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RESEARCH ARTICLE

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PRODUCTION ANDQUALITYOF HYBRIDS OF BROCCOLI TYPE UNIQUE INFLORESCENCE CULTIVATED UNDER DIFFERENT SHADING SCREENS INTROPICAL CLIMATE

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ABSTRACT

The objective of this work was to evaluate the agronomic performance of broccoli cultivars cultivated underfour environmentsunder high temperature conditions in Nova Mutum- MT.The experiment was carried out from March to August 2015. The experimental design used was that of randomized blocks arranged in a 4 x 2 factorial scheme, with four replications.being evaluated two cultivars of single inflorescence of the type of broccoli, Imperial (Sakata®) and Salinas (TopSeed®), cultivated in three screened environments covered with shading screen - black, silver andred, all with 50% shadingand Without Cover. During the experiment the near, average and minimum temperatureswere 32.8ºC,17.6ºC and 19.3ºC, respectively. Both cultivars showed good agronomic performance for this climatic condition, but the Imperial hybrid obtained better results in relation to inflorescence production. The use ofshadingscreen s proved to be feasible in reducing temperature in cultivation environments, however the reduction of solar radiation delayed the emission of inflorescence, prolonging its vegetative stage. The Without Cover environment provided higher production and better inflorescence quality. The Imperial cultivar showed better performance under high temperature conditions.

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INTRODUCTION

The broccoli cultivars *(Brassica oleracea* L.) of the single inflorescencetype, used in Brazil, originate from temperate countries and therefore present difficulty in adapting to climatic conditions, especially in summer. This species obtains higher productivity indexes in environments with temperatures between 18 and 24°C (TREVISAN *et al*., 2003). In Brazil, planting is problematic, especially in tropical climate regions due to high rainfall, temperature, higher incidence of pests and diseases, reducing production and quality. In the country, winter autumn cultivars predominate, and some term tolerant cultivars are adapted. Summer planting is more profitable due to the higher price paid for the product due to the off-season, even obtaining lower productivity in this period(LALLA *et al*., 2010). The final product when harvested under these conditions has a lower commercial aspect, with smaller, lighter heads, lighter coloration, larger granulation, thicker, worse texture and less postharvest conservation, losing commercial interest (TAVARES, 2000). The use of thermotolerant cultivars allows the expansion of the growing regions, planting times and period of supply of the product in the market, in addition to increasing the profitability of the crop (TREVISAN *et al*., 2003; ANTUNES *et al*., 2019). The cultivation in a protected screened environment is efficient in reducing air and soil temperature and luminosity, besides providing an increase in relative humidity, indicating that it is feasible to use these materials for cultivation under tropical conditions (RAMPAZZO *et al*., 2014). The use of protected environment covered with screens has proved to be a viable alternative at some times of the year, mainly in order to minimize high temperatures. Santos *et al*. (2010), obtained positive results regarding the use of shading screens in the cultivation of vegetables in a region of high temperatures. Plants in general need sunlight to perform photosynthesis to produce energy for the various metabolic processes of growth and development. This energy aims to ensure the maintenance of plants in the field and allow crops that can be fruits, vegetables, flowers and medicinal principles (OLIVEIRA *et al*., 2008). Thus, evaluating the effect of the growing environment and thermotolerant cultivars can contribute to the production system, enabling production, enabling the supply of the local market and contributing directly to the generation of income and employment for the family farmer. In addition to reducing the price of the product in the region, favoring the consumption of this vegetable. Thus, this study aimed to evaluate the agronomic performance of broccoli cultivars cultivated under four environments under high temperature conditions in Nova Mutum- MT.

MATERIAL AND METHODS

The experiment was carried out in Nova Mutum - MT, in the experimental area of the State University of Mato Grosso - UNEMAT, which is located at south latitude 13º 05' 04" and west longitude 56º 05' 16". The soil is Dystrophic Yellow Red Latosol. The climate is a tropical Type Aw (Koppen), with concentrated rains in summer (October to April). The average annual rainfall is 1900 mm and the average temperature is 26°C (NOGUEIRA *et al*., 2010). The experimental design used was in randomized blocks arranged in a 2x4 factorial scheme, with four replications. The assay had as factors two cultivars ofbroccoli colis type single inflorescence that present thermotolerance recommended by Seabra *et al*. (2014). The two single inflorescence broccoli cultivars used were Imperial (Sakata®) and Salinas (TopSeed®), cultivated in three screened environments with shading screen - black, silver and red, all with 35% shading and Without Cover (full sun). The cultivation environments had dimensions of 8 m long and 4 m wide and right foot of 2 m. The planting lines were spaced using the double rows method, with spacing of 0.8 m between double rows, 0.5 m between plants and between rows in the row, totaling 30,769 plants ha^{-1}. The seedlings were produced in a protected environment covered with transparent polyethylene with a thickness of 150µm. Sowing occurred on 21/03/2015, in transparent plastic cups with a capacity of 300 milliliters filled with commercial substrate Platmax® using a seed in each cup. The transplant was performed on 12/05/1015, at 52 days after sowing (DAS), when the seedlings had on average six definitive leaves and 0.25 m high. Irrigation was performed using micro orbital sprinklers arranged at a distance of 2.5 meters from each other in the experimental area. Soil fertility was corrected based on soil chemical analysis according to the recommendation of Trani & Raij (1997) and Seabra Júnior (2005), being applied in planting 60 Kg ha^{-1} of N, 200 Kg ha^{-1} of P_2O_5 and 120 Kg ha^{-1} of K_2O, using as source; urea (44% N), potassium chloride (58% K_2O) and simple superphosphate (18% P_2O_5), using 4.09g urea $plant^{-1}$, 33.3g of simple superphosphate $plant^{-1}$ and 6.2g of potassium chloride $plant^{-1}$. For cover fertilization, we used 200 Kg ha^{-1} of N and 120 Kg ha^{-1} of K_2O, divided into seven applications throughout the cycle, in addition to foliar fertilization application with Boric Acid (17% B) and Ammonium Molybdate (54% Mo) at concentrations of 1 g L^{-1} and 0.5 g L^{-1} respectively, applied at 15, 30 and 45 DAT. When the inflorescences presented maximum size, compact and with well-closed granules, the coita was performed. I started on July 9, 2015 and extended until August 5, 2015, andthe parameters of production and quality of broccoli such as: total fresh mass (g $plant^{-1}$), inflorescence production (g $plant^{-1}$), fresh stem mass (g $plant^{-1}$), and diameter of inflorescence (cm) and visual aspect scale through a scale of notes (SEABRA JÚNIOR *et al*) were evaluated., 2014). With data collection, the values were submitted to variance analysis and the means compared by the Tukey test($p<0.05$), using the Assistat program (SILVA and AZEVEDO, 2002).

RESULTS AND DISCUSSION

In the research period the average temperatures of near, average and minimum air reached 34.6°C, 24.5°C and 17.6°C, respectively, and the maximum and absolute minimum were 37.4°C and 13°C. In Nova Mutum-MT, there are limitations of cultivation, mainly due to high temperatures, where the annual average is 24.6°C. Although climatic conditions do not favor crop development, both cultivars analyzed emitted inflorescence and ended the cycle, showing productive potential even in high temperature conditions. The temperatures observed in the period were higher than those found by Lalla *et al*. (2010), in Campo Grande, where air temperatures in the growing period were 16.5°C, 22.4°C and 33.6°C for minimum, average and maximum, respectively. High air temperatures are cited as one of the factors that negatively affect commercial productivity and the quality of the broccoli head (Lalla *et al*, 2010), with average temperatures of 15°C to 18ºC and maximum of 24ºC more favorable to the productive and qualitative development of the crop (TREVISAN *et al*. , 2003) , but several breeding programs in Brazil, has directed its research to adaptation and genotypes at high temperatures, because in addition to enabling production in several regions, it also enables a strategy to ensure the production of species in the future, due to global warming. Studies should be done to adapt cultivars and efficient production arrangements in the scenarios predicted to meet the demand for food for humanity and reduce disasters (GONDIM, 2010). Plant development and growth are directly influenced by climatic factors, such as light and temperature, and others related to soil conditions, such as moisture content, pH and saline level, as well as biotic factors such as pests and diseases, and these factors influence the population dynamics of the species, so cultivars with greater ability to adapt to environmental factors are favored (MENESES *et al*., 2006; SOUZA FILHO, 2000; ZHU *et al*., 2001). The use of technologies such as cultivation in a protected environment under screened can be an efficient alternative for crop development. The use of thermoreflective meshes and shading meshes have shown promising results for other species, such as the results obtained by Seabra Júnior *et al*. (2009), where lettuce production increased in environments covered with screened, in relation to the Without Cover, and may present potential for broccoli. The measurement of the light intensity of the environments was performed daily, always at 13:30 hours, with the aid of a digital luximeter model Testo 540 with sensor adapted to the spectral sensitivity of the view, which performs measurements in LUX (luminosity). The readings provided the characterization of the light intensity, where there was a reduction ranging from 45 to 58% when compared to the Without Cover (Figure 1).

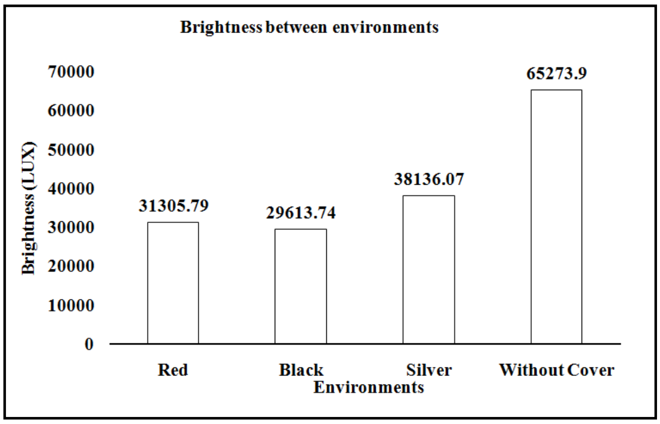

Figure 1. Luminous intensity in LUX within each environment, recorded between May and August 2015.

The manufacturer of the screens (Polysac Plastic Industries) states that the red ChromatiNet mesh has the purpose of changing the spectrum of light, reducing the blue, green and yellow waves, and adding waves in the spectral range of red and distant red. And the black screen is considered neutral, so it does not alter the light spectrum, it acts only by reducing irradiance. The thermal reflector screen reflects heat waves, reducing temperature and providing diffuse light to the environment. Gotto and Tivelli (1998) state that for cultures sensitive to excess luminosity, the use of shading screens, with 30 to 50% shade, satisfactorily solves the luminosity problem, and the change in luminosity in the environment interferes with other environmental factors. The inflorescence emission was between 25/06/2015 and 21/07/2015, and in this absolute minimum period it reached 13°C and the average temperature was 22.7°C, totaling 18 dayswith a minimum temperature between 15°C and 17°C, a fact that favored the development of inflorescences, opposing the statement of Nowbuth (1998), which states that to favor floral induction, it takes 30 days with temperatures of 15 to 17°C. With regard to the cultivation environment, the highest total fresh mass (g $plant^{-1)}$ was obtained under black screen, followed by red and silverenvironments, which did not differ statistically from each other, the lowest mean was observed in the Without Cover environment (Table 1). Bhering (2013), in a study comparing different shading meshes for broccoli production in Viçosa, MG, also obtained higher averages of total fresh mass in the covered environments, compared to the Without Cover, evidencing that broccoli when cultivated in an environment with limiting light changes its morphology, investing more in stem and leaf expansion, to the detriment of inflorescence production.

Table 1. Total Fresh Mass (g plant^{-1}), Fresh Stem Mass (g plant^{-1}), Production and Inflorescence (gplant^{-1}), Inflorescence Diameter (cm) and Visual Aspect Index

	Fresh Weight (g plant^{-1})	Head Weight (g plant^{-1})	Head Diameter (cm)	Stem F.W. (g plant^{-1})	Visual aspect index
Hybrids					
Salinas	1588.5 a	350.9 b	15.6 a	462.3 a	3.7 a
Imperial	1442.1 b	421.2 a	15.9 a	339.8 b	3.2 b
Shading Screens					
Red	1489.3 ab	337.2 b	15.4 ab	442.7 a	2.7 b
Black	1602.9 a	389.2 b	16.0 ab	407.1 a	3.9 a
Silver	1576.6 ab	349.8 b	14.8 b	368.8 a	3.4 ab
OF	1392.4 b	468.1 a	16.7 a	385.8 a	3.9 a
CV %	8,8	12,7	7,9	15,4	16,1

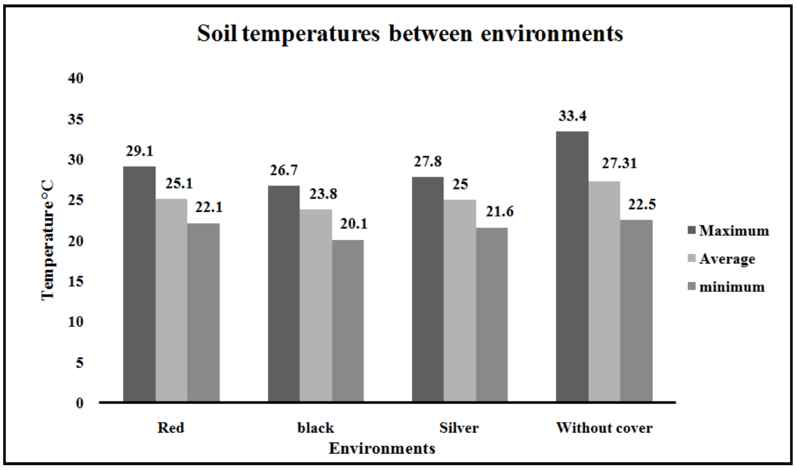

Figure 2. Maximum, average and minimum soil temperatures between environments

The cultivar Salinas was the hybrid that presented the best results for total fresh mass, surpassing the Imperial cultivar. Plants kept in shading have a larger leaf area and tend to be taller when compared to plants that grow in full sunlight, because plants that grow in a covered environment have higher formation of lacunous parenchyma, due to the search for luminosity (KENDRICK; FRANKLAND, 1981). According to Corrêa (2008), the use of shading meshes most often does not provide adequate levels of light, affecting production.
The Imperial cultivar showed higher inflorescence production with an average of 421,2 g plant^{-1}, being obtained in the Without Cover environment. This result was higher than that obtained by Bhering (2013), in which he obtained an average of 415.4 gplant^{-1} in the uncovered environment in Viçosa, MG. However, they were lower than those obtained by other authors such as Seabra Jr *et al.* (2014) that obtained averages of 706.0 g plant^{-1} in Cáceres - MT between the months of June to September and Cecilio *et al.* (2012) which obtained averages between 430.08 and 706.56 g plant^{-1} in Itatiba - SP between march and July, but in the last case, the crop was benefited by the lower temperatures recorded in the period. The other environments showed no statistical difference. In the evaluation of the inflorescence diameter, there was no significant difference between the cultivars (table 1). In the evaluation between environments, the Without Cover environment obtained the best average diameter of the inflorescence for the Without Cover environment. The average diameter ranged from 16.7 to 14.8 cm, a result lower than those found by Seabra *et al.* (2014) that in conditions of high temperatures, where 33.4ºC; 26.3º C and 19.2º C was recorded, for maximum average, compensated average and minimum average, respectively, reached average inflorescence diameter of 20.8 cm for the cultivar Salinas and 18.9 cm for the cultivar Imperial, with the same spacing between rows and plants. Observing the results of total fresh massand inflorescence production in the present study, it is noticed that the productivity of the inflorescence, which is the commercial part of interest of broccoli, was lower in the environments covered with screens compared tothe Without Cover, and in the latter, the production of the commercial part was higher, to the detriment of the total fresh mass. This result is in line with the statement of Taiz & Zeiger (2010), in which plants submitted to low irradiance levels have an adaptive strategy, in which there is greater elongation of the petiolo and greater expansion of the leaf area, aiming to increase the capture of light energy and allow greater photosynthetic efficiency. With this, broccoli, whencultivated under limiting light, invests more energy in the vegetative part, to the detriment of the commercial part, in this case the inflorescence (BHERING, 2013). The use of spectral filters in protected cultivation selectively transmits certain wavelengths, which affect the photomorphogenic response of plants, bringing changes in growth, development, morphology and physiological functions of plants, resulting in adaptation to a different environmental condition (TSORMPATSIDIS *et al*., 2008). For the parameter fresh stem mass there was no significant difference for broccoli grown under the differentenvironments, however it*was*found that the cultivar Salinas presented higher fresh stem mass. There are not many studies evaluating fresh stem mass, but this parameter can be directly linked to the production of fresh inflorescence mass, according to results obtained by Seabra *et al*. (2014), in which the highest averages of fresh stem mass coincided with higher inflorescence yield. Regarding the visual aspect index, broccoli cultivated under black screen and the environment without coverage obtained the best averages. Among the cultivars, the hybrid Salinas obtained the best average (3.71). Despite the high temperatures recorded in the period, the inflorescences showed good indices of visual aspect, good development of inflorescence, good texture, dark green color, uniform and with small granulation. Bjorkman and Pearson (1998) and Tavares (2000) state that high temperatures cause deformations in inflorescences and lower visual appearance, and prolonged periods of temperature above 25 reducehead size and cause development of leaves or bracts between inflorescences, however the resultsobtained in the present study contradict this information, since there was nodevelopment of leaves or bracts in inflorescences.

The low temperatures recorded in the period contributed to the emission of the inflorescence, as well as to the good visual aspect, because during the emission of the inflorescence was recorded 18 days with an average temperature of 22.7°C, because according to Tavares (2000) when broccoli is planted under mild temperature, between 15°C and 24°C, higher productivity and better inflorescence quality are obtained. Salinas and Imperial materials are hybrids with production potential under high temperature conditions and, in general, presented excellent inflorescence quality for commercialization, in addition to good productivity (ANTUNES *et al*., 2018; SEABRA JÚNIOR *et al*. (2014). According to New et. al. (2008) the use of shading screens is a solution of lower economic cost to reduce temperatures in the production environment, as well as Goto & Tivelli (1998) state that soil temperature is influenced by coverage, always having a difference between the temperature of the soil inside and outside the protected environment. Soil temperatures were lower in the environment covered with black shading screen, while the environment with the highest temperature was the environment without cover (Without Cover) (Figure 2). The environments covered with red screen and silver reflective term averaged 25.19ºC and 25.01ºC, respectively, with maximum and minimum son of 29.1ºC and 22.1ºC for the environment with red coverage, and the environment with silver reflective term coverage obtained a maximum of 27.8ºC and a minimum of 21.6ºC.

According to the manufacturer (Polysack, 2013), thermoreflective meshes reflect heat waves causing the ambient temperature to drop by 10 to 20% compared to the Without Cover. These results demonstrate that the shading meshes were efficient in reducing soil temperatures, but in the case of broccoli, these results did not favor in the production ofinflorescence, due to the reduction of radiation caused by the cover screens. According to Corrêa (2008) the shading screens affect the development and productivity of several species due to the lack of adequate levels of light required by the crop. The average cycle for the Imperial hybrid was 125 days, and the Salinas was 136 days (Table 2), a result higher than those found by Perin *et al*. (2003) who obtained cycles of 80 to 95 days, Seabra Júnior *et al*. (2013) obtained cycles from 99 to 114 days, Lalla *et al*. (2010) from 89 to 116 days and Melo *et al*. (2010) from 87 to 128 days.

Table 2. Cycle of imperial and salinas cultivars, from sowing to the end of harvest, produced in environments covered by red screen, black shading screen, silver converter thermo screen and Without Cover

		Cycle (days)
Cultivars	imperial	125.2 to
	Salinas	136.4 b
Environments	Red	131.8 b
	Black	143.3 a
	Silver	130.7 b
	Without Cover	117.3 c
CV (%)		1,17

Distinct vertical means differ from each other by the Tukey test (P<0.05).

Among the environments, the effect of the covers interfered inthe cycle of the s culture, where the Without Cover provided a shorter cycle, followed by environments covered with red and silver screen, which did not differ statistically from each other, and the environment covered with black shading screen was responsible for greater prolongation of the broccoli cycle. According to Maciel *et al*. (2009), the use of shading screens may represent a reduction in the flow of light at inadequate levels, promoting cycle extension, plant iotation and reduced productivity. According to Faria Júnior *et al*. (2000), it is important to consider the negative effect on light restriction on crop behavior, as it can cause excessive reduction of solar radiation. Leite (2005) and Medina and Machado (2006) report precocity *of Phalaenopsis sp*. and citrus seedlings with the use of red and silver screens, but in the case of broccoli in the present study they were not efficient in reducing the cycle. Therefore, it is necessary to study on adequate indices of light restriction to avoid damage in the development and production of crops of interest.

CONCLUSION

Without Cover cultivation provided higher production and quality of broccoli inflorescence, notrecommending the use of screen for this crop. The Imperial cultivar showed better performance in the yield parameter under high temperature conditions. The use of colored screens provided prolongation of the crop cycle.

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