation. This response occurred likely due to the presence of photoreceptors, pigment-protein that promotes morphological responses in plants. Among them, phytochrome is the main photoreceptor and acts by absorbing red, distant red and blue light (Weller, 2017). Moreover, it is worth suggesting that the jambu plant behavior showed in the present study may be likely a “shadow avoidance” response. In close agreement with this, Queiroga *et al*. (2001) demonstrated the higher lettuce plants occurred under higher reflective shading screens, indicating thus an etiolation event in such plants.

Regarding the number of inflorescences and inflorescences dry weight (Table 1), significant differences were observed only between varieties. The yellow flower variety for instance demonstrated higher values on average than purple flower for both variables.

In contrast to what was demonstrated in the present study, Neves *et al*. (2013) observed a significant difference between types of shading screens for the number of inflorescences in jambu. In their study, treatment composed by 30%-shading screen provided higher production of floral chapters, as compared to both 50%-shading screen and the control (open-top field). In this vein, it is worth highlighting that parameters related to jambu inflorescence production are extremely important, because most of the compounds demanded by the cosmetics and pharmaceutical manufacturing industries are found in the inflorescences (Borges, 2012), as spilanthol, the main isolated metabolite in jambu (Barbosa *et al*., 2016).

For the number of secondary branches (Table 1), there was no statistical difference for either shading screens or varieties. This response seems not immediately obvious since it is well-known that the environment alongside genetic factors influences plant’s morphological characteristics, as the higher branching (Jurado *et al*. 2006). Thus, given the behavior was not observed in the present study, further studies seeking to comprehend how the branching pattern in jambu varieties responds to environmental conditions are needed.

Another important assessed parameter was shoot fresh weight (Table 1). For this variable, there was a significant difference only for shading screens factor, with the 50%-shading screen leading to an increased shoot fresh weight accumulation. Studies carried out by Hirata & Hirata (2015), with watercress, *Rorippa nasturtium-aquaticum*

Table 2: Summary of analysis of variance for main branch length (MBL), number of inflorescences (NI), number of secondary branches (NSB), shoot fresh weight (SFW) and shoot dry weight (SDW), obtained in varieties of jambu ‘purple flower’ and ‘yellow flower’ as a function of shading screens. UFRA, Capanema-Pará, 2019

FV	GL	Mean square of variabels				
		MBL	NI	NSB	SFW	SDW
Blocks	3	423.71	28.71	21.04	1167.65	134.56
Treatments	7	598.29^{**}	71.28^{ns}	21.29^{*}	24897.17^{**}	50.95^{ns}
Error	21	135.00	44.52	6.39	3253.77	56.18
Within	160	69.05	12.11	5.63	1329.27	14.58
Average	28.58	6.01	10.48	104.48	9.39	
CVe^1		16.59	45.28	9.84	22.28	32.55
CVe^2		11.59	38.63	3.38	17.14	28.01
CVga		15.36	17.55	7.51	28.74	-
CVgw		26.61	30.40	13.01	49.78	-
CVga/CVe^2		1.32	0.45	2.21	1.67	-
CVgw/CVe^2		2.29	0.78	3.84	2.90	-

Significant by F test at $p < 0.05$ (*) and $p < 0.01$ (**) levels; ^{ns}: not significant; CVe^1 and ^{2}: Coefficient of experimental variation; CVga: Coefficient of genetic variation among; CVgw: Coefficient of genetic variation within.

(L.) Hayek, a leafy vegetable species alike jambu, observed the shading promoted a positive impact on the shoot fresh weight, leading to an increase of 59% in productivity as compared to control (cultivation under full sun). In this context, Pezzopane *et al*. (2004) predicted the radiation balance determines available energy for photosynthesis and processes such as evaporation, heating or cooling of air and soil. Hence, the incidence of direct radiation impedes the maintenance of soil moisture at open environments and this may affect plant development, since jambu is highly adapted to elevated moisture into the soil (Gusmão & Gusmão, 2013). An increased shoot fresh weight in jambu growing under shading screens has been already reported in climatic conditions other than Pará, such as observed by Neves *et al*. (2013) using a 50%-shading screen under Cáceres - MT environmental condition.

When shoot dry weight and leaf dry weight were examined (Table 1), no major influence of either shading screens or varieties of jambu was observed. This may suggest the increase in shoot fresh weight is likely attributed to the higher water content in the tissues.

For shoot water content (Table 1), a significant difference only between shading screens treatments was verified. Markedly, plants growing under both 50% and 70%-shading screens showed higher shoot water content regardless of variety. According to Borges *et al*. (2013), covered environment affects considerably tissue water content in jambu. In their study, 50%-shading screen benefited transpiration regulation and provided higher water accumulation in plants (Silva *et al*., 2006). In the present study, this behavior is evidenced by the higher shoot water content observed in jambu plants under 50%-shading screen.

For leaf area, specific leaf area and leaf area index (Table 1), no statistical differences between shading screens and jambu varieties were observed. Thus, an increase in leaf area, specific leaf area, and LAI under shading conditions would be so far expected and also closely related to anatomical changes observed in shade-adapted-leaf, as thinner cuticles and epidermis, less mesophilic thickness, a lower proportion of conductive and supporting tissues as well as a greater proportion of intercellular spaces and lower stomatal density (Gobbi *et al*., 2011). However, such alterations were not observed in the present study. Therefore, it seems sensible and necessary more studies addressed to understand how leaf development in jambu responds to the light intensity dynamics.

For productivity (Table 1), a significant difference was observed only for shading screens. Notably, the cultivation of jambu under 50%-shading screen promoted the best productive performance, differing statistically as compared to other treatments. Based on this data, the use of the 50% shading screen provided a gain of 46.23% in productivity. This response has been also described for other vegetable species (Bezerra Neto *et al*., 2005; Brant *et al*., 2009; Espindola Júnior *et al*., 2009; Otoni *et al*., 2012; Silva *et al*., 2015).

Yield, expressed in packs of jambu per area, was another productive characteristic evaluated (Table 1). As seen in productivity, the highest yield was obtained under 50%-shading screen, reaching approximately 12 bunches per m^{-2} bed cultivation. Regardless of how, it is important to bear in mind that the way of cultivation practiced by jambu producers in Pará is under full sun, which yielded six-packs per m^{-2} bed cultivation in the present study.

Based on the yield obtained with the cultivation of jambu under 50%-shading screen as well as on the average of pack price produced in a conventional system - e.g. R$ 1.00 (Gusmão & Gusmão, 2013) - is evidenced that the producer can compensate the costs with the acquisition of shading screens even though in the first year. Therefore, the use of a 50%-shading screen increases considerably the productive efficiency of jambu cultivation when compared to the open field system, currently the main way practiced by the Pará's farmers.

Another aspect to highlight in the present study is the high coefficients of variation observed for some evaluated characteristics. Because of this, an analysis of variance within the plot was carried out to comprehend the variation based on individual plant data. According to the analysis of variance within the plot (Table 2), a significant difference was observed between the treatments (jambu varieties) cultivated under the shading screens, such as the main branch length, number of inflorescences, number of secondary branches and shoot fresh and dry weight. The higher values of the genetic variation coefficient within the plot (CVgw) demonstrated the lack of homogeneity among plants within the same variety.

For the main branch length, number of secondary branches and shoot fresh weight, a variation within the parcel was 2.3, 3.43 and 2.90 times higher than the experimental error observed, as stated by the CVgw/CVe ratio. This means that such variation among individuals was not due to an experimental but to a genetic effect, in a manner that this inflated the variation coefficient for most of the analyzed characteristics.

Thus, it is possible to claim that either purple or yellow flower variety displays genetic variation between the plants. Consequently, they are not a stable genetic material. The existence of variance may be also a fundamental feature, as it is a basic premise for the genetic improvement of plants and subsidizes genetic progress with the practice of selection (Cruz *et al*., 2004). Therefore, this material may be harnessed by breeding programs that are seeking to exploit natural genetic variation of jambu.

Table 1: Mean values for main branch length (MBL), number of inflorescences (NI), inflorescence dry weight (IDW), number of secondary branches (NSB), shoot fresh weight (SFW), shoot dry weight (SDW), leaf dry weight (LDW), shoot water content (SWC), leaf area (LA), specific leaf area (SLA), leaf area index (LAI), productivity (PROD) and yield (Y) of jambu varieties as a function of shading screens. UFRA, Capanema-Pará, 2019

Shading screens	**MBL (cm)**	**NI**	**IDM (g)**	**NSB**	**SFW (g)**	**SDW (g)**	**LDW (g)**	**SWC (g plant^{-1})**	**LA (cm^2 plant^{-1})**	**SLA (cm^2 g^{-1})**	**LAI**	**PROD (kg m^{-2})**	**Y (bunches m^{-2})**
Open field	24.80 b[1]	5.12 a	0.49 a	10.20 a	82.94 b	11.01a	5.46 a	71.92 b	228.28 a	9.18 a	0.57 a	2.07 b	6.87 b
30%	25.05 b	6.00 a	0.56 a	10.12 a	84.65 b	8.99 a	6.09 a	75.65 b	235.27 a	26.92 a	0.58 a	2.11 b	6.87 b
50%	32.54 a	7.87 a	0.45 a	10.12 a	154.06 a	8.02 a	5.98 a	146.05 a	298.28 a	32.02 a	0.74 a	3.85 a	12.87 a
70%	31.94 a	5.12 a	0.43 a	11.50 a	96.61 b	9.56 a	4.90 a	87.05 a	249.59 a	35.05 a	0.62 a	2.41 b	8.00 b
F test	6.39 **	1.90 ns	0.50 ns	3.24 ns	14.67 **	1.34 ns	2.77ns	19.13 **	0.42 ns	0.58 ns	0.42ns	14.61 **	14.97 **
MSD	6.59	3.70	0.31	1.42	34.53	4.26	1.29	31.11	191.06	18.26	0.47	0.86	2.91
Varieties[2]													
Purple	30.50 a	5.00 b	0.33 b	10.93 a	103.80 a	9.35 a	5.50 a	94.45 a	273.97 a	202.35 a	0.68 a	2.59 a	8.50 a
Yellow	26.66 b	7.06 a	0.63 a	10.18 a	105.33 a	9.44 a	5.71 a	95.89 a	231.74 a	279.77 a	0.58 a	2.63 a	8.81 a
F test	5.26 *	4.81 *	14.15 **	4.32 ns	0.03 ns	0.01 ns	0.40 ns	0.03 ns	0.46 ns	0.98 ns	0.75 ns	0.03 ns	0.18 ns
MSD	3.48	1.95	0.16	0.75	18.21	2.25	0.68	16.42	100.79	9.63	0.25	0.45	1.53
Interaction	2.47 ns	0.91 ns	0.63 ns	1.20 ns	0.91 ns	0.76 ns	1.68 ns	0.93 ns	1.81 ns	2.28 ns	1.82 ns	0.91 ns	0.88 ns
CV (%)	16.56	44.11	47.29	9.66	23.69	32.56	16.61	23.45	54.21	42.54	54.36	23.72	24.16

[1]Means followed by the same letter in column do not differ by Tukey's test at $p < 0.05$ (*) and $p < 0.01$ (**) levels; ns: not significant; MSD: minimum significant difference; CV: coefficient of variation (%). [2] Purple: purple flower variety; Yellow: yellow flower variety.

CONCLUSIONS

The use of 50%-shading screen improves the agronomic performance of jambu, hence being a suitable technological alternative available for the farmers.

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