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Growth, development and quality of gladiolus 'White Goddess': season, shade net, and mulching

Dislaine Becker[1]; Dalva Paulus[1]; Leosane Cristina Bosco[2]

[1]Universidade Tecnológica Federal do Paraná (UTFPR), Dois Vizinhos-PR, Brasil; engdislainebecker@gmail.com; dalvapaulus@utfpr.edu.br [2]Universidade Federal de Santa Catarina (UFSC), Curitibanos-SC, Brasil; leosane.bosco@ufsc.br

ABSTRACT

To reduce the risks associated with the production of gladiolus flowers in the climatic conditions of southwestern Paraná, Brazil, this study characterized the growth, development, and floral stem quality of plants cultivated under different-colored shade nets and mulching in four growing seasons. The gladiolus cultivar 'White Goddess' was grown in beds with and without mulching in the soil. Three shade nets individually stained black, silver and red all with 35% shading, were used in this study, and an additional treatment (control) in which plants were grown in full sun. Growth (LAI and height), development (cycle in days, and degree-days), and flower quality (size and stem damage) were evaluated in eight plants in each treatment. Plants were distributed in a randomized block design in a factorial scheme (season x mulching x shade screen). The cycle ranged from 66 to 89 days and 1732 to 1268°C day. The mean difference of the cycle between treatments was 3 days. Less floral stem damage happened under silver net and was more in full sun. The shading net associated with mulching favored the growth characteristics of the plants, and in autumn, the flowers had the highest quality standard.

Keywords: *Gladiolus × grandiflorus*, temperature, shading nets, soil management.

RESUMO

Crescimento, desenvolvimento e qualidade do gladíolo 'White Goddess': época de cultivo, tela de sombreamento e cobertura do solo

Para reduzir os riscos associados à produção de flores de gladíolo nas condições climáticas do sudoeste do Paraná, Brasil, este estudo caracterizou o crescimento, desenvolvimento e qualidade de hastes florais de plantas cultivadas sob telas de sombreamento de diferentes cores e com cobertura morta em quatro épocas de cultivo. A cultivar de gladíolo 'White Goddess' foi cultivada em canteiros com e sem cobertura morta no solo. Três telas de cor preta, prata e vermelho, todas com 35% de sombreamento, foram utilizadas neste estudo, e um tratamento adicional (controle) em que as plantas foram cultivadas a pleno sol. O crescimento (IAF e altura), o desenvolvimento (ciclo em dias e graus-dia) e a qualidade das flores (tamanho e dano na haste) foram avaliados em oito plantas de cada tratamento. As plantas foram distribuídas no delineamento em blocos casualizados no esquema fatorial (época x cobertura morta x tela de sombreamento). O ciclo das plantas variou de 66 a 89 dias e 1732 a 1268°C dia. A diferença média de duração do ciclo, entre os tratamentos, foi de 3 dias. Menos danos nas hastes florais ocorreram sob a tela prata e mais danos foram observados em pleno sol. A tela de sombreamento associada à cobertura morta favoreceu as características de crescimento das plantas, sendo que no outono, as flores apresentaram o maior padrão de qualidade.

Palavras-chave: *Gladiolus × grandiflorus*, temperatura, telas de sombreamento, manejo do solo.

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Gladiolus (*Gladiolus × grandiflorus*) or 'Palma-de-Santa-Rita' is an important cut flower used worldwide (Salma *et al*., 2018) for ornamentation during events and special dates, such as Mother's Day, Valentine's Day, and Souls' Day (Schwab *et al*., 2015a). Galdiolus is in the top 10 cut flowers and the first bulbous flower in world trade. Brazil is among the largest producers of gladiolus in the world (Schwab *et al*., 2019) for having areas with a favorable climate for this species. The cultivation of gladiolus is considered easy in all parts of the world due to its rusticity, although in warmer regions, to be successful in the production of quality floral stems, producers need to use additional management to reduce or increase luminosity and air temperature.

The cultivation system is carried out by corm implantation in a conventional way, which consists of preparing the beds with intensive soil tillage. In the last years, some studies introduced the idea of improving the soil management with complementary soil cover by artificial or natural mulching (Donjadee & Tingsanchali, 2016) or using a minimum tillage system (Bosco *et al*., 2021). These actions are in line with the UN's sustainable development goals, which seeks to develop more sustainable agriculture, reducing soil loss, promoting improved fertility and soil water conservation, reducing the thermal amplitude, in order to protect the soil and the roots of extreme temperatures (Wang *et al*., 2021).

Gladiolus can be cultivated throughout the year, however, in some seasons, adverse conditions may occur, such as reduced luminosity and reduced or increased air and soil temperature. These adversities can cause changes in the developmental cycle, for example, when planting occurs during periods of high air temperatures the cycle is shorter and when planting occurs in periods of low air temperatures the cycle is higher than in the optimal temperature. Furthermore, high temperatures cause visual damages in the stems, and the low temperatures, which in addition to causing visual damage in leaves and flowers, paralyze plant development, resulting in lower commercial quality (Severino, 2007; Schwab *et al*., 2018).

The greatest climatic obstacle to the growth, development, and quality of gladiolus is related to extreme air temperatures, that is, those above 35°C or below 0°C, mainly in the reproductive phase (Uhlmann *et al*., 2017; Schwab *et al*., 2018). Owing to the environmental conditions in some regions of southern Brazil with Cfa (warm subtropical summer) climate, such as southwest Paraná, Brazil, temperatures above 35°C can occur, especially in spring-summer season. Although the gladiolus is classified as a full sunlight plant, the use of shade nets above the plants can be a viable and low-cost alternative to protect plants in warmer seasons, maintaining year-round production and quality of flowers (Santos, 2014; Schwab *et al*., 2018). Shade nets reduce the direct incidence of sunlight, thus, causing a reduction in air temperature. In addition, colored nets provide physical protection by solar radiation filtration, promoting specific light-regulated plant responses (Santos, 2014; Ferron *et al*., 2021).

The production of gladiolus in southwestern region of Paraná has increased in recent years due to the stimulus to produce these flowers brought by the PhenoGlad Brazil team. This team aims to encourage production in short chains and contributes to the growth of flower production, taking the results of research with practical application to the field through the link between research and rural extension (Schwab *et al*., 2019). However, technicians and field extensionists still do not have enough support to indicate the best management or growing season for farmers in that region. This is because little is known about the growth, development and quality of gladiolus flowers produced at different times of the year, although some initial experiments in Paraná (Ferron *et al*., 2021) showed a risk of loss of the floral stem due to extreme temperatures and water deficit during warmer periods.

Our hypothesis is that the use of a more sustainable soil cultivation system using natural mulching associated with plant cover with shading nets, promotes changes in growth characteristics, such as increase in height and leaf area. In addition, an increase in the duration of the development cycle and better quality of floral stems are expected. Therefore, it is hypothesized that their growth and development characteristics will be affected by different shade nets and mulching.

The objective of this study was to characterize the growth, development and floral stem quality of gladiolus cultivated under shade nets with mulching in different growing seasons in southwestern region of Paraná.

MATERIAL AND METHODS

The experiments were carried out in a field at the Universidade Tecnológica Federal do Paraná (UTFPR), Campus Dois Vizinhos, southwest Paraná, Brazil (24°42’1”S, 53°5’58”W, altitude 525 m). According to Köppen’s classification, the climate of the region is Cfa (warm subtropical summer) (Alvares *et al*., 2013), with 21°C average annual temperature, 80% relative humidity, and 2000 mm total annual rainfall. The soil is classified as distroferric Red Nitosol (Bhering & Santos, 2008), with 46.91 g/dm³ of organic matter, 27.27 g/dm³ of carbon content, 1.05 cm/dm³ of potassium, and 36.41 mg/dm³ of phosphorus.

The experiments were conducted during four seasons: I) the first season started on March 21 [planting (PL)] and lasted until June 22, 2019 [complete senescence of the floral stem (R5)], which we call autumn 2019, II) the second season started on August 13, 2019 (PL) and lasted until November 11 (R5), which we call winter 2019, III) the third season started on August 8, 2020 (PL) and lasted until November 11 (R5), which we call winter 2020, and, IV) the fourth season started on October 4, 2020 (PL) and lasted until January 15, 2021 (R5), which we call spring 2020.

White Goddess was used as the cultivar. The corms were purchased from Terra Viva® with 10-12 cm in circumference. Cultivation was performed in beds with and without mulching in the soil. The furrows for planting the corms were prepared with a line marker at a depth of 15 cm.

Planting fertilization was done with 75 kg/ha urea [$CO(NH_2)_2$], 30 kg/ha phosphorus (P_2O_5), and 80 kg/ha potassium (K_2O). For cover fertilization in the V3 stage (Schwab *et al*., 2015a) 75 kg/ha of urea and 30 kg/ha of potassium chloride (KCl) were used in all seasons.

Mulch was made-up of vegetable residues and was added after planting, with 4 t/ha oat straw (*Avena sativa*) in the autumn 2019 season, 4.5 t/ha ryegrass (*Lolium multiflorum*) in the winter 2019 season, 6.5 t/ha ryegrass + turnip (*Raphanus sativus*) in the winter 2020 season, and 6.0 t/ha ryegrass + turnip in the spring 2020 season. The plant species used as soil cover was not considered a treatment and differed according to the availability of material in each growing season.

The black, silver, and red shade nets with 35% shading intensity were installed on the plots at an approximate height of 1.70 m above the ground surface from the date of emergence and remained there throughout the cycle. The shading (%) was measured with a LP-80 ceptometer.

The microclimatic characteristics of each treatment were measured with and without shade net, air and soil temperature and light intensity. Air temperature data were obtained from four temperature sensors connected in dataloggers (AKSO® 172) installed 1.2 m above the ground. Soil temperature was observed once during 24 h for each experiment in autumn and winter 2019. Light intensity was evaluated with an ITLD-300 digital luximeter at 10:00 am, 12:00 pm, 15:00 pm, 18:00 pm, and 21:00 pm GMT.

All plants were distributed in a randomized block design using a factorial scheme with split plots. The primary plots were those with and without the presence of mulching above the soil, and the subplots were those with and without (control) the presence of shading nets in black, silver, and red, all having 35% shading intensity (Figure 1). The experimental plot had a total area of 62.0 m² (9.4 × 6.6 m), and subplots of 9.4 × 1.0 m and 1.5 × 1.0 m, respectively. Each subplot comprised 14 plants arranged in paired rows of 0.4 and 0.2 m between plants.

Eight plants were used per plot to examine the growth and development of gladiolus. Weekly evaluations of the number of leaves, height of plants and, measurement of length and width of leaves were carried out until the final leaf was completely visible in each marked plant. The leaf area was calculated by methodology proposed by Schwab *et al*. (2014) and these results were used to calculate the leaf area index (LAI).

To characterize the development of the plants in each treatment, daily phenological evaluations were carried out to obtain the mean date of occurrence of the stages of emergence (EM) and complete senescence of the floral stem (R5). The total cycle duration of gladiolus was determined in days, and degree-days using the thermal time method as described by Schwab *et al*. (2017), considering Tb = 2°C for the vegetative and Tb = 6°C for the reproductive phase (Uhlmann *et al*., 2017) and the data of air temperature obtained from each treatment.

The quantitative aspects to quality the floral stems were evaluated in eight plants of each treatment when the plant was at harvest point 1 (R2 stage), by measuring the total (from the base of the plant to the tip of the spike) and rachis length (from the insertion to the tip of the spike) of the plant. The spike diameter was measured at the insertion of the first floret with a pachymeter. Floral stems were classified according to the standards established by the cooperative Veiling Holambra (2013) into the class 75, class 90, and class 110 as described by Bosco *et al*. (2021).

The damage to florets was counted from the first appearance of the damaged plants, and the percentage of damage in all plants of the treatment was evaluated, considering damage >1 cm in the florets (Veiling Holambra, 2013).

The homogeneity and normality of the data were verified, and transformation was performed wherever required. For growth, development and stem quality variables, a three-factor analysis (season × mulching × shade screen), Tukey's test ($p \leq 0.05$), and multidimensional scaling analyses were performed. All analyses were performed using the R statistical program (R Core Team, 2013).

RESULTS AND DISCUSSION

Plant growth characteristics

Shade nets under uncovered soil conditions did not influence Leaf Area (LA) and Leaf Area Index (LAI), however, in mulching soil condition, lower LA and LAI were observed in the treatment without netting (Table 1). In the environment without shade net, higher luminosity was observed compared to the treatments with black, silver and red shade nets (Table 2). Plants are photoautotrophic organisms that use the leaves to optimize light capture as well as gas exchange and temperature regulation (Legris *et al*., 2021). Under shade net with reduced light conditions, plants of gladiolus expanded their leaf blades to maximize light capture.

Growing gladiolus with mulching contributed to increasing LA and LAI in silver, and red shade net condition (Table 1). Air and soil temperature may also influence leaf growth characteristics (Öztürk *et al*., 2015). In the soil without mulching treatment the thermal amplitude was 2°C greater (10 to 18°C) than in soil with mulching (12 to 18°C), and only the minimum soil temperature increased in the mulching condition (Table 2). Freitas' *et al*. (2014) study show that soil conservation systems, namely, soil cover, increase the plant growth rates.

Spring 2020 exhibited a greater height of plants in both soil conditions (Table 1). The highest air temperatures were observed during this period, with an average maximum temperature of 33.8°C, 33.2°C, 31.4°C, and 32.6°C in black, silver, red and without shade net, respectively, and a minimum temperature of 18.1°C,18.3°C, 18.7°C and 18.4°C in black, silver, red, and no shading screen, respectively (Table 2). However, the height variability of gladiolus plants is mainly caused by genetic factors, and environmental influences are less important for this trait (Azimi & Banijamali, 2019).

Plants grown with mulch showed greater height during the winter and spring seasons compared to those without mulch (Table 1). Salma *et al*. (2018) attributed the lower plant height of gladiolus to the use of soil cover.

The cultivation of gladiolus using shading net associated with mulching favored the growth characteristics of the plants. Highest final height, LA, and LAI respond to adjustments in metabolic rates to allocate more carbon to the stem, favoring plant stem growth (Mota *et al*., 2013). This type of response, combined with a higher LA and LAI, can be considered a survival strategy under low-light conditions (Grecco *et al*., 2011). Shading of up to 50% in some forest species favored the growth characteristics, however, there was a reduction in benefits when the shading was above 70% (Souza & Freire, 2018).

Plant development characteristics

The total duration of the gladiolus development cycle [emergence of plants (EM) to complete senescence of the floral stem (R5)] ranged from 66 to 89 days and 1732 to 1268°C day (Table 3). The thermal time in spring 2020, in both condition of the soil cover, was remarkable. In this season the air temperatures were higher than autumn and winter seasons (Table 2). In the treatments with mulching, in spring 2020 the environment with no shade net presents the highest thermal time (1716°C day), while in winter 2019 plants under black shade net had the highest demand (1618°C day). In spring 2020, no differences were observed in the thermal time of the plant cycle considering treatments with and without shade net (Table 3).

The mean difference of the gladiolus cycle between treatments with and without mulching was 3 days and 56°C day and between shade nets was 3 days or 32°C day. These small differences observed in the total duration of the cycle can be explained by the variation of temperatures in the growing seasons. According to Zubair *et al*. (2006), the duration of the gladiolus development cycle is directly influenced by the air temperature of the growth seasons. Thus, different results may be obtained when cultivating gladiolus at other season, year and, places (Tomiozzo *et al*., 2018).

For gladiolus, when the air temperature is close to the optimal cardinal temperature (25°C), the growth rate of the culture is maximum with a shorter cycle duration. However, the growth rate reduced with a longer cycle duration when the temperature is below or above 25°C (Uhlmann *et al*., 2017). The total duration and thermic demand of the gladiolus cycle of this study was directly related to the air temperature of the treatments, being more influenced by the growing season than shading net or soil cover (Table 3). In addition to the air temperature, other factors can interact with the plants, such as light and air and soil moisture (Bahuguna & Jagadish, 2015).

Quality of floral stems

The greatest stem length was observed in condition with mulching

Table 1. Final leaf area (LA), leaf area index (LAI) and height of gladiolus cultivar White Goddess in different shade nets with 35% shading intensity, seasons and, mulching in conditions of Cfa climate of Paraná state, Brazil, during 2019 and 2020. Dois Vizinhos, UTFPR, 2020.

Shade nets	Mulching	Without mulching
	LA (cm²)	
Black	1040.0 aA*	956.8 aA
Silver	1111.0 aA	1011.0 aB
Red	1077.9 aA	944.8 aB
No shade net	839.4 bB	945.9 aA
CV (%)	0.3	
	LAI	
Black	1.3 aA	1.1 aA
Silver	1.4 aA	1.3 aB
Red	1.3 aA	1.9 aB
No shade net	1.0 bA	1.8 ab
CV (%)	1.2	
Seasons	**Height (cm)**	
Autumn 2019	68.1bA	68.4 bA
Winter 2019	68.0 bA	63.2 cB
Winter 2020	65.2 bA	60.3 cB
Spring 2020	85.6 aA	78.0 aB
CV (%)	4.3	

*Means followed by different lowercase letters in the column and uppercase in the row differ statistically by Tukey's test at 5% significance.

Figure 1. Image of experiment with shading nets in black, silver and, red with 35% shading intensity and without net (A) in production of gladiolus cultivar White Goddess with and without mulching (B) in conditions of Cfa climate of Paraná state, Brazil, during winter 2020 season. Dois Vizinhos, UTFPR, 2020.

Table 2. Meteorological data of average luminosity, maximum air temperature (Tmax), minimum air temperature (Tmin), absolute maximum air temperature (Tmax_abs), absolute minimum air temperature (Tmin_abs) and soil maximum and minimum temperatures in conditions of Cfa climate of Paraná state, Brazil, during experiments carried out in 2019 and 2020 with gladiolus White Goddess in different shade nets with 35% shading intensity, seasons and, with and without mulching. Dois Vizinhos, UTFPR, 2020.

Season	Shade net	Meteorological data				
		Luminosity (lx)	T max (°C)	T min (°C)	Tmax abs (°C)	T min abs (°C)
Autumn 2019	Silver	16694.7	26.6	15.1	38.0	-2.4
	Black	14384.3	27.0	15.4	34.1	-2.7
	Red	14245.7	26.1	14.9	38.6	-2.9
	No screen	34287.0	28.3	14.5	34.1	-3.8
Winter 2019	Silver	31796.2	30.8	16.5	38.4	8.3
	Black	21137.9	30.0	21.2	37.4	13.0
	Red	24408.6	30.5	16.3	41.5	8.2
	No screen	42933.7	32.0	15.7	50.1	7.1
Winter 2020	Silver	26708.6	31.5	15.9	39.7	6.4
	Black	27181.6	33.5	15.8	44.4	5.7
	Red	26980.6	31.2	16.1	39.7	5.8
	No screen	45178.1	32.0	15.8	40.1	5.8
Spring 2020	Silver	25022.5	33.2	18.3	49.4	9.8
	Black	26608.6	33.8	18.1	51.1	9.7
	Red	24671.7	31.4	18.7	39.3	9.9
	No screen	42923.7	32.6	18.4	40.1	9.3

	Soil temperature (°C)			
	Mulching		Without mulching	
	Tmax	Tmin	Tmax	Tmin
Autumn 2019	18.0	12.0	18.0	10.0
Winter 2019	18.0	12.0	18.0	10.0

during winter 2019 (126.9 cm) and spring 2020 (116.0 cm) (Table 4). The rachis was longer, in both conditions of soil mulching, in autumn 2019 and spring 2020 (50.2 cm). This may be related to the climatic characteristics [(Cfb) Temperate climate, with mild summers], as already reported by Schwab *et al*. (2015b) and Tomiozzo *et al*. (2018). Additionally, the greater the length of stem and floral rachis, the greater is the presence of carbon, thereby allowing greater longevity/durability of the gladiolus in the post-harvest period (Schwab *et al*., 2015b).

The gladiolus cultivation carried out in winter 2020 demonstrated the shortest stem and rachis length in both conditions of soil mulching (Table 4). When gladiolus was grown in low luminosity and temperature, especially in winter months, plants could reduce size, length, and quality of the floral stems (Severino, 2007; Zubair *et al*., 2006).

There was interaction only between the factors season x shade net and season x soil mulching for the variable number of florets (Table 5). The final number of florets of the cultivar White Goddess ranged from 10.4 to 18.0 florets considering different seasons, shading nets, and soil mulching. This range is considered suitable for gladiolus (Schwab *et al*., 2015b). In the autumn and winter season 2019, there were no differences between the shading nets (Table 5). In the 2020 winter season, the final number of florets was the lowest observed across all shading nets. In the winter season 2019 (17.2) and spring 2020 (17.8) with soil mulching, the gladiolus plants produced the highest number of florets. In autumn 2019 and spring 2020 did not occur differences between the soil mulching conditions. However, in the winter season 2019, the highest number of florets (17.2) was found in mulching condition and, in winter 2020 it happened in the cultivation without mulching (12.3).

The number of florets observed in our study was different from those reported by Bosco *et al*. (2021), who found that the number of florets of the White Goddess was not affected by the soil tillage system and seasons in three different regions of Santa Catarina. Therefore, we can state that the response of growth, development, and quality of the gladiolus flowering stems differ according to the growing seasons and soil management in different geographical regions of cultivation.

Our results are in agreement with the relationship that the greater the length of the stem, the greater is the

Table 3. Total duration of the gladiolus development cycle [emergence of plants (EM) to complete senescence of the floral stem (R5)] in days and in thermal time (°C day) of gladiolus cultivar White Goddess in different shade nets with 35% shading intensity, seasons and, with and without mulching in conditions of Cfa climate of Paraná state, Brazil, during 2019 and 2020. Dois Vizinhos, UTFPR, 2020.

Seasons	Cycle (°C day), Shade nets in mulching condition			
	Black	Silver	Red	No shade net
Autumn 2019	1425cAB	1408cAB	1380cB	1471cA
Winter 2019	1618bA	1514bB	1500bB	1549bB
Winter 2020	1440cAB	1374cBC	1470bA	1324dC
Spring 2020	1732aA	1718aA	1664aA	1716aA
	Cycle (°C day), Shade nets in no mulching condition			
Autumn 2019	1387cBC	1433cAB	1323cC	1458cA
Winter 2019	1631aA	1518bB	1514bB	1546bB
Winter 2020	1492bA	1343dB	1546bA	1268dB
Spring 2020	1534bB	1692aA	1755aA	1692aA
	Cycle (day), Shade nets in mulching condition			
Autumn 2019	85aA	84aA	85aA	86aA
Winter 2019	77bA	76bA	80bcA	78bA
Winter 2020	71cAB	70cAB	74 cA	67cB
Spring 2020	80bA	80abA	80bA	81bA
	Cycle (day), Shade nets in no mulching condition			
Autumn 2019	83aBC	89aA	81aBC	85aBC
Winter 2019	78abA	77bA	77bA	77bA
Winter 2020	73bAB	68cBC	79bA	66cC
Spring 2020	73bB	79bAB	84aA	79bA

*Means followed by different lowercase letters in the column and uppercase in the row differ statistically by Tukey’s test at 5% significance.

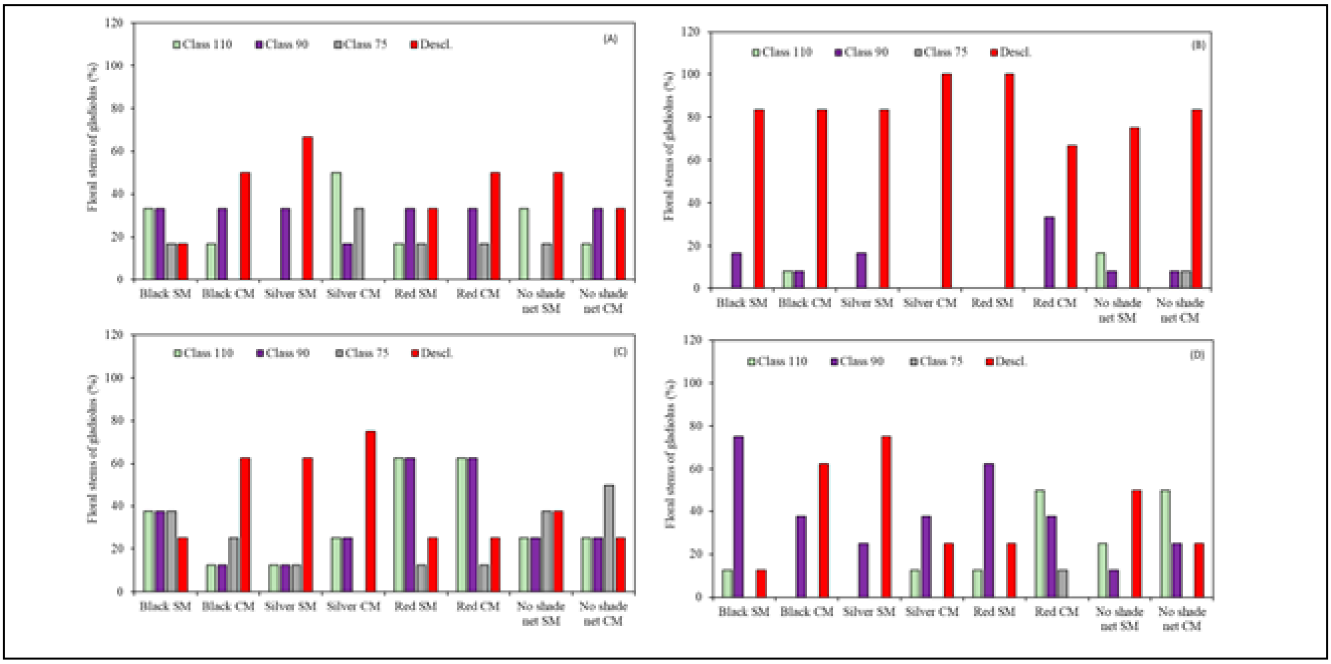

Figure 2. Stem marketing classes according to Veiling Holambra (2013) for gladiolus cultivar White Goddess cultivated at different seasons (A) Autumn 2019; (B) Winter 2019; (C) Winter 2020 and (D) Spring 2020, in different shade nets with 35% shading intensity and without net and, with (CM) and without mulching (SM) in conditions of Cfa climate of Paraná state, Brazil. Dois Vizinhos, UTFPR, 2020.

final number of florets, i.e., these floral stems will be more attractive to flower sellers and consumers that use longer floral stem with a large number of florets in decorations (Severino, 2007; Schwab *et al*., 2015a).

The mulching soil had little influence on the quality and characteristics of gladiolus floral stems, making it feasible to use straw cover on the soil (mulching) and favoring its physical, chemical, and biological characteristics, reducing erosion, weeds, and soil evaporation as observed by Bosco *et al*. (2021). Coverage reduces the thermal amplitude of the soil, as observed in soil temperatures in our study and contributes to the accumulation of organic matter and maintains soil moisture (Mathew *et al*., 2012).

In autumn 2019, the treatment of silver shade net without mulching had the highest number of disqualified plants (Figure 2A). In winter 2019, in all treatments, the number of discarded stems was above 60% (Figure 2B) although having the highest total rachis length however, it did not reach 40% of the total stem, according to the standards of commercialization (Veiling Holambra, 2013).

In winter 2020, the best response was observed in the red shade net in both soil mulchings, with most stems in classes 110 and 90 (Figure 2C), which collaborated with the highest rachis length found among the shade nets (Table 4). Similar results were found by Maia (2015), who used a red shade net in alpinia (*Alpinia purpurata*) cultivation. In the treatments of black shade net with mulching (Black CM) and silver with (Silver CM) and without (Silver SM) mulching presented more than 60% of declassified floral stems.

In spring 2020, the best quality stems were observed in the red shade net with mulching (Red CM), with the highest number of stems in classes 110 and 90 and no disqualified stems (Figure 2D). Plants grown under red nets receive electromagnetic waves that promote elongation characteristics such as greater stem and rachis length (Oren-Shamir *et al*., 2001). In black (with mulching), silver (without mulching), and without shade nets (without mulching), 62.5%, 75.0%, and 50% of the stems, respectively, were disqualified (Figure 2D).

The number of disqualified plants was higher in winter 2019 than those in winter 2020, with 84.4% in the different treatments. Class 75, with the lowest commercialization value, was higher in the winter 2020 crop, and contained 23.4% of the total plants (Figure 2C). Class 90 was higher in winter 2019 and 2020 cultivation, with 39.1% of the total plants (Figure 2B), and class 110 had very similar number of floral stems on autumn 2019 and spring 2020, with

Table 4. Stem total length and rachis length at harvest point (R2) of gladiolus cultivar White Goddess in different shade nets with 35% shading intensity, seasons and, with and without mulching in conditions of Cfa climate of Paraná state, Brazil, during 2019 and 2020. Dois Vizinhos, UTFPR, 2020.

Seasons	With mulching	Whithout mulching
	Stem total length (cm)	
Autumn 2019	115.6 bA*	113.7 abA
Winter 2019	126.9 aA	116.8 aB
Winter 2020	90.7 cA	93.5 cA
Spring 2020	116.0 bA	106.8 bB
CV (%)	1.8	
	Rachis lenght (cm)	
Autumn 2019	50.2 aA	46.6 aA
Winter 2019	45.0 bA	41.5 bcB
Winter 2020	35.9 cA	37.3 cA
Spring 2020	49.1 abA	43.7 abB
CV (%)	6.9	

*Means followed by different lowercase letters in the column and uppercase in the row differ statistically by Tukey's test at 5% significance.

Table 5. Final number of gladiolus florets, cultivar White Goddess, in different shade nets with 35% shading intensity, seasons and, with and without mulching in conditions of Cfa climate of Paraná state, Brazil, during 2019 and 2020. Dois Vizinhos, UTFPR, 2020.

Seasons	Shade nets			
	Black	**Silver**	**Red**	**No shade net**
	Final number of florets			
Autumn 2019	15.1 bA*	15.0 aA	14.6 bA	15.5 bA
Winter 2019	17.2 aA	16.7 aA	16.1 bA	17.0 abA
Winter 2020	12.3 cAB	10.4 bB	12.3 cA	11.6 cAB
Spring 2020	16.3 abAB	15.9 aB	18.0 aA	17.4 aAB
CV (%)	13.1			
	Soil cover			
	Mulching		**Without mulching**	
Autumn 2019	15.4 bA*		14.7 bA	
Autumn 2019	17.2 aA		16.3 aB	
Winter 2020	10.9 cB		12.3 cA	
Spring 2020	17.8 aA		16.1 aA	
CV (%)	13.1			

*Means followed by different lowercase letters in the column and uppercase in the row differ statistically by Tukey's test at 5% significance.

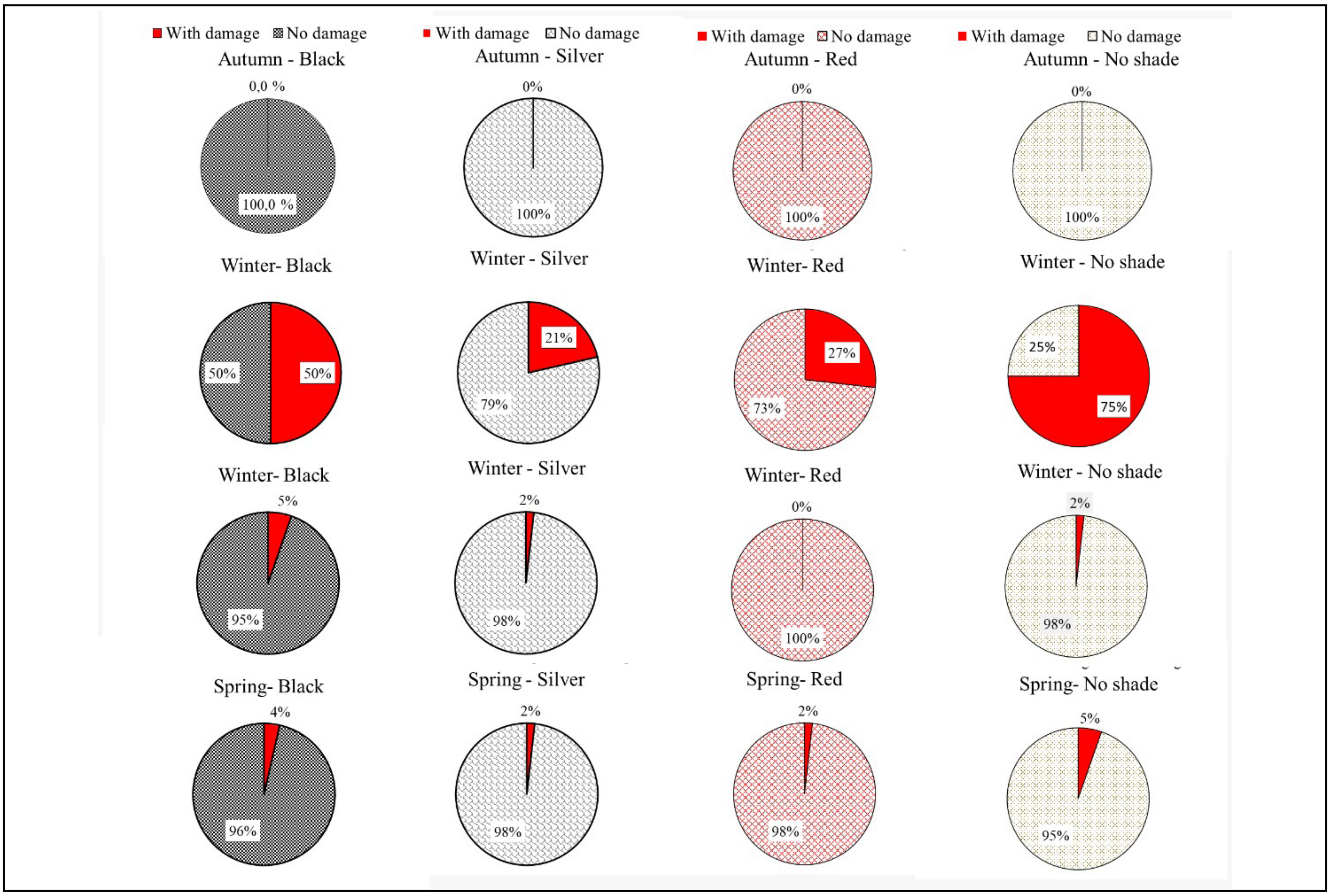

Figure 3. Percentage of floral stems damage to gladiolus cultivar White Goddess at the harvest point (R2) considering only the averages related to treatments in different shade nets with 35% shading intensity and, seasons in conditions of Cfa climate of Paraná state, Brazil, during 2019 and 2020. Dois Vizinhos, UTFPR, 2020.

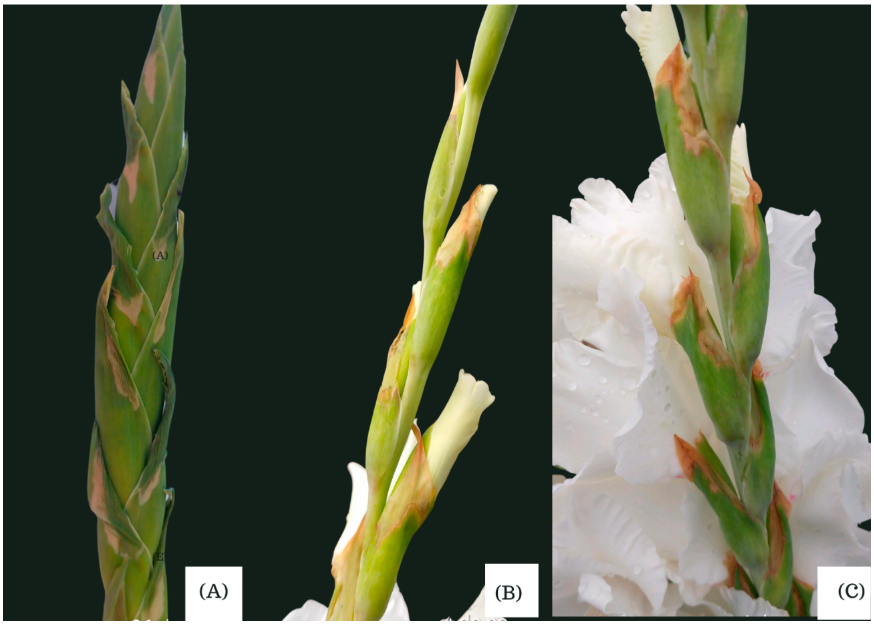

Figure 4. Floral stems of gladiolus cultivar White Goddess cultivated in winter 2019 season in conditions without shading showing damage to the sepals greater than 1 cm in stages of beginning of earing (R1) (A), harvest point (B) and in full bloom (C) in Cfa climate of Paraná state, Brazil. Dois Vizinhos, UTFPR, 2020.

20.8% and 20.3%, respectively (Figure 2A and 2D). Plants of the winter 2020 presented stems with lowest commercial quality. Evaluating the shade nets, the highest plants in class 110 were observed in autumn 2019, at 25%, 25%, 31.3%, and 37.5% for black, silver, red, and without shade nets, respectively (Figure 2A).

Regarding the quality of floral stems, it is important to highlight that in small rural properties, sales of gladiolus floral stems are destined for local commerce, in short production chains. In this case, the producer does not classify the stems according to the Veiling Holambra (2013) standards, and they can sell flowers even if the stems are smaller, out of standards, or substandard.

Our data obtained from experiments carried out in the southwest region of Paraná (Cfa climate) indicate that autumn (from March to June) has ideal climatic conditions for the gladiolus floral stems to obtain higher quality standards in class 110, as it had milder temperature. In autumn 2019, no damage was observed to the gladiolus floral stems in any of the shade nets (Figure 3). The lowest damage was observed in the silver shade nets and the highest in the condition without shade and black shade net.

In periods with high temperatures, silver and red shade nets reduced an average of 47.5% of possible damage. In the treatment with a red shade net (35%), the plants exhibited longer rachis length, higher final number of florets, and higher quality. The silver and red shade nets reduced the high-temperature damages in the floral stems.

The highest damage was observed in winter 2019, ranging from 21% to 75% of the total stems (Figure 3), with damage above 1 cm (Figure 4). These damages can be attributed to the temperature conditions of the growing season, where temperatures above 34°C occurred for three consecutive days (Uhlmann *et al*., 2017) during the reproductive period.

We conclude that the gladiolus cycle ranged from 66 to 89 days. The silver and red shade nets reduced the high-temperature damages in the floral stems. The cultivation of gladiolus using shading net associated with mulching favored the growth characteristics of the plants, as highest final height, LA, and LAI. In autumn, the flowers had the highest quality standard.

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