Agronomic performance and physicochemical characteristics of onion genotypes under different spacing in the humid Amazonian tropics

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Abstract

The Southwest region of Pará state, Brazil, imports 100% of all onion consumed from other regions of the country, which generates market dependence and raises the product's costs. The present study investigated parameters related to germination, agronomic performance and postharvest characteristics of five onion cultivars at different planting densities. The experiment was conducted in two stages. In the first, in a greenhouse, the germination kinetics was evaluated. In the second, in the field, the seedlings were transplanted into beds. The experimental design was in complete randomized blocks in a 5 x 3 factorial scheme with three replications. The treatments consisted of the combination of five cultivars (Mata Hari, Dulciana, Cimarron, NUN 1205-F1 and Vale Ouro IPA 11) and three line spacing (20, 30 and 40 cm) 8 cm between plants. As for the germination rate (GR), the results allowed to highlight the cvs. Cimarron and Vale Ouro IPA 11 with an 80.55% and 77.77% of GR, respectively. There was a significant difference for total bulb productivity, highlighting Vale Ouro IPA 11 in the 8 x 20 cm spacing. For the bulb diameter, cv. Vale Ouro IPA 11 obtained the best results in all classes. In the average weight of the bulbs, *cv. Vale Ouro IPA 11 in the 8 x 40 cm spacing was the best treatment with 60.77g. As for total soluble solids, cv. Vale Ouro IPA 11 presented °Brix higher than the others, being significant at 1%. These results demonstrate that it is possible to produce quality onions in the Southwest region of Pará, which would reduce prices, since all commercialized onions come from regions outside the state.*

Keywords: *Allium cepa* L., bulbs, climate adaptation, planting density, sensory analysis; post-harvest.

1. Introduction

In Brazil, the onion (*Allium cepa* L.) is considered the third most important vegetable from an economic point of view, supplanted only by tomatoes and potatoes (Santos et al., 2018). World production data show that 98 million tons were produced in 2016, with an average productivity of 16.23 t ha^{-1} (FAO, 2018). In 2017, the national average productivity was 31.2 t ha^{-1} (IBGE, 2019).

Onion cultivation is of great socioeconomic importance in the country, since it is cultivated by small producers and demands a large amount of labor, generating employment and income and maintaining producers in the rural area (Resende and Costa, 2009; Lima et al., 2011a). In addition to being an extremely versatile plant and having good acceptance due to its spicy flavor, nutritional and medicinal value (Kale and Ajjappalavara, 2015).

In Brazil, onion production stands out in the South region with the states of Santa Catarina and Rio Grande do Sul, the Southeast region, mainly the states of São Paulo and Minas Gerais and the Northeast, in the São Francisco Valley, with the states of Pernambuco and Bahia as the largest producers (IBGE, 2019; Aline et al., 2020).

The productivity and quality of onion bulbs are associated with genetic, climatic and phytotechnical factors (Gonçalves et al., 2019). In onion culture, the choice of cultivar is conditioned by environmental factors, especially photoperiod and temperature, characteristic of each region, which favors the bulbification process. However, through management practices, it is sought to guarantee conditions that help the cultivar adopted to express its maximum potential, in order to meet the desirable productive characteristics for commercialization (Menezes Junior and Vieira Neto, 2012).

Among the factors of agronomic management that determine the success of commercial bulb production, the establishment of the ideal population of plants per hectare for each cultivar and cultivation system stands out (Baier et al., 2019). The use of higher or lower population densities directly influences several parameters such as productivity, diameter, fresh mass of the bulbs and their classification, which will reflect on the commercial value and profitability of the cultivation (Menezes Junior and Vieira Neto, 2012). In this context, several studies have been conducted in Brazil to demonstrate that planting density is extremely important in the quality of production (Menezes Junior and Vieira Neto, 2012; Henriques et al., 2014; Harms, et al., 2015; Santos et al., 2018).

Another considerable factor that benefits the onion's productivity is the way of producing seedlings. Crops established with tray seedlings, in addition to the shorter cycle, generally require less crop treatment, lower seed costs, more vigorous seedlings and better uniformity. Allied to this, there is the possibility of producing more than one seedling per tray cell, which contributes to reducing the cost per seedling produced (Nascimento et al., 2003).

Maximum and minimum temperatures are also important. Onion seeds germinate over a wide temperature range, however, temperatures above 30ºC affect both the germination percentage and all other parameters of germination kinetics (Pinheiro et al., 2014). The occurrence of temperatures above 30ºC can accelerate the formation of bulbs in the field (Costa et al., 2012). Thus, a warmer climate can be favorable for onion production. On the other hand, temperatures below 15ºC, in addition to delaying bulbification, can cause changes in bulb morphology (Wurr et al., 1998).

Water supply is another important factor in onion crops, as irrigation is considered an essential tool to increase its yield (Carvalho et al., 2018). Severe irrigation deficits applied in the growth and bulbification stages, negatively affect biomass production and productivity (Abdelkhalik et al., 2019). Drip irrigation allows greater efficiency in the application of water and fertilizers and allows for high-frequency irrigations, thus maintaining the soil water potential (SWP) relatively constant compared with furrow irrigation (Shock et al., 2000).

As with most vegetables, onion quality is closely linked to genetic factors that affect the variability of many characteristics, predisposing differences between cultivars (Sekara et al., 2017). External appearance, bulb size, color, flavor, firmness and chemical composition are genetic parameters. These attributes are determined, in part, by the genotype, by cultural treatments in the pre-harvest, by the appropriate harvest time and by post-harvest treatments, which aim, mainly, to guarantee the physical integrity and maintenance of the chemical quality of the bulbs (Finger and Casali, 2002).

Among the physical-chemical characteristics used to assess the post-harvest quality of vegetables, the soluble solids content, the total titratable acidity and the pH stand out (Chitarra, 1994). One of the most important characteristics of onion for industrialization, and in particular for the production of dehydrates, is its total solids content.

In addition to the temperature, the photoperiod is important for the bulbification process. Onion cultivars are called short days, requiring less than 12 hours of light, intermediate, requiring 13 to 14 hours and days between 15 and 16 hours (Sekara et al., 2017). Photoperiod combined with temperature, genetic factors and post-harvest qualities are important when you want to introduce onion cultivars in a given region.

The cultivation of onions represents a necessity for Pará, since the state supplies itself with products from other regions, mainly from the Northeast, which results in a high price offer to the consumer. With the construction of the Belo Monte Hydroelectric dam, demand for vegetables increased, making the region even more dependent on supply and prices. In addition, Brazil is not self-sufficient in onion production. The high consumption of this bulb during the year, associated with the smaller harvests in some producing regions, in certain periods of the year, makes its import essential. Until 2011, the regular share of imported onion in the Brazilian supply was 15%, mainly from China and Argentina (Camargo and Camargo, 2017).

Given the above, the objective was to evaluate the adaptation of onion genotypes in conditions of humid Amazonian tropics, related to seedling production, productivity, bulb classification and post-harvest characteristics at different densities using drip irrigation, in a production cycle.

2. Material and Methods

2.1 Experiment location and seedling preparation

The experiment was carried out from July to December 2016, in the experimental area of the Casa Familiar Rural in Altamira-PA, located in the following geographical coordinates: 03º09'28.6 "S (lat.) and 052º16'40.6" W (long.), altitude of 175 m. The climate of the region, according to the Köppen classification, is of the equatorial type Am (Dubreuili, et al., 2019), presenting two well-defined climatic seasons: the drought period from July to December corresponding to “summer” and the rainy period from January to June that corresponds to “winter”, with annual rainfall around 2.123 mm (Silva et al., 2009). Five cultivars of onions were used Table 1. The average maximum temperature during the field study reached 34.5ºC and the average minimum temperature was 24.4ºC.

Table 1. Cultivars of onions used in the experiment, Altamira-PA

Cultivar[1]	Type of cultivar	Bulb shape	Cycle[2]	Place of origin	Harvest
Mata Hari	Hybrid	Oblong	Super early	South Africa	2015
Dulciana	Hybrid	Oblong	Super early	South Africa	2015
Cimarron	Hybrid	Oblong	Super early	Itaty	2015
NUN 1205 - F1	Hybrid	Oblong	Super early	South Africa	2015
Vale Ouro IPA 11	Variety	Oblong	Super early	Brazil	2015

[1]Onion cultivars obtained in partnership with Casa Agropecuária Agrosanta and the Bayer S.A. Company

[2]Cultural cycle between 90 and 130 days.

The seedlings were prepared in a greenhouse covered with 150 micron plastic film and conducted in expanded polystyrene trays of 128 cells, with a volume of 32 cm³, containing 80 L of fine coconut fiber as a substrate, 20 L of indigenous black earth, 300 g of castor cake, 250 g of osmocote and 150 g of phosphate fertilizer yorin master. Three seeds per cell were sown at an inch of depth. The nursery was irrigated twice with a manual watering can.

For the study, three trays of each cultivar were sown. For each treatment, a completely randomized design with three replications was adopted. In each repetition, the eight central cells of the trays were considered for analysis, totaling 72 seedlings per treatment. Variables of percentage and kinetics of emergence and seedling growth were evaluated for each onion cultivar.

The Germination Rate (GR) was evaluated from the daily seedling emergency count for 11 days, at the same time. Emerging seedlings were those that showed visible hypocotyl emission above the substrate. From the daily evaluations, the Average Germination Time (AGT), the Average Germination Speed (AGS) and the Germination Speed Index (GSI) were estimated.

AGT is the average time, in days, required for seeds to germinate (Labouriau, 1983; Santana and Ranal, 2000). The AGS was calculated to be the inverse of the AGT, through daily counts (Labouriau, 1970; Santana and Ranal, 2000). The GSI, a measure widely used to predict the relative vigor of seed samples, was calculated from the sum of germinated seeds divided by the time required for this to occur (Maguire, 1962; Santana and Ranal, 2000). The results were subjected to analysis of variance (F test), comparing the means by the Scott-Knott test, at the level of 5% probability using the program Assistat Beta version 7.7 (Silva and Azevedo, 2016). The data for GR and GSI were transformed into a square root. The other data did not undergo transformation.

2.2 Field experiment setup

The soil of the area, Yellow Latosol, sandy loam, terrace phase, sandy texture, presented, according to the soil analysis in the layer from 0 to 20 cm deep, the characteristics: pH in H_2O = 4.7; organic matter = 1.7 dag kg; P = 3.0 mg dm^{-3}; K = 31 mg dm^{-3}, Zn = 0.2 mg dm^{-3}, Cu = 0.9 mg dm^{-3}, B = 0.53 mg dm^{-3}, S = 9.0 mg dm^{-3}e, in cmolc dm^{-3}, Ca^{2+} = 1.1; Mg^{2+} = 0.3; Al^{3+} = 0.7; H + Al = 4.2; SB = 1.5; CTC (t) = 2.2; CTC (T) = 5.7 and V = 26.9%.

The area used for the experiment was 200 m². First, the area was cleared and then the liming was carried out on 07/21/2016 with virgin dolomitic lime Geox, a material that has 60% CaO and 30% MgO and PRNT = 180%, in the dose of 1.5 t ha, aiming at raise the pH to 6.0. The limestone was distributed on the soil surface and incorporated with the aid of a cultivator at a depth of 20 cm, 30 days before transplantation. The construction sites were constructed in three different dimensions (0.80 x 15 m; 1.20 x 15 m and 1.60 x 15 m) with 0.20 m high, about 0.70 m apart from each other. The basic fertilization was done with 300 kg ha^{-1} of P_2O in the form of triple superphosphate, in addition to 5 kg m^{-2} of tanned pig manure in each site eight days before transplanting. The characteristics of swine manure are shown in Table 2.

Table 2. Result of analysis of swine solid organic fertilizer

ANALYZED PARAMETERS			
Humidity at 60-65 ^{0}C (%)	14.94	Phosphor (P_2O_5) (%)	2.25
pH in $CaCl_2$	7.82	Calcium (Ca) (%)	2.08
Total Organic Matter (%)	80.6	Potassium (K_2O) (%)	1.58
Compostable Organic Matter (%)	54	Magnesium (Mg) (%)	0.56
Organic Carbon (%)	30	Sulfur (S) (%)	0.57
Relationship C/N	11/1	Iron (Fe) (%)	0.58
Nitrogen (N) (%)	2.76	Zinc (Zn) (ppm)	149
Manganese (Mn) (ppm)[1]	176.5	Copper (Cu) (ppm)	107.5
Boron (ppm)	18.4		

[1] ppm = parts per million.

The experimental design used in the field was in randomized blocks, in a 5 x 3 factorial scheme, comprising five onion genotypes Table 1 and three spacing between lines (20, 30 and 40 cm) and 8 cm between plants, with three replications.

The seedlings were transplanted 43 days after sowing (DAS). The stand for each cultivar was made using a digital pachymeter and a scale to evaluate the parameters: leaf length and diameter of the pseudostem. On average, the seedlings went to the field measuring 3 mm in diameter in the pseudostem and 19 cm in height, obtained by measuring between the ground level and the end of the largest leaf.

Four lines were implanted per bed, spaced 20, 30 and 40 cm between them and 8 cm, between plants, with plots of 0.80 m^2 (1.00 m x 0.80 m), 1.20 m^2 (1.00 m x 1.20 m) and 1.60 m^2 (1.00 m x 1.60 m) with 48 plants distributed, making a population of 600, 400 and 300 thousand plants per hectare, respectively.

At 15 days after transplanting (DAT), 3.0 kg ha^{-1} of boron (boráx) and 4.0 kg ha^{-1} of zinc (FTE - 12 granulated) were added at a depth of 5 cm together with fertilization of coverage with 40 kg ha^{-1} of N (Urea) and 50 kg ha^{-1} of K (Potassium chloride), repeated at 30 and 45 DAT based on soil analysis and Embrapa recommendations (Cravo et al., 2007).

The adopted irrigation system was drip. The self-compensating emitters were of the *in-line* type, model NAAN PC with nominal flow of 1.6 L h^{-1} and spaced apart at 0.30 m. The drip tube was positioned in the plot, in order to meet the two rows of plant, working with a service pressure of 6 m of water column.

The control of pests and diseases, as well as the elimination of invasive plants was carried out while representing a threat to productivity. Since the manual weeding of the beds was all manual. For the prevention of diseases such as purple spot (*Alternaria porri* (Ellis) Cif.), Burning of the tips (*Botrytis squamosa*) and downy mildew (*Peronospora destructor* (Berk) Casp. Ex Berk), two applications were made with 20% mancozeb + ditiocarbamate 80% (Dithane®) in weekly sprays, in the dosages of 1.5 g L^{-1} of water. The thrips control (*Thrips tabaci*) was performed with two applications of Deltametrine (Decis 25 CE®), in the dose of 0.3 ml L^{-1} of the commercial product.

To determine productivity, the 16 central plants of each plot of a total of 48 that formed the repetitions were considered, with 8 plants from each central row. Discarding the plants that formed the border, with two plants from each row at the beginning and end of each plot and the two outer rows.

The harvest was carried out after the vegetative development of the bulbs, when the plants had more than 60% of "snap" that is, tipping of the aerial part, on average, 110 DAS. The bulbs were harvested manually, remaining for two days in the field and, subsequently, taken for “curing” in the shade and with good ventilation, where they remained for ten days until drying. After the "curing" process, the bulbs were weighed and classified into five classes, based on the transverse diameter: ≤35 mm, class I; > 35≤50 mm, class II; > 50≤70 mm, class III; > 70 ≤90 mm, class IV; > 90 mm, class V (Brasil, 1995). The total production of bulbs was determined by the sum of all classes and the commercial production by the sum of classes with a diameter greater than 35 mm.

2.3 Post-harvest analysis

After 15 days of the procedure of weighing and classification of the bulbs, some post-harvest parameters were verified to better differentiate the materials. These procedures were performed at the Post-Harvest Physiology and Technology Laboratory of the Faculty of Agronomic Engineering at UFPA in Altamira. The ºBrix content of each material was calculated, as well as the Total Titratable Acidity (TTA) and the respective pH.

Soluble solids (SS) - To find TSS (% in °Brix - Sugar content of each sample) a numerical scale refractometer was used. Two drops of juice were placed on the device's display and the results were expressed in % soluble solids (or °Brix).

Total Titratable Acidity (TTA) - It was determined by titration with 0.1N sodium hydroxide (NaOH) using a volumetric procedure. To the sample diluted in water (0.5 mL of extract from the samples of each genotype in 50 mL of distilled water) and for titration 3 drops of phenolphthalein; 0.1N NaOH was added slowly to the container by means of a burette, until the color of the solution changed to slightly pink; the volume used in the base was duly noted to calculate the percentage of organic acid in the sample according to the formula TTA = $V.f_a.f_b$ / TE where: TTA = total titratable acidity in g / 100 ml or %; V = spent volume of 0.1N NaOH in the titration; f_a = 0.1N alkali factor of the acid; f_b = NaOH correction factor and TE = test intake, that is, the amount of juice used for the titration in ml (Brasil, 1986).

Hydrogenionic potential (pH) - was found from the use of a digital bench pH meter. In this case, he used the onion juice without dilution in distilled water.

For all post-harvest data, he used three onions from each cultivar, which required 10 g of macerated onion of class II (transversal diameter between 35 to 50 mm) and three different repetitions. Statistical analyzes were performed with the assistance of the Assistat Beta version 7.7 program (Silva and Azevedo, 2016).

3. Results

3.1 Percentage variables and kinetics of seedling emergence and growth

All cultivars belong to the 2015 harvest, as shown in Table 1. Regarding germination, the values shown on the packaging labels were 90% for Mata Hari, 89% for Dulciana, 90% for Cimarron, 90% for NUN 1205 - F1 and 90% for Vale Ouro IPA 11. Table 3 shows that there was a significant difference at the level of 1% between cultivars for GR and GSI. For the other parameters analyzed, there was no significant difference.

Table 3. Anova summary for Germination Rate (GR), Germination Speed Index (GSI), Average Germination Time (AGT) and Average Germination Speed (AGS) of five onion cultivars under greenhouse conditions

		Average square			
Variation Sources	FD	GR	GSI	AGT	AGS
Treatment	4	1516.20**	1.4030**	0.81372^{ns}	0.00015^{ns}
Waste	10	244.21	0.2340	0.78321	0.00012
Total	14				
CV (%)		25	25.2	10.49	8.99
X^2		16.85*	18.16*		

** Significant at the 1% probability level (p <0.01); * significant at the 5% probability level (0.01> p <0.05); ns not significant; CV. Coefficient of variation.

The results presented allowed to highlight the cvs. Cimarron and Vale Ouro IPA 11 with GR of 80.55% and 77.77%, respectively. The cultivar Mata Hari, with only 25% GR, had the worst result in this parameter, while the cultivars Dulciana and NUN 1205 - F1 with 59.72% and 69.44%, respectively, were classified as intermediate (Table 4).

Table 4. Germination Rate (GR), Germination Speed Index (GSI), Average Germination Time (AGT) and Average Germination Speed (AGS) of five onions cultivars in greenhouse conditions in Altamira-PA

Treatments	GR	GSI	AGT	AGS
Mata Hari	25.00 b	0.803 b	8.948 a	0.115 a
Dulciana	59.72 a	1.815 a	8.431 a	0.119 a
Cimarron	80.55 a	2.258 a	8.884 a	0.113 a
NUN 1205 - F1	69.44 a	2.126 a	8.225 a	0.122 a
Vale Ouro IPA 11	77.77 a	2.595 a	7.675 a	0.130 a

The means followed by the same letter do not differ statistically. The Scott-Knott test was applied at the level of 5% probability ($\alpha \leq 0.05$).

For the GST, the results were significant at the 5% probability level. The highest GST was found in the cultivar Vale Ouro IPA 11, with 2,595 seedlings day^{-1}, corresponding to 13.9% per day. Also, according to Table 4, the cultivars Dulciana, Cimarron, Num 1205 - F1 and Vale Ouro IPA 11 formed a group, whose GSI is between 1.815 to 2.595. In the other group, the Mata Hari genotype had a GSI of 0.803. There was no statistical difference for the AGT and AGS parameters between onion genotypes.

Regarding the stand formation parameters of each cultivar, on average, the seedlings went to the field measuring 19 cm in height and 3 mm in diameter in the pseudostem. Vale Ouro IPA 11 stands out for its uniformity, being the best seedling stand, followed by Dulciana (Table 5).

Table 5. Leaf Length (LL) and Pseudostem Diameter (PD) ratio of five onion cultivars in house conditions of vegetation in Altamira-PA

Cultivars	LL (cm)	PD (mm)
Mata Hari	17.62 a	2.66 b
Dulciana	18.57 a	3.02 a
Cimarron	18.77 a	2.72 b
NUN 1205 - F1	19.00 a	2.72 b
Vale Ouro IPA 11	19.90 a	3.11 a
CV (%)	18.19	16.55

The means followed by the same letter do not differ statistically. The Scott-Knott test was applied at the level of 5% probability ($\alpha \leq 0.05$). CV. Coefficient of variation.

3.2 Onion productivity

There were significant differences for the isolated effect of cultivars on agronomic characteristics, bulb diameter, bulb height, average bulb weight and productivity (Table 6), showing that the cultivars from a genetic point of view are different.

The productivity data indicate that there were significant differences in the interaction between treatments and between cultivars ($p < 0.01$). The cultivar Vale Ouro IPA 11 provided greater productivity in the spacing between lines of 20 cm (30.03 t ha^{-1}). The Mata Hari and Cimarron hybrids with production of 27.59 and 24.86 t ha^{-1}, respectively, in the 20 cm spacing, also presented a production similar to the national average.

The lowest productivity was found in the hybrid Dulciana with 6.81 t ha^{-1} in the spacing of 40 cm between rows (Table 6).

Table 6. Bulb diameter, Bulb height, Fresh bulb mass and Average yield of different onion cultivars, 70 days after transplanting. Altamira-PA

Treatments	Bulb diameter in t ha^{-1}			Bulb height	Fresh bulb mass	Average yield
	≤ 35 mm	>35 ≤ 50 mm	>50 ≤ 70 mm	mm	g	t ha^{-1}
M.H x 20 cm	10.55 a	16.23 b	0.81 b	54.26 b	44.14 b	27.59 a
M.H x 30 cm	8.89 a	4.44 c	0.37 b	51.01 b	32.89 c	13.71 c
M.H x 40 cm	1.87 b	11.23 b	3.74 a	57.18 a	53.90 a	16.84 c
DUL x 20 cm	12.05 a	8.48 c	0.89 b	55.58 b	34.27 c	21.42 b
DUL x 30 cm	6.55 a	0.90 d	0.00 b	48.57 b	17.89 d	7.45 d
DUL x 40 cm	6.08 a	0.72 d	0.00 b	51.33 b	21.79 d	6.81 d
CIM x 20 cm	9.70 a	15.16 b	0.00 b	64.63 a	39.77 b	24.86 a
CIM x 30 cm	7.66 a	2.78 d	0.00 b	58.80 a	25.06 d	10.44 d
CIM x 40 cm	6.46 a	6.46 c	0.92 b	62.98 a	44.28 b	13.84 c
NUN x 20 cm	10.67 a	1.33 d	0.00 b	53.89 b	19.21 d	12.01 c
NUN x 30 cm	9.20 a	2.93 d	0.00 b	59.59 a	29.10 c	12.12 c
NUN x 40 cm	6.20 a	3.40 d	0.00 b	58.73 a	30.71 c	9.60 d
IPA 11 x 20 cm	1.88 b	26.28 a	1.88 b	56.03 b	48.05 b	30.03 a
IPA 11 x 30 cm	3.98 b	12.74 b	0.80 b	51.58 b	42.06 b	17.52 c
IPA 11 x 40 cm	0.41 b	14.04 b	4.54 a	57.41 a	60.78 a	18.99 b
Averages	7.52	14.08	3.72	57.18	43.41	19.79
CV (%)				6.95	19.55	18.32

The means followed by the same letter do not differ statistically. The Scott-Knott test was applied at the level of 5% probability ($\alpha \leq 0.05$). M.H = Mata Hari; DUL = Dulciana; MIC = Cimarron; NUN = NUN 1205 - F1; IPA 11 = Vale Ouro IPA 11. CV. Coefficient of variation.

The average bulb weight (ABW) is commercially important, as it defines the value and directs the type of market to which they are destined (Tavares, 2015). A peculiar characteristic of the onion is that, once the bulb growth phase begins, the growth of the leaves stops. Therefore, the size of the bulb at harvest is greatly influenced by the size and number of leaves on the plant, and it is important that the stimulation of the photoperiod only occurs after the plant has reached a certain degree of growth so that it is able to produce a large and well-formed (Oliveira et al., 2015). In the experiment there were significant differences for this parameter (p <0.01), the cultivar Vale Ouro IPA 11 with 60.78 g and Mata Hari with 53.90 g, both in the spacing between lines of 40 cm, were the ones that presented the highest ABW. Dulciana being 30 cm between lines, the one with the lowest average weight was 17.89 g (Table 6).

The classification of the bulbs according to the size class is another indicator of the quality of production achieved. The national consumer market prefers medium-sized bulbs, with masses of 80 to 100 g and transversal diameter, varying between 40 to 80 mm (Souza and Resende, 2002). As for the diameter of the bulb, there was a significant effect on classes I, II and III (Table 6). The cultivars with the lowest number of bulbs considered non-commercial (refuse) (Class I) were the cultivars Vale Ouro IPA 11 and Mata Hari. Regarding class II, the highlight is the cultivars Vale Ouro IPA 11 in the three spacing between rows with 26.28 t ha^{-1} (87.5%), 12.74 t ha^{-1} (72.7%) and 14.04 t ha^{-1} (73.9%) and the Mata Hari and Cimarron hybrids, with 16.23 t ha^{-1} (58.8%) and 15.16 t ha^{-1} (61%), respectively, in the 20 cm spacing , of the total productivity for the treatments.

The cultivars Dulciana and NUN 1205 - F1 showed not to be adapted for the region, with a productivity in class II between 0.72 t ha^{-1} (10.6%) for Dulciana and 1.33 t ha^{-1} (11.1%) for NUN 1205 - F1. Only the cultivars Vale Ouro IPA 11 and Mata Hari achieved productivity in class III in all treatments, with Vale Ouro IPA treatments 11 x 40 cm with 4.54 t ha^{-1} (23.9%) and Mata Hari x 40 cm with 3.74 t ha^{-1} (22.2%) of the total productivity, obtaining the best yields among the six treatments, corresponding to the cultivars. For the other classes, productivity was not obtained in any of the cultivars (Table 6).

3.3 Post-harvest characteristics

Regarding the soluble solids of the treatments, there was a great variation between cultivars from 4.61% to 8.15%, where cv. Vale Ouro - IPA 11 had the highest value, being significant at the level of 1% probability (Table 7), followed by the hybrids Mata Hari, Cimarron and Nun 1205 - F1, and with lower performance for Dulciana. The high content of total soluble solids is linked to the high pungency and good storage quality of the bulbs. Another indication related to soluble solids is the maturation stage of the material, that is, higher percentages of ºBrix refers to saying that the cultivar is closer to maturation.

Table 7. Soluble solids, pH and titratable acidity of five onion cultivars produced in Altamira-PA

CULTIVARS	POST-HARVEST CHARACTERISTICS		
	Soluble Solids (°Brix)	pH	Titratable Acidity (%Pyruvic Acid)
Mata Hari	6.51 b	5.65 a	0.30 a
Dulciana	4.61 c	5.70 a	0.26 a
Cimarron	6.23 b	5.25 b	0.28 a
Nun 1205 - F1	5.18 c	5.24 b	0.29 a
IPA 11	8.15 a	5.26 b	0.24 a
Average	6.14	5.42	0.27
CV (%)	12.39	3.48	9.79

The means followed by the same letter do not differ statistically. The Scott-Knott test was applied at the level of 5% probability ($\alpha \leq 0.05$). CV. Coefficient of variation.

As for acidity, there was no significant difference between cultivars, data corrected in square root, maintained the degree of indifferent significance (Table 7).

For the pH, the cultivars Dulciana and Mata Hari had the highest values, standing out from the others in this parameter, with values 5.70 and 5.65, respectively. The one with the lowest pH value was the hybrid NUN 1205 - F1, with 5.24 (Table 7).

4. Discussion

Self-sufficiency in onion production is important because it makes the product more affordable to consumers. The hypothesis was tested that the production of onions in the Southwest region of the state of Pará would be viable, mainly in the dry season that comprises the Amazonian summer.

The results presented allowed to highlight the cvs. Cimarron and Vale Ouro IPA 11 with GR of 80.55% and 77.77%, respectively, with superior physiological potential, very similar to that found by Hölbig et al. (2011), who working with cv. Bola Precoce showed GR ranging from 58 to 88%.

Regarding the Germination Rate, Ramos et al. (2004), suggest the need to carry out as many tests as possible before classifying the lots as to their physiological potential, as each test has a different principle and provides complementary information for the decision regarding the final destination of each seed lot. Still regarding the result of the Mata Hari genotype, which presented a very low GR (Table 4), most of the seeds probably went into dormancy, and the environment and substrate were not conducive to overcoming this, since the seeds that remained at the end of the experiment were considered viable.

Seed dormancy is related to the length of the cycle and rusticity of the species, allowing seeds to remain viable for long periods in the soil, until some favorable environmental condition acts on the physiological mechanisms and provides germination. Other factors like temperature, cultivar, and seasonal change in weather conditions during the vegetation period show significant influence on dormancy of onion (Sharma et al., 2016).

The highest GSI was found in the cultivar Vale Ouro IPA 11, with 2.59 seedlings day^{-1}, corresponding to 13.9% per day, similar to that found by Hölbig et al. (2011) for cv. Early Ball, comprised between 8.5 to 12.8%. Vale Ouro IPA 11 formed a group with Dulciana, Cimarron and Num 1205 with GSIs between 1.81 to 2.59. Mauri et al. (2010), studying the germination of Brocolis (*Brassica oleracea* var. *Italica* L. Plenk) in the conventional system, found the oscillation of the GSI between 2.53 to 4.85 seedlings day^{-1} in different commercial and organic substrates. In a study by Trenhago et al. (2011), evaluating the GSI of garlic (*Allium sativum* L.) in different planting positions, found, on average, 2.05 seedlings day^{-1}.

For AGT, the result was not significant for both treatments (Table 4). However, four of the five treatments, the AGT was above 8 days^{-1}. According to work by Pinheiro et al. (2012) the temperature influenced the AGT of onion seeds, with the shortest germination time of five days for seeds submitted to 25ºC. In the study now presented, the temperature ranged from 28ºC to 42ºC.

According to Carvalho and Nakagawa (2012), the temperature below or above the optimum tends to reduce the speed of the germination process, exposing the seedlings for a longer period to adverse factors, which can lead to a reduction in the total germination. The optimum temperature provides the percentage of maximum germination in a shorter period of time, while maximum and minimum temperatures are restrictive points for seed germination. Onion seeds exposed in the field at temperatures between 10ºC and 30ºC can produce a higher germination percentage, lead to development of normal seedlings (Abu-Rayyan et al., 2012). Carvalho et al. (2015) evaluating the radish (*Raphanus sativus*) AGT found, for one of the varieties 5.2 days^{-1}. Costa et al. (2015), working with onions from cv. IPA 11 found AGT values of 6.49 at 25ºC and 4.19 at 34ºC. In the work in question, the temperature in the greenhouse fluctuated considerably, concluding the experiment at an average of 35ºC.

AGS is the opposite of AGT, that is, the higher the AGT the lower the AGS. In this parameter, there was no significant difference between the treatments studied (Table 4). The highest AGS of treatments was 0.13 day^{-1} of the Vale Ouro IPA 11 genotype and the lowest, 0.11 day^{-1} of Mata Hari. Costa et al. (2015) for a similar temperature situation, they found 0.23 day^{-1} for cv. Vale Ouro IPA 11. Rêgo et al. (2015) analyzing the same cv. Vale Ouro IPA 11 found AGS of 0.16 day^{-1} and 0.17 day^{-1} for different concentrations of CO_2, corroborating the results presented in the present study.

On average, the seedlings went to the field measuring 3 mm in diameter in the pseudostem and 19 cm in height, highlighting Vale Ouro IPA 11 for its uniformity, followed by cv. Dulciana (Table 5). These results demonstrate the possibility of producing onion seedlings under the conditions of the study region.

In terms of productivity, the cv. Vale Ouro IPA 11 with productivity 30.033 t ha^{-1} in the spacing between lines 20 cm (Table 6), well above the national average, estimated at 27.844 t ha^{-1} (IBGE, 2016). A result similar to that found by Lima et al. (2011b) with 33.81 t ha^{-1} for the same cv. Vale Ouro IPA 11 in conditions of the state of Rondônia, corroborating with the data of this research.

This significant difference in productivity between the genotypes demonstrates that the interaction between genotype x environment (GxE) was decisive in filling the bulb and, consequently, in the final production. Biotic factors such as photoperiod and temperature are decisive, given that for bulbification, the length of the day must decrease and the temperature increase, but the length of the day must be sufficient. Precise temperature control is therefore especially important when studying different growth phases of onion (Sekara et al., 2017; Khosa et al., 2018). This interaction effect can even lead different genotypes evaluated to a huge diversity of patterns and results (Coimbra et al., 2009).

Interaction (GxE) arises when a genotype responds differently to environmental variations, and in this situation, the best genotypes in one location may not necessarily be the best in other locations. Thus, the cultivar choice is linked to local climatic conditions (Sekara et al., 2017). This explains why genotypes such as Dulciana and NUN 1205 - F1 do not achieve the same performance as in other regions.

In Brazil, there has been little research on hybrids studied in this work. Tavares (2015) studying the hybrids NUN 1205 - F1, Dulciana and Cimarron obtained satisfactory results both for productivity and for average bulb mass, with transplantation in July, in the state of Tocantins. Reghin et al. (2004) when evaluating bulb yield of Crioula and Bola Precoce cultivars, using 40 cm spacing between lines and four different spacing between plants (5, 8, 11 and 14 cm) observed that, in the lowest density, there were no differences between the two cultivars in terms of productivity and proportion of marketable bulbs, however, found different behavior between genotypes in other planting densities.

The data referring to the ABW showed statistical differences with Vale Ouro IPA 11 and Mata Hari with the best averages in the 40 cm spacing (Table 6). This difference in ABW is explained by the increase in the population of plants as well as by the genotypic characteristic of each cultivar. Meneses Junior and Vieira Neto (2012) found that in the densities employed for the cultivar EMPASC 355-Juporanga, the smallest ABW (50.37 g bulb^{-1}) was obtained in a population of approximately 503 thousand plants ha^{-1}, while the largest ABW (114.60 g bulb^{-1}) was observed in populations of 200 thousand plants ha^{-1}. In the experiments now presented, treatments with 300 thousand plants ha^{-1} (greater spacing) obtained greater ABW, corroborating with the literature.

The cultivars that showed the lowest number of bulbs considered non-commercial (Class I refuse) were the cultivars Vale Ouro IPA 11 and Mata Hari ranging from 0.41 to 1.87 t ha^{-1}, in percentage this represents 2.2% to 11.1%, a result very similar to that of Lima et al. (2011b) for the cultivar Vale Ouro IPA 11, with 1.07 t ha^{-1} of refuse. The quantities of scrap bulbs decreased simultaneously with the increase in spacing between lines, with the exception of Vale Ouro IPA 11 in the 30 cm spacing.

Smaller spacing increases productivity per cultivated area, but, in most treatments, the average weight of the bulbs has decreased. Resende et al. (2005), observed an inverse relationship between the increase or reduction of line spacing in onion bulb productivity, that is, as the density of plants per hectare increases, reducing these spacing, a reduction in the size of the plant occurs simultaneously bulb. Clearly observed in the study with respect to the 40 cm spacing between lines. For all treatments there was a greater increase in ABW. However, the highest total productivity occurred in the spacing between 20 cm lines, corroborating with the data presented.

Regarding TSS, there was a significant difference with cv. Vale Ouro IPA 11 with values averaging 8.15% of ºBrix standing out and cv. Dulciana presenting the lowest value 4.61% of ºBrix (Table 7). The high TSS content is linked to the high pungency and good storage quality of the bulbs. Another indication related to TSS is the stage of maturation of the material, that is, higher percentages of ºBrix refers to saying that the cultivar is closer to maturation. Grangeiro et al. (2008), when working with the cultivar Primavera, found 9.3% of TSS, that is, results very similar to those presented in this work.

There was no significant difference for the parameter Total Titratable Acidity-TTA (% of pyruvic acid). The highest average was of cv. Mata Hari with 0.30% and the lowest of CV Vale Ouro IPA-11 with 0.24%. Chagas et al. (2004), evaluating the cultivars Baia Periforme, Crioula, Granex 33, Jubileu, Pira Ouro and Texas Grano-502 in Southern Minas Gerais, found results similar to those observed in this study. The highest acidity was found in the Crioula and Pira Ouro cultivars, with 0.370% and 0.315%, followed by the Jubileu and Baia Periforme cultivars, with 0.308% and 0.305%, respectively. The lowest values were found in the cultivars Texas Grano 502 and Granex 33, with 0.190% and 0.195%, respectively.

The pH range varied between 5.24 and 5.70 (Table 7). In a similar study, Schunemann et al. (2006) found that the physical-chemical and chemical results varied between cultivars, being in the pH range of 5.44 to 5.61, corroborating with this research. Rocha et al. (2015), when analyzing the cv. of onion Vale Ouro IPA 11 in cube, found for Total Titratable Acidity and Total Soluble Solids values of 0.24% and 9.46, respectively, similar to this study. Resende et al. (2010), comparing organic and conventional cultivation of onions, find results similar to this research for TTA and TSS for some cultivars.

5. Conclusions

The results obtained allow us to conclude that there is a possibility of producing seedlings and onions under the conditions of the study region. Total productivity increased linearly with plant density, providing maximum total productivity, even higher than the national average. Waste production decreased linearly with increased spacing. The same was true for the average bulb weight. The bulb diameter was another factor influenced by the spacing between lines. Some highly productive hybrids did not achieve the same agronomic performance in the region's climatic conditions. However, the highlight is the cultivar Vale Ouro IPA 11, which obtained productivity above the national average and good adaptation to regional conditions. Post-harvest data showed that all cultivars are within the recommended standard for onion cultivation, and it is possible to recommend Mata Hari cultivars and especially Vale Ouro IPA 11 for commercial plantations in the region.

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