Acta Scientiarum
http://www.periodicos.uem.br/ojs/
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v43i1.53105

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Competition of onion genotypes in the soil and climatic conditions of Guarapuava, State of Paraná

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ABSTRACT. The use of genotypes more adapted to climatic conditions can contribute to increase the yield of onion producers. The goal of this study was to evaluate the agronomic performance of 15 onion genotypes in the soil and climatic conditions of Guarapuava, state of Paraná. The study was conducted in the experimental area of Horticulture, Cedeteg campus, *Universidade Estadual do Centro-Oeste* (UNICENTRO), Guarapuava, state of Paraná, Brazil, from July to November 2018. The experimental design used was randomized blocks, with four replications, and the treatments consisted of four commercial cultivars Optima F_1, Bella Dura, Sirius F_1, Soberana F_1 and eleven experimental genotypes N1, N2, N3, N4, N5, N6, N7, N8, N9, AF4241 and AF4243. Biometric characteristics of the plants, production components and early flowering were evaluated. Plants presented between 6 and 9 leaves, in which N1, N3, N4 and N6 had less than 7 leaves, differing statistically from the others. The cultivar Optima F_1 and the genotypes N2, N3, N5, N6, N7 and N8 presented the tallest plants, with 66.1 to 76.0 cm. The pseudostem diameter did not differ significantly between genotypes, showing values between 15.2 and 20.4 mm. Total productivity was higher in genotypes N2, N6, N5, N4, N3, N7 with values from 43.6 to 50.3 t ha^{-1}. The highest average bulb mass was found in N2, N4, N6, Sirius F_1, Optima F_1 and Soberana F_1, with 74.2 to 91.1 g $bulb^{-1}$. Regarding the commercial classification, the genotypes N2, N4, N5, N6 and the cultivars Sirius F_1 and Soberana F_1 presented more than 50% bulbs of classes 3+3C+4. Early flowering did not occur in any of the analyzed genotypes. The use of cultivars with high productive performance and adapted to climatic conditions, when handled properly, can result in greater yield and quality of bulbs.

Keywords: *Allium cepa*; productivity; classification; agronomic performance.

Received on April 11, 2020.
Accepted on December 15, 2020.

Introduction

In 2019, Brazil produced more than 1.5 million tons of onion (Food and Agriculture Organization [FAO], 2020), a large part of which is obtained in the southern region of the country. Onion productivity is limited by climatic factors, such as photoperiod and temperature (Lancaster, Triggs, De Ruiter, & Gandar, 1996; Khokhar, Hadley, & Pearson, 2007). Bulb formation is a photoperiodic response, although it is influenced by the interaction between other environmental factors, such as temperature, light intensity and quality, plant density, nitrogen nutrition and irrigation regime. Meanwhile, flowering occurs on warmer, clearer days (Khokhar, 2017). Exposure to low temperatures for prolonged periods results in early flowering, an undesirable situation in the production of bulbs for commercial purposes.

In production, the choice of cultivar should take into account its climatic requirements, as well as the conditions available at the site where it will be grown, and through the appropriate management to allow the maximum expression of its potential (Menezes Júnior & Vieira Neto, 2012; Baliyan, 2014). Hybrid cultivars have greater productive potential when compared to open pollination cultivars, however, when the breeding program uses parents not adapted to the climatic conditions of cultivation, their yield can be reduced (Alves et al., 2018).

In addition to the selection of the cultivar, the sowing time appropriate to the climate and environment of the production area are essential factors for obtaining satisfactory yields (Ikeda, Kinoshita, Yamamoto, & Yamasaki, 2019). A stable environment, with low temperature and humidity variation, absence of heavy rain, low incidence of pests and diseases, as well as the use of appropriate technologies for irrigation, fertigation, sowing and density (Santos et al., 2018), also contribute to good plant development and increased productivity in onion cultivation.

Therefore, studies that seek to verify the performance of cultivars in different cultivation regions are important to inform producers the conditions required for the development of each cultivar, aiming at the best productive results. The present study aimed to identify among the 15 genotypes evaluated the most adapted to the soil and climatic conditions of the region of Guarapuava, state of Paraná, selecting the onions with the highest yield and commercial quality.

Material and methods

The experiment was conducted at the *Universidade Estadual do Centro-Oeste* (UNICENTRO), Cedeteg campus, in Guarapuava, state of Paraná (25°23'06" S; 51°29'31" W; 1.028 m altitude), from July to November 2018. The soil is oxisol with a clayey texture (Bognola, Fasolo, Potter, Carvalho, & Bhering, 2002). The predominant climate in the region is humid, without a dry season and with frequent frosts, classified by Köppen-Geiger as Cfb. During the experimental period, data on average temperature, relative humidity and total rainfall were collected at the meteorological station, located 120 m from the experiment (Figure 1).

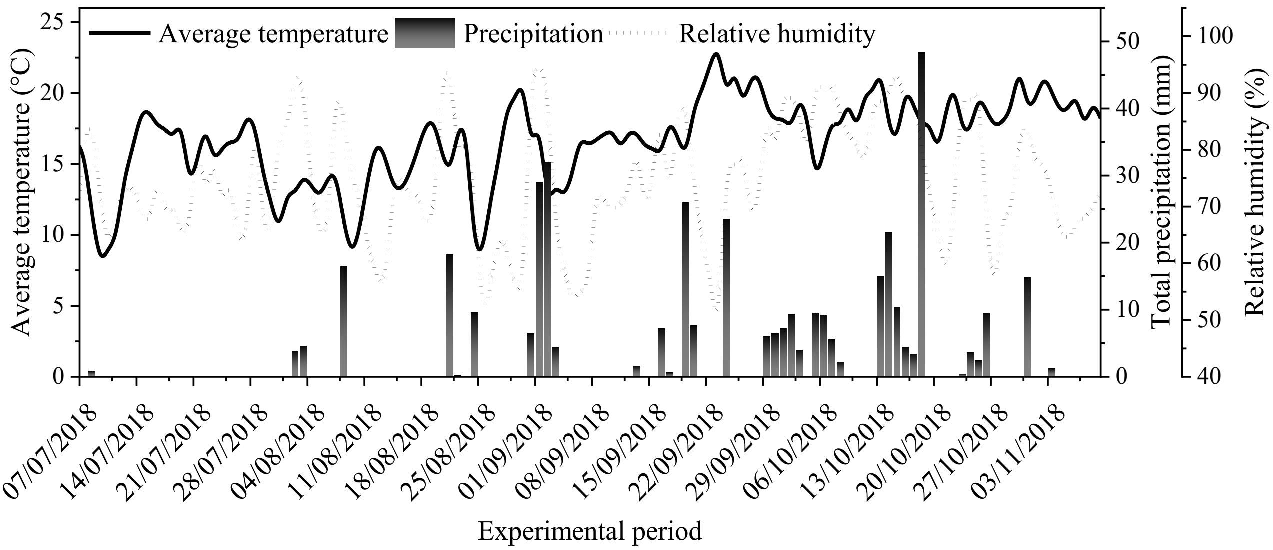

Figure 1. Average temperature (°C), relative humidity (%) and total rainfall (mm) recorded during the experimental period. * Data obtained from the Meteorological Station of the *Universidade Estadual do Centro-Oeste* (UNICENTRO), Cedeteg campus.

This was a randomized block experimental design, with four replications, the experimental plots contained 1 m^2, without the presence of a border because it is an evaluation of the competition between plants. Fifteen treatments were evaluated, corresponding to the commercial cultivars Bella Dura, Optima F_1, Sirius F_1 and Soberana F_1, and to the experimental genotypes named AF4241, AF4243, N1, N2, N3, N4, N5, N6, N7, N8, N9.

Seedlings were produced in a greenhouse, in polystyrene trays and commercial substrate, and were transplanted after 40 days. The spacing used was 0.15 m between rows and 0.10 m between plants, totaling 70 plants per m^2. Fertilization was carried out five days before planting, with the application of 150 g m^2 of the formula NPK 04-14-08, while topdressing consisted of three applications (at 30, 60 and 90 days after planting) of the formula NPK 20-00-20 at a dose of 100 g m^2.

Preventive disease control was performed every seven days, with alternate application of the fungicides copper oxychloride (250 g a.i.), trifloxystrobin (150 mL a.i.), captan (240 g a.i.), mancozeb (300 g a.i.), methyl thiophanate (70 g a.i.), procimidone (75 g a.i.) and metalaxyl-M + mancozebe (400 g), adding 0.25% adjuvant to the solution, using a volume of 100 L water per ha^{-1}. Pest control was carried out with the application at regular intervals of 10 to 15 days of the insecticides, thiamethoxam + λ-cyhalothrin (100 mL), chlorpyrifos (400 mL) with 0.25% adjuvant solution, using a volume of solution of 100 L ha^{-1} water for all products. Invasive plants, on the other hand, were controlled manually.

The experiment was irrigated by conventional sprinkler, depending on the region's rainfall, and suspended 15 days before harvest. The harvest was carried out when 70% plants were at physiological maturity identified by the 'fall-down' or 'soft-neck' of the aerial part. Onion bulbs were then cured for 15 days, cleaned (removal of roots and leaves, leaving two cm of pseudostem), quantified and classified according to the transverse diameter.

The evaluations took place 60 days after transplantation (DAT), when the plant completed its growth phase and began bulb formation. The average plant height was verified by measuring the distance from the ground level to the tip of the longest leaf with the aid of a ruler, the values were obtained in centimeters (cm). The average number of leaves per plant was determined by counting photosynthetically active leaves. Total productivity was obtained through the total mass of bulbs harvested in the useful area of the plot, and expressed in tons per hectare (t ha^{-1}), considering 7500 m^2 useful area. Early flowering was assessed visually at 30 DAT.

Pseudostem diameter was determined with a digital caliper measuring the neck of the plant and the data were expressed in millimeters (mm). The average mass was obtained by dividing the total average mass of bulbs by the total number of bulbs harvested, expressed in g $bulb^{-1}$. The commercial classification was carried out according to the transverse diameter of the bulbs (Class 1: 15 < Ø < 35 mm, Class 2: 35 < Ø < 50 mm, Class 3: 50 < Ø < 60 mm, Class 3C: 60 < Ø < 70 mm, Class 4: 70 < Ø < 90 mm and Class 5: > 90 mm) (Brasil, 1995).

Data were tested for normality of residues and homogeneity of variances, those that did not meet the assumptions were transformed by $\sqrt{x} + 1$. An analysis of variance and Scott Knott's mean test at 5% probability were run, using the software RStudio (2015) (version 1.1.463© 2009-2018) along with the ExpDes.pt package (Ferreira, Cavalcanti, & Alves, 2018). For cluster analysis, the means of the variables were used and data were standardized because they have different units of measurement. The UPGMA method (Unweighted Pair Group Method using Arithmetic averages) and the Euclidean distance metric were adopted, as they have the highest CCC (Cophenetic Correlation Coefficient = 0.7107).

Results and discussion

There was a significant difference between the evaluated genotypes regarding the number of leaves, plant height, total productivity and average bulb weight, except for pseudostem diameter. The largest number of leaves was found in the AF4243 genotype (9.1 leaves per $plant^{-1}$), although it did not differ statistically from N8, Sirius F_1, Soberana F_1, AF4241, N5, N9, Bella Dura, Optima F_1, N7 and N2. The genotypes N6, N4, N1 and N3 had the lowest number of leaves (<7.0 leaves per $plant^{-1}$) (Table 1).

Table 1. Comparison of means for the variables number of leaves per plant (NL), plant height (PH), diameter of the pseudostem (PD), total productivity (TP), fresh bulb mass (BM) of the analyzed onion genotypes.

Genotype	NL	PH	PD	TP	BM
	un	cm	mm	t ha^{-1}	g $bulb^{-1}$
AF4241	8.4 a	58.6 b	16.8	30.9 b	54.3 c
AF4243	9.1 a	62.9 b	20.4	37.3 b	63.5 b
Bella Dura	8.3 a	56.8 b	15.2	39.5 b	63.3 b
N1	6.6 b	60.9 b	15.9	35.6 b	68.5 b
N2	7.8 a	69.5 a	17.5	50.3 a	83.4 a
N3	6.4 b	76.0 a	17.4	43.6 a	68.6 b
N4	6.6 b	62.9 b	15.5	46.0 a	79.8 a
N5	8.3 a	71.9 a	17.5	47.5 a	68.1 b
N6	7.0 b	66.1 a	17.1	50.0 a	91.1 a
N7	8.1 a	69.3 a	17.8	43.6 a	63.7 b
N8	8.9 a	67.1 a	19.1	31.2 b	52.7 c
N9	8.3 a	60.2 b	18.5	32.3 b	53.7 c
Optima F_1	8.1 a	66.5 a	18.0	36.2 b	74.2 a
Sirius F_1	8.8 a	62.5 b	19.3	37.0 b	82.5 a
Soberana F_1	8.5 a	64.8 b	18.8	34.4 b	75.0 a

Means followed by different letters in the same column are significantly different by the Scott-Knott test (α=0,05).

According to Lancaster et al. (1996), plants can produce up to 8 ± 8 leaves before bulb formation, and the number of leaves produced is related to the accumulated thermal time, presenting an average leaf emergence rate of 1 ± 2 leaves every 100 day-degrees. Although, leaf production is also influenced by genetic factors. The number of leaves and their development influence from the emergence of seedlings to the maturity of the onion, therefore they determine the final size of the bulb (De Ruiter, 1986).

The tallest plants were found in the genotypes N3, N5, N2, N7, N8, Optima F_1 and N6, with 66.1 to 76.0 cm, differing from the others that presented plants with height less than 64.8 cm (Table 1). Leaf development can be influenced by environmental factors and also by management practices (Gebretsadik & Dechassa, 2018), although the response and the magnitude of the effects depend on the individual characteristics of each genotype. Temperature influences vegetative development, causing the appearance of leaves to increase as the temperature approaches the ideal level (Hatfield & Prueger, 2015). The optimum temperature during the leaf initiation phase in onion is lower and increases linearly in the range of 3.5 - 23°C, while in the range of 6 - 20°C there is an increase in the growth rate of the leaf (Brewster, 2008).

A study on the effects of temperature during onion growth reported that the height of plants in a high temperature area (15.9 - 26.8°C) was significantly lower than in areas of moderate (13.9 - 25.8°C) and low (12.5 - 23.7°C) temperatures, with a reduction of 9.6 and 14.6%, respectively. As for the fresh bulb mass, when under the same conditions, the high temperature promoted a reduction of 53% when compared to the moderate temperature area. The total number of leaves and the pseudostem diameter were also suppressed after 25 days of transplantation when exposed to high temperature (Ikeda et al., 2019).

Plant height can also be influenced by planting density, which can promote shading and lead to competition for light and result in taller plants (Aboukhadrah, El-Alsayed, Sobhy, & Abdelmasieh, 2017), as well as by the planting method, where direct sowing produces lower plants than transplanted plants (Ketema, Dessalegn, & Tesfaye, 2018). However, as all genotypes were submitted to the same environmental and management conditions, the genetic characteristics of each may have influenced the result obtained in this study.

Pseudostem diameter is related to the size of the bulb (Mondal, Brewster, Morris, & Butler, 1986; Brewster, 2008) and to the photosynthetically active part of the plant (Torquato-Tavares, Pascual-Reyes, Barros-Milhomens, Alves-Ferreira, & Rodrigues-do-Nascimento, 2017). In addition, pseudostem is responsible for the translocation of carbohydrates produced in the leaf to the bulb, through the activity of enzymes that are controlled by the photoperiod (Lercari, 1982). The results showed that there were no significant differences in pseudostem diameter between the evaluated genotypes, which showed values between 15.2 and 20.4 mm (Table 1).

Significant differences were detected for the average bulb mass, which ranged from 52.7 to 91.1 g bulb^{-1}. Bulbs with the highest fresh mass were found in genotypes N6 (91.1 g bulb^{-1}), N2 (83.4 g bulb^{-1}), Sirius F_1 (82.5 g bulb^{-1}), N4 (79.8 g bulb^{-1}), Soberana F_1 (75.0 g bulb^{-1}) and Optima F_1 (74.2 g bulb^{-1}) (Table 1). While, for total productivity, genotypes N2 (50.3 t ha^{-1}), N6 (50.0 t ha^{-1}), N5 (47.5 t ha^{-1}), N4 (46.0 t ha^{-1}), N3 (43.6 t ha^{-1}) and N7 (43.6 t ha^{-1}) differed significantly from the others because they had the highest yields (Table 1).

In other studies, developed in the region, the highest productivity was found for the Bucanner hybrid, 24.8 t ha^{-1} and the cultivars Baia Periforme, Crioula Vermelha, Bola Precoce resulted in values lower than 18 t ha^{-1} (Resende, Pires, Camargo, & Marchese, 2007). While, the performance evaluation of 19 hybrids and 50 lineages, showed that the hybrids can present yields from 38.6 to 75.2 t ha^{-1} and the lineages between 7.9 and 48.9 t ha^{-1} (Faria et al., 2012).

Onion productivity depends on its adaptation to the climatic conditions of the growing region (Baliyan, 2014), which can influence the final bulb mass (Kimura, Okazaki, Yanagida, & Muro, 2014). Besides that, when genetically improved plants have parents that are not adapted to all environmental conditions, they also result in low yield (Alves et al., 2018). Therefore, the selection of the cultivar and the sowing time appropriate to the climate of the production area, are important factors for obtaining satisfactory yields in the production of onion (Ikeda et al., 2019).

The production quality can be obtained by classifying the bulbs according to their size class (Reghin, Otto, Olinik, & Jacoby, 2006; Baier et al., 2009). Onions classified as 3+3C+4 are considered ideal for commercialization, and the experimental genotype N6, presented the highest percentage of bulbs of these classes (64.8%), followed by N2, Sirius F_1, Soberana F_1 and N5, with values greater than 50%. In genotypes N8, AF4241, N7, N9, N3, Bella Dura and AF4243 more than 40% bulbs belonged to class 2, however, more than 20% bulbs produced by genotypes N8, AF4241, Optima F_1 and N9 belonged to class 1 (Table 2).

Table 2. Commercial classification of onion bulbs, with values expressed as percentage and tons per hectare.

Genotype	Class (%) 1	Class (%) 2	Class (%) 3+3C+4	Class (%) 5	Class (t ha^{-1}) 1	Class (t ha^{-1}) 2	Class (t ha^{-1}) 3+3C+4	Class (t ha^{-1}) 5
AF4241	22.7	48.6	28.8	0.0	7.0	15.0	8.9	0.0
AF4243	15.5	41.2	43.3	0.0	5.8	15.4	16.2	0.0
Bella Dura	18.4	43.4	38.3	0.5	7.3	17.1	15.1	0.2
N1	17.3	36.3	46.4	0.0	6.2	12.9	16.5	0.0
N2	3.6	37.6	58.9	0.0	1.8	18.9	29.6	0.0
N3	12.8	44.4	42.3	0.5	5.6	19.4	18.4	0.2
N4	15.0	33.0	52.0	0.0	6.9	15.2	23.9	0.0
N5	11.7	37.6	50.7	0.0	5.6	17.9	24.1	0.0
N6	5.0	30.2	64.8	0.0	2.5	15.1	32.4	0.0
N7	19.6	46.1	34.3	0.0	8.5	20.1	15.0	0.0
N8	23.0	48.7	28.3	0.0	7.2	15.2	8.8	0.0
N9	20.4	45.6	34.0	0.0	6.6	14.7	11.0	0.0
Optima F_1	21.9	33.1	45.1	0.0	7.9	12.0	16.3	0.0
Sirius F_1	18.5	26.0	55.5	0.0	6.8	9.6	20.5	0.0
Soberana F_1	12.0	34.7	53.3	0.0	4.1	11.9	18.3	0.0

*Class 1: 15<Ø<35 mm, Class 2: 35<Ø<50 mm, Class 3: 50 <Ø<60 mm, Class 3C: 60<Ø<70 mm, Class 4: 70 <Ø<90 mm and Class 5:>90 mm.

Regarding early flowering, it was not observed in any of the evaluated genotypes. In general, early flowering occurs by exposing the plants to prolonged periods (30 days) at low temperatures (<10°C), being highly undesirable when aiming at the production of commercial bulbs (Melo & Ribeiro, 1990).

Cluster analysis

The cluster analysis of the 15 genotypes resulted in the formation of 5 distinct groups. The AF4243 genotype and the commercial cultivars Sirius F_1, Optima F_1 and Soberana F_1 belong to group I. This group had the largest number of leaves, reaching 9 leaves per plant and highest values for the pseudostem diameter, from 18.0 to 20.4 mm. Values of height, total productivity and bulb mass were intermediate, not exceeding 66.5 cm, 37.3 t ha^{-1} and 82.5 g bulb^{-1}, respectively (Figure 2).

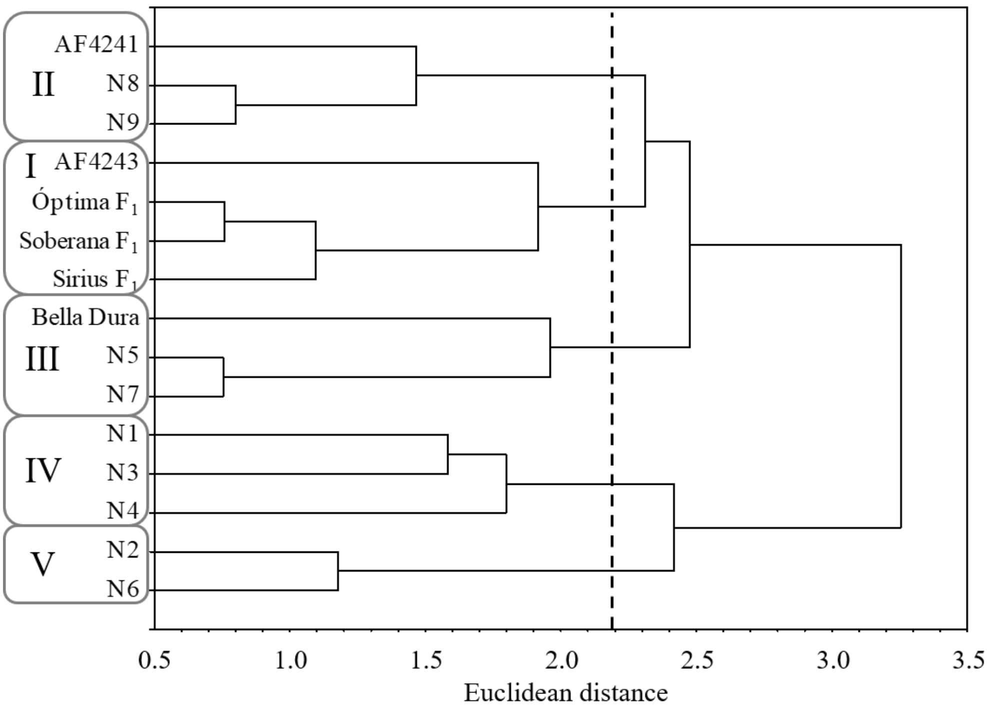

Figure 2. Dendrogram of productive performance of the evaluated genotypes.

Experimental genotypes N9, N8 and AF4241 constitute group II. These showed the lowest values for total productivity and average bulb mass, which were less than 32.3 t ha^{-1} and 54.3 g bulb^{-1}. Plants had an average of 8 leaves, pseudostem diameter between 16.8 and 19.1 mm and height from 58.6 to 67.1 cm. Group III composed of N7, N5 and Bella Dura presented median values for all parameters evaluated. Plants had a maximum of 8 leaves, 71.9 cm in height, pseudostem diameter of 17.8 mm, total productivity of 47.5 t ha^{-1} and average bulb mass of 68.1 g $bulb^{-1}$ (Figure 2).

The experimental genotypes N4, N3 and N1, belonging to group IV, presented 6 leaves per plant, that is, the lowest number of leaves in relation to the other groups. However, they presented values of total productivity between 35.6 to 46.0 t ha^{-1} and average bulb mass between 68.5 and 79.8 g $bulb^{-1}$. Group V consists of the genotypes that obtained the highest total productivity and average bulb mass. Onions N2 and N6 showed a yield of 50 t ha^{-1} and bulbs from 83.4 to 91.1 g $bulb^{-1}$. The maximum averages for number of leaves, height and pseudostem diameter were 7.8, 69.5 cm and 17.5 mm, respectively (Figure 2).

The most productive genotypes were not those with the highest number of leaves, differently from what was reported in another study (Ferreira, Santos, Oliveira, Alencar, & Silva, 2017). Nevertheless, the number of leaves can influence the pseudostem diameter, since the plant with the largest number of leaves also had the largest pseudostem diameter.

Conclusion

The use of new genotypes can contribute to increase the yield and commercial quality of onions produced in Guarapuava, state of Paraná. All materials tested in this study did not flower early and showed yields greater than 30 t ha^{-1}. Although, N6 and N2 stood out for their total productivity of 50 t ha^{-1} and high production of bulbs from the most commercially valued classes, which may be the result of a good adaptation to the soil and climatic conditions of the region.

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