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Scientific article

# Growth and vase life of gladiolus plants cultivated under different conditions in the semi-arid region of Brazil

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**Abstract**

Cultivation conditions are determining factors that affect the quality of cut flowers. The objective of this study was to evaluate the vegetative growth, flowering and vase life of commercial gladiolus cultivars under different shading conditions in the Brazilian semi-arid region. Two cultivars of gladiolus (Jester and Rose Friendship) were grown under two conditions: full sun and 70% shade. Biometrics were evaluated 60 days after planting and the growth rate of the crop was evaluated at 15-30, 30-45 and 45-60 days for the variables: number of tillers, stem diameter, number of leaves and plant height. After 45 days, the fresh weight, dry weight and total relative water content of the area and root parts of the plants were evaluated. After the harvest, the stems were kept at a temperature of 22±3 °C and relative humidity (RH) of 60%. Visual assessment, pH of the solution, variation in the volume of water and loss of fresh mass were measured every two days. Cultivation with 70% shading resulted in greater accumulation of biomass in the aerial part of gladiolus plants, greater neck diameter and height. The Rose Friendship cultivar underwent a greater translocation of dry matter to the aerial part of the plants, resulting in greater height. On the other hand, the gladiolus stems from cultivation under full sun conditions resulted in longer vase life, 10 days under conservation conditions at 22±3 °C and RH 60%.
**Keywords:** *Gladiolus x grandiflorus* L.; postharvest; stem height; relative water content; dry mass.

**Resumo**

**Crescimento e vida de vaso de plantas de gladíolo cultivadas em diferentes condições na região semi-árida do Brasil**

As condições de cultivo são fatores determinantes que afetam a qualidade das flores de corte. Diante disso, objetivou-se, neste estudo, avaliar o crescimento vegetativo, floração e vida de vaso de variedades de gladíolos comerciais no semiárido brasileiro, sob diferentes condições de sombreamento. Duas variedades de gladíolos (Jester e Rose Friendship) foram cultivadas em duas condições: sol pleno e 70% de sombreamento. Avaliou-se a biometria em 60 dias após o plantio e a taxa de crescimento da cultura aos 15-30, 30-45 e 45-60 dias para as variáveis: número de perfilhos, diâmetro do colo, número de folhas e altura da planta. Após 45 dias, avaliou-se a massa fresca, massa seca e conteúdo relativo de água total da parte área e da parte radicular das plantas. Após a colheita, as hastes foram mantidas em temperatura de 22±3 °C e umidade relativa (UR) de 60%. A cada dois dias, realizou-se avaliação visual, além de avaliação do pH da solução, variação no volume de água e perda de massa fresca. O cultivo com 70% de sombreamento resultou em maior acúmulo de biomassa na parte aérea das plantas de gladíolos, maior diâmetro do colo e altura. A variedade Rose Friendship resultou em maior translocação de massa seca para a parte aérea das plantas. Isso resultou em maior altura. Por outro lado, as hastes de gladíolos provenientes do cultivo nas condições de pleno sol resultaram em maior vida de vaso: 10 dias em condições de conservação a 22±3 °C e UR 60%.
**Palavras-chave:** *Gladiolus x grandiflorus* L.; pós-colheita; altura de hastes; teor relativo de água; massa seca.

## Introduction

Ornamental floriculture is one of the sectors of Brazilian agribusiness that has developed greatly in recent years. Since 2013, there has been a consolidation of income in the country resulting from this sector, with a growth of 6% per year (Junqueira and Peetz, 2018). Cut flowers from the genus *Gladiolus* are among the five main cut flowers marketed in Brazil (Junqueira and Peetz, 2018). The palm-of-Santa-Rita (*Gladiolus x grandiflorus* L.), also known as gladiolus, is an herbaceous plant belonging to the Iridaceae family. It presents inflorescences of different colors and is

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used in ornamental gardens, bouquets and vases (Memon et al., 2013). This makes it an important species for the flower trade in Brazil (Memon et al., 2013).

In Brazil, in 2018, 16,400 establishments producing flowers and ornamental plants were registered. Most of these are found in the Southeast (46.2%), the largest concentrations of which are in the states of São Paulo and Minas Gerais (Brainer, 2018). The cultivation of gladiolus has higher yields in areas with temperatures ranging from 20 to 25 °C. In addition, this crop is very sensitive to light restriction; on long days, the gladiolus shows more vigorous growth and development (Schwab et al., 2015a). A crucial aspect for the aesthetic quality and consequent commercialization of flowers is their post-harvest longevity, which is influenced by the pre-harvest conditions (Schwab et al., 2015b; Qayyum et al., 2020). Climatic factors such as temperature, relative humidity, $CO_2$ levels and light conditions directly influence the development of flowers, with effects on their longevity, depending on the species and plant cultivar. Irradiance regulates the photosynthetic process; it induces the absorption of mineral nutrients and the accumulation of carbohydrates, which are responsible for maintaining the quality of flowers in post-harvest (Davarynejad et al., 2008; Gupta and Dubey, 2018).

Tomiozzo et al. (2018) evaluated six species of gladiolus grown in Rio Grande do Sul, Brazil, and found variations in the length of the production cycle depending on the time and place of planting. Souza et al. (2020) evaluated the achievement of different cultivation systems in the production of gladiolus in the Alto Vale do Itajaí – Santa Catarina region and found that the minimum cultivation system produced plants with a larger diameter and stem length. Ferron et al. (2021) suggested that high temperatures influence the size of the tassel, affecting the commercial quality of the rods. However, semi-arid regions present a challenge to the cultivation of this flower, as the average temperature stays between 26 °C and 27.5 °C, and precipitation is 750 mm. In other regions of Brazil, the gladiolus is usually planted in regions with average temperatures of 15 °C and 18 °C and precipitation above 1,300 mm (Tomiozzo et al., 2018; Uhlmann et al., 2019).

In the semi-arid region, such as in the Northeast of Brazil, data on the adaptation of fresh cut gladiolus flowers for commercialization is restricted. The studies have been exclusively restricted to conditions in the south of Brazil, such as the recent works of Becker et al. (2021a) and Becker et al. (2021b). In addition, Becker et al. (2021b) carried out a climate risk zoning for gladiolus under climate change scenarios in three regions of Rio Grande do Sul, and showed that the hotter and drier places were a disadvantage to the plants in the Veiling Holambra pattern. The authors suggested the adoption of cultivars that are better adapted to heat and the use of shade screens. The conditions they described are typical of the semi-arid region of Brazil. This makes the present work of great importance for the region, since the Northeast occupies the third position in the national production of flowers, with about 16.5% of the producers (Brainer, 2018; Souza et al., 2020). In the Northeast, the highest amount of flower production is concentrated in the city of Gravatá, in the state of Pernambuco, with 295 production establishments. The city has an average temperature of 22 °C, with lows reaching 15 °C in the coldest months (Brainer, 2018). The present work hypothesizes that gladiolus cultivars have the potential to be cultivated under different conditions in the semi-arid region of Brazil, given that the scenario of high temperatures and drought is increasingly frequent, even in southern Brazil.

A study on how to make this plant adapt to local cultivation conditions is important for flower growers in semi-arid regions. Thus, the objective of our study was to evaluate the growth, flowering and life of the gladiolus cultivated in the Brazilian semi-arid region, under different cultivation conditions.

## Material and Methods

### Characterization of cultivation conditions

The present work was carried out at the Universidade Federal Rural de Pernambuco, Serra Talhada Academic Unit, located in the municipality of Serra Talhada, Pernambuco, Brazil. The average annual temperature is above 25 °C, global average radiation 17.74 MJ/m$^2$, average relative humidity 64.85% and the average annual precipitation is 647 mm. According to the Köppen classification, the climate of the region is of the BSh type, characterized as hot and dry semi-arid, having an altitude of 481 m (Beck et al., 2018). The climatic conditions, average temperature, global radiation, relative humidity and rainfall during the experimental period are described in Figure 1.

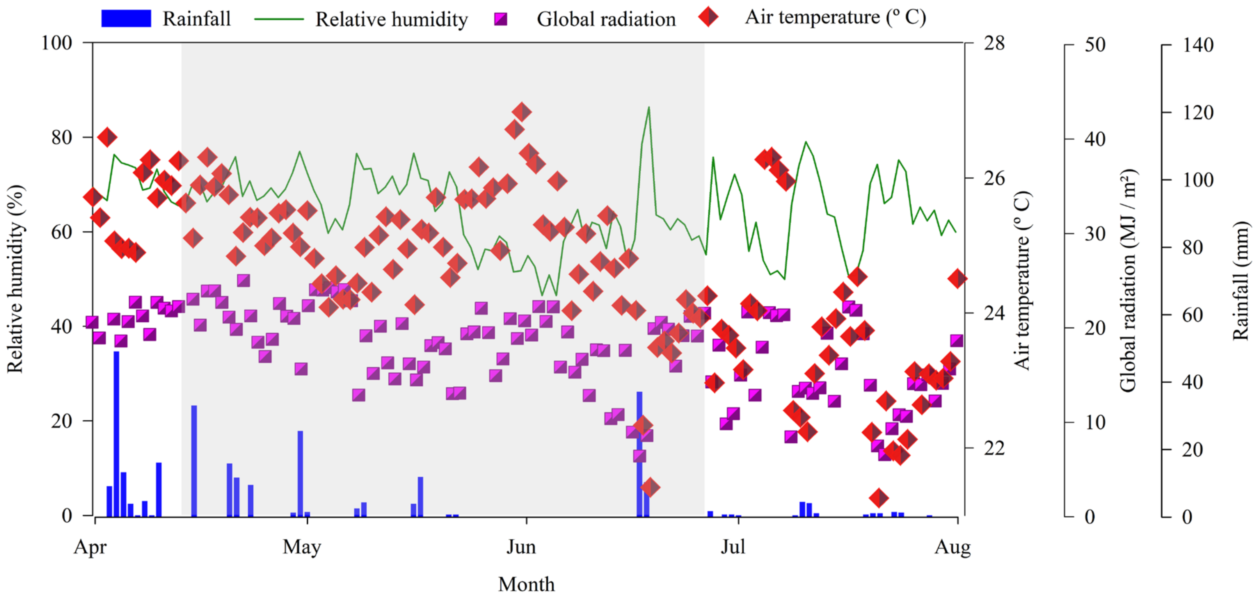


**Figure 1.** Average air temperature (°C), global radiation ($MJ/m^2$), relative humidity of the air (%) and precipitation (mm) between April and August 2019 in the municipality of Serra Talhada-PE, Brazil. Source: INMET (2021). The months highlighted in gray indicate the period of data collection and analysis.

**Plant material, planting, cultivation and harvesting**

Corms of two cultivars of gladiolus (*Gladiolus x grandiflorus* L.) 'Jester' and 'Rose Friendship' were chosen, acquired from the company Terra Viva, located in the city of Santo Antônio de Posse-SP, Brazil. Corms were planted on April 18, 2019. 100 corms with a diameter of 12-4 cm were selected from each cultivar of gladiolus. Then, they were planted in beds, under conditions of both full sun and 70% shade, provided by a plastic screen. Drip irrigation was performed daily at 5:00 a. m. and 5:00 p. m. by emitters with a flow rate of 0.95 L $h^{-1}$ (100 kPa), spaced 0.20 m apart, with duration of 0.5 hours in each period. The uniformity coefficient of the system was 93% and the irrigation events were performed considering the location coefficient in function of the percentage of the wet area, and e leaching depths of 10%, as suggested by Mantovani et al. (2006). Water was applied according to the crop evapotranspiration (ETc), obtained via the multiplication of the reference evapotranspiration (ETo) by the crop coefficient (Kc). The reference evapotranspiration was calculated according to Allen et al. (1998). The value of Kc adopted was established in the study by Doorenbos and Pruitt (1977). The water depth applied via irrigation totaled 281 mm (average of 3.7 mm $d^{-1}$), plus the rainfall accumulated during the period of cultivation (76 days): 135 mm, resulting in 416 mm.

The water used for irrigation had a pH of 6.8 and electrical conductivity of 1.506 mS $cm^{-1}$. In addition, in the planting area, soil analysis and fertilization were carried out according to the recommendations for cultivation using nitrogen, phosphorus and potassium (NPK 10:10:10 kg $ha^{-1}$) (Schwab et al., 2019). Fertilization maintenance was performed with urea, at day 45.

The soil of the experimental area was a typical Eutrophic Ta Haplic Cambisol, which presented the following physical and chemical results at depth of 0.00 to 0.20 m (Jardim et al., 2021): pH (water) of 5.95; electrical conductivity of the saturated soil extract (ECe) of 0.32 dS $m^{-1}$; P (Mehlich-1) of 168.96 mg $dm^{-3}$; K+ of 13.8 cmolc $dm^{-3}$; Na+ of 1.09 cmolc $dm^{-3}$; $Ca^{2+}$ of 3.45 cmolc $dm^{-3}$; $Mg^{2+}$ of 1.90 cmolc $dm^{-3}$; H + Al of 0.6 cmolc $dm^{-3}$; sum of bases (SB) of 20.25 cmolc $dm^{-3}$; cation-exchange capacity (CEC) of 20.85 cmolc $dm^{-3}$; base saturation of (V%)=97.15%; organic C of 4.6 g $kg^{-1}$; organic matter of 7.93 g $kg^{-1}$; sand of 828.6 g $kg^{-1}$; silt of 148.25 g $kg^{-1}$; clay of 23.15 g $kg^{-1}$; and bulk density of 1.45 g $cm^{-3}$.

At days 15, 30, 45 and 60, biometric evaluations were carried out: plant height, stem diameter, number of leaves and number of tillers, as detailed in Table 1. At 45 days, the aerial part and the corms were also collected to determine the fresh and dry mass, the relative water content and the dry mass partition. These assessments were adapted from Schwab et al. (2015a).

**Table 1.** Harvest and height of gladiolus stems (*Gladiolus x grandiflorus* L.) of the cultivars Jester and Rose Friendship cultivated in full sun and using 70% shade.

| Cultivar | Insolation condition | Harvest (Days after planting) | Average height of stem (cm) |
|---|---|---|---|
| Jester | Full sun | 74 | 45.40±8.6 |
| | 70% shade | 65 | 53.60±3.9 |
| Rose Friendship | Full sun | 76 | 57.25±8.4 |
| | 70% shade | 69 | 58.30±6.8 |

±: standard deviation from the mean.

The flowering of the gladiolus started 60 days after planting. The harvest was carried out at 65, 69, 74 and 76 days for the different treatments, as registered in Table 1. The stems were harvested with closed flower buds and the first foil showing its color. The flowers were transported, the leaves were removed and the peduncle cut 20 cm below the inflorescence. The stems were kept in vases containing 500 mL of distilled water, and maintained under conditions of constant light of 27 μmol $m^{-2}$ $J^{-1}$, with a temperature of 22±3 °C and relative humidity between 45% to 60%, for 10 days. Every two days, the visual aspect, changes in the fresh mass of the stems, pH and variations in the volume of water in each vase were evaluated.

**Growth assessments**

Plant height (PLH), stem diameter (SD), number of leaves (NL) and number of tillers (NT) were measured at 15, 30, 45 and 60 days after planting, as adapted from Schwab et al. (2015a) and Schwab et al. (2019). To evaluate the plant height, a ruler graduated in centimeters was used, to measure from the soil surface to the tip of the highest leaf. For the diameter of the stem, a caliper was used and the measurement was performed at 1 cm from the surface of the substrate. Then, the number of leaves produced per plant was counted. In plants with tillers, the number of tillers was counted and the average was calculated for each plant.

With the biometric data, the plant height rate ($R_{PH}$), stem diameter rate ($R_{SD}$), leaf number rate ($R_{LN}$) and tiller number rate ($R_{TN}$) for periods 15–30 were calculated, after 30-45 and 45-60 days, using the following formula: Rate=(W2-W1) / (T2 - T1), where W1 and W2 are the biometric data analyzed at times T1 and T2, according to Hunt (1978). In addition, growth was assessed using data collected 60 days after planting. The quality parameters, diameter and plant height were classified according to Schwab et al. (2015b) and to the Cooperative Veiling Holambra system.

**Fresh and dry biomass and relative water content**

The aerial part and the root part (corms+roots) were weighed, and we obtained the total fresh mass ($T_{FM}$), fresh mass of the aerial part ($FM_{AP}$) and fresh mass of the bulb ($FM_B$), which were then dried in an oven with forced air circulation at 70 °C for 48 hours and weighed again in order to obtain the total dry mass ($T_{DM}$), dry mass of the aerial part ($DM_{AP}$) and dry mass of the bulb ($DM_B$). The relative total water content ($C_{H2OT}$), the relative water content of the aerial part ($C_{H2OAP}$) and the relative corm content ($C_{H2OB}$) were determined using the Equation 1:

$$C_{H2OY}=[(FM_Y-DM_Y)/100] \quad (1)$$

Where:
$C_{H2OY}$ = relative water content of Y, %;
$FM_Y$ = fresh mass of Y, g;
$DM_Y$ = dry mass of Y, *g*.

The dry mass partition for the aerial part - pDM-AP and pDM-B - of the corm was obtained through the Equation 2:

$$pDM\text{-}_Y=[(DM_Y/DM_T)\times 100] \quad (2)$$

In which:
$pDM\text{-}_Y$ = dry mass partition of Y, %;
$DS_Y$ = dry mass of Y, g;
$DM_T$ = total dry mass of the plant, *g*.

**Visual analysis**

The stems harvested and kept in an air-conditioned environment (laboratory) were removed every two days for evaluations of the visual aspect, as shown in Table 2. The commercialization limit adopted was score 2. The score used was chosen according to Silva et al. (2008), with modifications.

**Table 2.** Score for visual assessment of gladiolus stems (*Gladiolus x grandiflorus* L.).

| Score | Evaluation of Flowers |
|---|---|
| 0 | No visible defects: marketable |
| 1 | Stems with up to three open flowers: marketable |
| 2 | Stems with up to five open flowers: marketable |
| 3 | Stems with all flowers open and up to five showing withered petals: not marketable |
| 4 | Stems with up to five flowers showing dryness: not marketable |
| 5 | Stems with all flowers showing dry petals: not marketable |

**Variation of fresh mass**

The following mathematical relationship was used (Equation 3):

$$FM=[(FM1-FM2)/FM1]\times 100 \quad (3)$$

Where:
FM = percentage of fresh mass;
FM1 = fresh mass from the previous day (g);
FM2 = fresh weight on the day of analysis (g).

**Solution pH and water volume variation**

The pH was measured using a pH meter (TECNAL, TEC-5, Piracicaba, Brazil) at a temperature of 25 °C, by direct immersion of the electrode in the water of the vases with the stems.

The volume of water was measured with the aid of a 500 mL beaker, by transferring water from the containers to the beaker. A total water change was carried out every 48 h.

**Experimental design and statistical analysis**

The field experiment was arranged in subdivided plots with a completely randomized design and a 2x2 factorial scheme (two cultivars and two cultivation conditions), with five replications, each replicate containing 10 samples. The experiment in an air-conditioned environment was arranged in a completely randomized design in a 4x6 factorial scheme (four treatments: 1. Rose Friendship, 70% shade; 2. Jester, 70% shade; 3. Rose Friendship, full sun; 4. Jester, full sun; and six evaluation days: 0; 2; 4; 6; 8; and 10 days), with five replications. The data collected was submitted to normality tests, analysis of variance and Tukey's test at 5% probability with the aid of the software R x 64 3.4.0. The graphics were made using the software Sigma Plot version 14.

## Results

**Growth and flowering of cultivars of gladiolus under different shade conditions**

There was no interaction effect between the factors studied for $DM_{AP}$, $FM_{AP}$, $C_{H2OAP}$, $DM_B$, $FM_B$, $C_{H2OB}$, pDM-$_{AP}$ and pDM-$_B$. Table 3 presents the effect of environments and cultivars in isolation. Both cultivars grown under 70% shade resulted in an increase in the content of dry, fresh mass and relative water content in the aerial part of the plants (Table 3). As for the mass partition, there was a greater accumulation of dry mass in the aerial part of those plants cultivated in the shade (Table 3).

**Table 3.** Fresh mass aerial part ($FM_{AP}$), dry mass aerial part ($DM_{AP}$), relative water content aerial part ($CH2O_{AP}$), fresh mass of the bulb ($FM_B$), dry mass of the bulb ($DM_B$), content relative water of the bulb ($CH2O_B$), total fresh mass ($T_{FM}$), total dry mass ($T_{DM}$), total relative water content ($CH2O_T$), aerial part dry mass partition (pDM-AP) and dry mass partition of the bulb (pDM-B) evaluating the cultivars (Jester and Rose Friendship) grown in the environments (full sun and 70% shade)*.

| Cultivation condition | $FM_{AP}$ | $DM_{AP}$ | $C_{H2OAP}$ | $FM_B$ | $DM_B$ | $C_{H2OB}$ | $T_{FM}$ | $T_{DM}$ | $C_{H2OT}$ | pDM$_{-A}$P | pDM-$_B$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (g plant$^{-1}$) | | | | | | | | (%) | | |
| Full sun | 32.22b | 4.72b | 27.50b | 24.87a | 7.10a | 17.78a | 57.10a | 11.82a | 45.28b | 40b | 60a |
| 70% shade | 59.42a | 8.70a | 50.72a | 27.39a | 7.75a | 19.64a | 86.81a | 16.45a | 70.36a | 53a | 47b |
| **Cultivar** | $FM_{AP}$ | $DM_{AP}$ | $C_{H2OAP}$ | $FM_B$ | $DM_B$ | $C_{H2OB}$ | $T_{FM}$ | $T_{DM}$ | $C_{H2OT}$ | pDM-$_{AP}$ | pDM-$_B$ |
| | (g plant$^{-1}$) | | | | | | | | (%) | | |
| Jester | 40.22b | 6.17b | 34.04b | 26.99a | 8.62a | 18.37a | 67.21a | 14.79a | 52.42a | 41a | 59a |
| Rose Friendship | 51.43a | 7.26a | 44.17a | 25.27b | 6.22b | 19.05a | 76.70a | 13.48a | 63.22a | 53a | 47b |

*Means followed by the same letter in the column do not differ by Tukey's test, at 5% probability; ±: standard deviation from the mean.

It was found that both cultivars of gladiolus showed higher RNT, RNL and RPH in the period of 15 to 30 days, regardless of the cultivation conditions (Table 4). In addition, plants grown in shade resulted in higher RPH in the period 15 to 30 days after planting, followed by plants grown in full sun in the same period (Table 4). The Rose Friendship cultivar had the highest RPH, in the period from 15 to 30 days (Table 4).

**Table 4.** Stem diameter rates ($R_{SD}$), tiller number rates ($R_{TN}$), leaf number rates ($R_{LN}$) and plant height rates ($R_{PH}$) on the isolated effect of the periods (15-30; 30-45 and 45-60 days); plant height rates ($R_{PH}$) on the effect of interaction between environments (full sun and 70% shade) and periods (15-0; 30-45 and 45-60 days) and leaf number rates ($R_{LN}$) and plant height rates ($R_{PH}$) on the effect of the interaction between the cultivars (Jester and Rose Friendship) and the periods (15-30; 30-45 and 45-60 days)*.

| Isolated effect | | | |
|---|---|---|---|
| **Periods** | $R_{TN}$ | $R_{LN}$ | $R_{PH}$ |
| 15-30 | 0.038a | 0.124a | 2.227a |
| 30-45 | 0.002b | 0.072b | 0.766b |
| 45-60 | 0.007b | 0.062b | 0.263c |

| Cultivation condition x Period interaction | | |
|---|---|---|
| **Cultivation condition** | **Period** | $R_{PH}$ |
| Full sun | 15-30 | 1.618b |
| | 30-45 | 0.703cd |
| | 45-60 | 0.366de |
| 70% shade | 15-30 | 2.836a |
| | 30-45 | 0.830c |
| | 45-60 | 0.159e |

| Cultivar x Period Interaction | | | |
|---|---|---|---|
| **Cultivar** | **Period** | $R_{LN}$ | $R_{PH}$ |
| Jester | 15-30 | 0.104ab | 1.867b |
| | 30-45 | 0.074cb | 0.737c |
| | 45-60 | 0.080cb | 0.413cd |
| Rose Friendship | 15-30 | 0.143a | 2.587a |
| | 30-45 | 0.071cb | 0.796c |
| | 45-60 | 0.071cb | 0.112d |

*Means followed by the same lowercase letter in the columns do not differ by Tukey's test, at 5%.

The stems harvested at 60 days did not show significant interaction between the environments studied with regard to the diameter of the stem, number of tillers, number of leaves and height of the plants. It was found that plants grown under full sun conditions resulted in a smaller diameter and height when compared to plants grown in the shade (Figures 2A and 2B). Gladiolus of the Rose Friendship cultivar showed greater height (Figure 2).

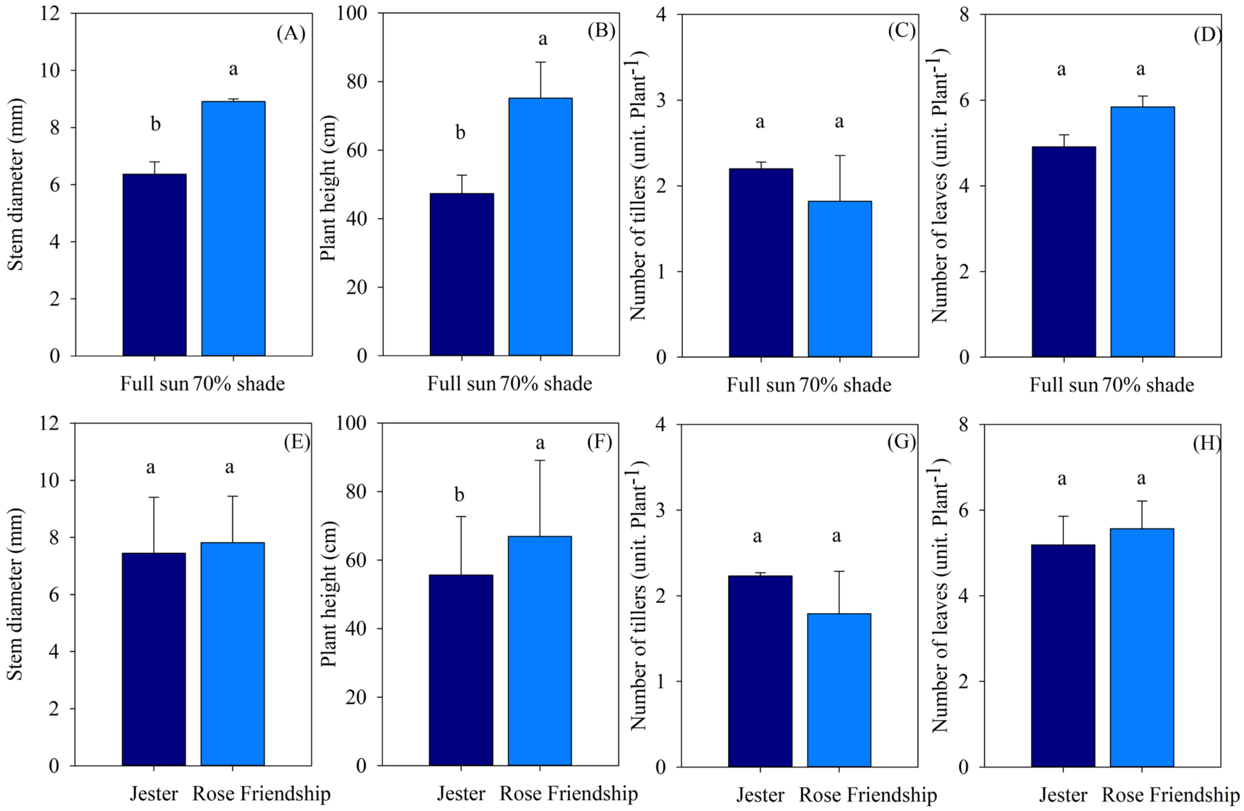


**Figure 2.** Stem diameter (SD), plant height (PLH), number of tillers (NT) and number of leaves (NL) and cultivars (Jester and Rose Friendship) of gladiolus (*Gladiolus x grandiflorus* L.) grown in different environments (full sun and 70% shade). The bars represent the standard error of the mean. The different letters indicate a significant difference by Tukey's test (p<0.05).

**Vase life of flower stems**

Jester and Rose Friendship cultivars of gladiolus obtained from the two cultivation conditions (full sun and 70% shade) had a zero score at the beginning of conservation, i.e., without visible defects (Figure 3A). During this period, the flower buds were mostly closed (Figure 4). On the eighth day, the flowers of the Jester cultivar, which were grown under shade, showed a slight change in color, showing five open flowers and some withered petals, indicating that they were not marketable, with a score of 3 (Figures 3A and 4). On the other hand, the Rose Friendship cultivar had an average score of 2.6, which did not compromise, according to the visual panel, the characteristics necessary for their sale (Figures 3A and 4). On the eighth day, both cultivars grown in full sun had a score of 2, indicating that the plants had up to five open leaves (Figures 3A and 4). On the tenth day, the cultivars Jester and Rose Friendship cultivated in 70% shade obtained a score of 4 on the visual scale (Figures 3A and 4). On the other hand, the combined cultivars grown in full sun at the end of the experiment had average values of 2, with up to five open flowers (Figures 3A and 4).

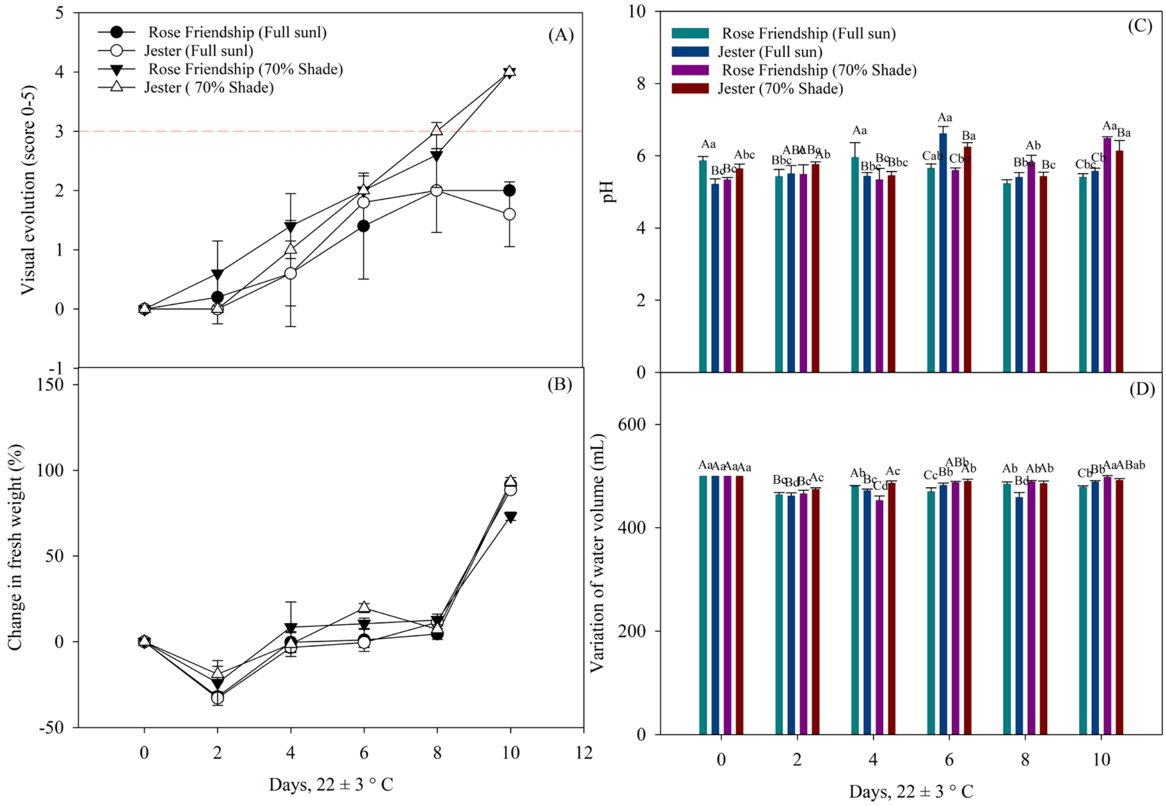


**Figure 3.** (A) Visual evolution, (B) variation in fresh weight, (C) pH and (D) variation in water volume of the gladiolus stems (*Gladiolus x grandiflorus* L.) obtained from the Jester and Rose Friendship cultivars grown in full sun and 70% shade environments. The bars represent the standard error of the mean. Capital letters compare treatments and lowercase letters compare storage days.

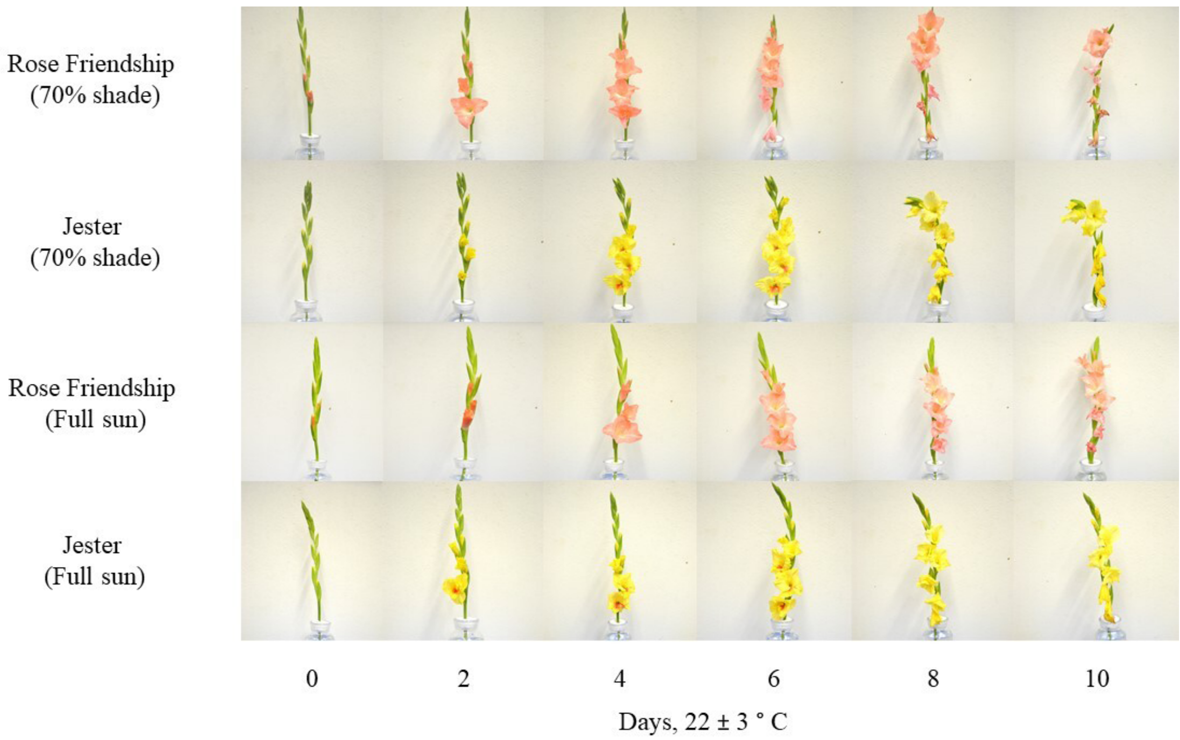


**Figure 4.** Visual aspect of the gladiolus stems (*Gladiolus x grandiflorus* L.) of the Jester and Rose Friendship cultivars grown in the environments: full sun and 70% shade. The base of the stems was kept immersed in distilled water for 10 days at 22±3 °C and RH 60%.

On the second day of evaluation, a loss of fresh mass was observed, resulting in negative values for both treatments studied, with greater absorption by the stems cultivated under full sun for both varieties (Figure 3B). From the fourth to the eighth day, the rate variations in mass were very low for all conditions (Figure 3B). After eight days, the rates of mass variation among the flowers increased significantly (Figure 3B).

At the beginning of the experiment, the Rose Friendship cultivar grown under full sun had a higher pH: approximately 6 (Figure 3C). In the same period, under the same sunshine condition, the Jester cultivar maintained a lower pH (Figure 3C). At the end of the experiment, both cultivars grown in full sun showed lower pH values, approximately 5 pH (Figure 3C).

In the first five days of conservation of the stems, there was little difference between the variations of water in the vases between treatments (Figure 3D). However, between the sixth and tenth days, the cultivars that had been grown in full sun showed greater variation in the volume of water in the vases where they were kept (Figure 3D).

## Discussion

The adaptation of radiation and temperature conditions is extremely important for the post-harvest of gladiolus, as reported by Becker et al. (2021b). The present work reports on research on how the different cultivation conditions (full sun and 70% shade) affected the gladiolus cultivars Jester and Rose Friendship - from growth to flowering and vase life - cultivated in the semi-arid region of Brazil. This region is characterized by average temperatures from 26 °C to 27.5 °C and precipitation of 750 mm, which makes it difficult to cultivate some ornamental plants. The shade introduced in this work aimed to reduce irradiance and high temperatures during growth in the field. Shading resulted in the anticipation of flowering and in larger stems (Table 1), and larger and heavier stems (Figures 2A and 2B). These characteristics make these stems closer to Veiling Holambra standards (Schwab et al., 2015a). Under the shade condition, the cultivar Rose Friendship presented a larger size in relation to Jester (Figure 2F), although the diameter, number of tillers and number of leaves did not differ significantly between cultivars (Figures 2E, 2G and 2H). A larger diameter stem gives the flowers a higher degree of stiffness, increasing their post-harvest durability, and allows for longer commercialization periods (Tomiozzo et al., 2018). In addition, the binomial height and diameter are extremely important to meet Veiling Holambra standards, with classes ranging from 75 to 110 cm (Schwab et al., 2015a).

In the gladiolus, biometric data are quantitative parameters, which are used as quality parameters, by which the flowers are classified in the Veiling Holambra system. Thus, for gladiolus, the height of the plant must vary from 75 to 110 cm, and the diameter of the stem must be between 5.0 to 7.5 mm (Schwab et al., 2015a). In the present study, cultivation in full sun resulted in a plant height of 47 cm and a diameter of 6 mm. Under 70% shade, the plant resulted in a height of 75 cm and a diameter of 9 mm (Figures 2A and 2D). The Rose Friendship cultivar reached a height of 67 cm and a diameter of 8 mm, while the Jester cultivar had a height of 56 cm and a diameter of 7 mm (Figures 2E and 2H). In addition, the shading promoted a higher content of fresh, dry mass, and a higher relative water content in the aerial part (Table 3), but larger dry matter partition only for the aerial part. In the case of the bulb, this partition was greater for plants grown in full sun. There was also no difference in the parameters regarding fresh and dry mass and relative water content (Table 3). The cultivar Rose Friendship maintained higher biometric parameters, such as fresh and dry mass and relative water content of the aerial part (Table 3). The dry mass partition was also greater in the aerial part (Table 3). Thus, the shade conditions used in the present work, an average temperature of 25 °C, a relative humidity of 65% and a cumulative total precipitation of 276 mm, with an overall radiation of 17 $MJ/m^2$ (Figure 1), resulted in rods in height and diameter closer to the Veiling Holambra classification, as also described by Schwab et al. (2015a). These results indicate that the semi-arid edaphoclimatic conditions that characterized the stem changes were further from the commercial standard adopted by Veiling Holambra, reducing the values of the biometric parameters studied, which resulted in a decrease in size and diameter of the stems. On the other hand, the shade conditions adopted in the present work caused the rods to be closer to the commercial standard adopted by Veiling Holambra. In addition, the cultivar Rose Friendship maintained the highest biometric parameters, resulting in standards closer to the commercial standard.

Biometric measurements were carried out to verify the rate of growth and development of the plant in the periods of 15 to 30 days, 30 to 45 and 45 to 60 days (Table 4). In the analysis of the separate periods, it was found that, in the period from 15 to 30 days, the plants showed a greater development in terms of the number of tillers, leaves and plant height. In the interaction between periods and cultivation systems, it was found that cultivation with shading resulted in greater growth in the period of 15 to 30 days. In the interaction between the periods and the cultivars, it was observed that the cultivar Rose Friendship showed a higher growth rate and number of leaves between 15 to 30 days. Thus, in the first 30 days, there was a greater accumulation of mass and distribution of resources among the crops destined for vegetative growth. This shows that the first 30 days are essential to maintain favorable conditions for growth, and, in this case, the shading, especially for the Rose Friendship. This information is extremely important, since it is known that the main factors that drive the development and production of gladiolus are temperature and intensity of the light (Akpinar and Bulut, 2011). In addition, this information can be used as a tool to help in the understanding of the application of gladiolus phenology models in the semi-arid region, such as the model developed by Uhlmann et al. (2017).

The vase life of gladiolus rods depends on the pre-harvest conditions, such as the time of planting, corm size, light intensity and planting density (Schwab et al., 2015a). Water balance is a determining factor that affects the quality and longevity of the stems (Gupta and Dubey, 2018). The gladiolus stems of both cultivars grown under full sun had a longer vase life: 10 days (Figure 3A). This fact may be associated to the amount of water in the vases under study (Figure 3D) and associated to the decline of the pH of the water of vases where the flowers were kept, especially after eight days (Figure 3C), confirming what is known: that absorption is facilitated in water with lower pH (Sun et al., 2001; Gupta and Dubey, 2018). This fact was accompanied by a slower wilting of the stems grown in full sun (Figure 4).

The results of the present study showed that, under semi-arid conditions, 70% shade influenced the growth, flowering and vase life of the gladiolus stems, meeting the quality criteria established for marketing under the Veiling Holambra system. On the other hand, the vase life of the flowers grown in the shade was shorter. Plants grown in full sun, although they did not meet Veiling Holambra standards, had longer vase life. These data may be indicative of new marketing parameters for gladiolus under cultivation conditions in the semi-arid region, as it is known that increasing vase life is important to ornamental floriculture. In addition, work must be continued to explain the dynamics of absorption, translocation of water in the vase, as well as its hormonal regulation and composition of reserves. As seen in Table 3, plants grown in full sun showed similar levels of total fresh and dry mass when compared to plants grown in the shade (Table 3). In addition, some parameters related to the bulb were equal or higher for shade plants, such as: fresh and dry bulb mass, relative water content and dry partition in the bulb (Table 3). This may have helped stems of plants grown in full sun to have a small increase in vase life, as observed in the present work. Continuation of the work needs to be done, with more field measurements of photosynthetic variables, reserve phytochemicals, as well as growth regulators to help explain the results found. Finally, it became evident that it is possible to adapt gladiolus management and cultivars for planting in the semi-arid region. This may indicate a need for changes in the commercial standards, especially in light of climate changes. These will be needed particularly for the cultivation of gladiolus.

## Conclusions

Cultivation in 70% shade resulted in greater accumulation of biomass in the aerial part of gladiolus plants, greater stem diameter and plant height. The Rose Friendship cultivar resulted in greater translocation of dry matter to the aerial part of the plants, resulting in greater development in height. On the other hand, the gladiolus plants cultivated under full sun conditions had longer vase life, with ten days in conservation conditions at 22±3 °C and RH 60%.

## Author Contribution

**LDCS.:** Conceptualization, methodology, software, formal analysis, investigation, data curation, writing original draft. **KSF:** Conceptualization, methodology, formal analysis, writing revision and editing, supervision, project administration. **LFS:** Conceptualization, methodology, formal analysis, writing revision and editing, supervision. **TGFS:** Conceptualization, methodology, software and formal analysis. **LVPA:** Methodology, investigation and critical evaluation of the manuscript. **ARMS:** Methodology, investigation and critical evaluation of the manuscript. **PLMF:** Methodology and research. **JFNS:** Methodology, investigation and critical evaluation of the manuscript. **ANS:** Conceptualization, methodology, writing revision and editing, visualization, supervision, project administration, funding acquisition.

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