Ornamental Horticulture
ISSN 2447-536X | HTTPS://ORNAMENTALHORTICULTURE.EMNUVENS.COM.BR/RBHO
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

Scientific Article

Flowering phenophases and morphoagronomic characterization of Palma Santa Rita cultivars

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Abstract

The characterization of flowering phenophases and morphoagronomic knowledge is important for crop management and harvest programming. This study aimed to evaluate the duration of reproductive phenophases and conduct morpho-agronomic characterization of gladiolus cultivars. Two experiments were conducted, one in a shaded environment and the other in a full sun environment. A split-plot design in randomized blocks was used, which consisted of the planting system with single rows and twin rows in the plots and the cultivars (White Goddess, Traderhorn, Peter Pears, and Gold Field) in the subplots. The reproductive phenophases, plant development and productivity of each cultivar were evaluated. The flowering cycle lasted from 58 to 65 days when the cultivars were grown in the shaded environment, while the duration of this cycle ranged from 78 to 87 days in the full sun environment. The yield of the Gold Field cultivar was significantly higher when grown in twin rows compared to single-row planting. A shaded environment and twin-row planting are the recommended conditions for the cultivation of gladiolus in the state of Mato Grosso since they promote better stem development and early flowering of the cultivars. The Peter Pears and Gold Field cultivars are recommended for cultivation in the region due to their greater production of marketable stems.
Keywords: cultivation environments, cut flower, *Gladiolus grandiflorus*, phenology.

Resumo

Fenofases de floração e caracterização morfoagronômica de cultivares de Palma de Santa Rita

A caracterização das fenofases de floração e o conhecimento morfoagronômico são importantes para o manejo da cultura e programação da colheita. Objetivou-se com esse trabalho, avaliar a duração das fenofases reprodutivas e realizar a caracterização morfoagronômica de cultivares de gladíolo. Foram conduzidos dois experimentos, um em ambiente sombreado e outro em ambiente de pleno sol. Foi utilizado o delineamento de parcelas subdivididas em blocos casualizados, que consistiu no sistema de plantio de linhas simples e duplas nas parcelas e as cultivares (White Goddess, Traderhorn, Peter Pears e Gold Field) nas subparcelas. Foram avaliadas as fenofases reprodutivas, o desenvolvimento da planta e a produtividade de cada cultivar. O ciclo de floração durou de 58 a 65 dias quando as plantas foram cultivadas em ambiente sombreado, enquanto a duração desse ciclo variou de 78 a 87 dias quando cultivado em pleno sol. A produtividade da cultivar Gold Field foi significativamente maior quando cultivada em fileiras duplas em relação ao plantio em fileira simples. O ambiente sombreado e o plantio em fileiras duplas são as condições recomendadas para o cultivo do gladíolo no estado de Mato Grosso, pois promovem melhor desenvolvimento da haste e floração precoce das cultivares. As cultivares Peter Pears e Gold Field são recomendadas para cultivo na região devido à maior produção de hastes comercializáveis.
Palavras-chave: ambiente de cultivo, fenologia, flor de corte, *Gladiolus grandiflorus*.

Introduction

The genus *Gladiolus* (Iridaceae) comprises more than 255 species (Bailey and Bailey 1976; Cordeiro et al., 2021). The flower stem of gladioli is highly valued by consumers due to of its beauty and by producers because of the easy production of these plants and their excellent financial return (Costa et al., 2021). In Brazil, gladiolus is popularly known as Palma de Santa Rita and its commercial importance is linked to the All Souls' holiday; however, its

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https://doi.org/10.1590/2447-536X.v29i3.2593
Received Jan 26, 2023 | Accepted June 23, 2023 | Available online Aug 8, 2023

Area Editor: Márkilla Zunete Beckmann-Cavalcante

demand is increasing on other commemorative dates such as Mother's Day, Valentine's Day, and Christmas (Schwab et al., 2014).

Gladiolus (*Gladiolus grandiflorus* Andrews) shows good adaptation to any type of soil, is resistant to diseases and pests, and can also be grown in full sunlight. However, in regions with temperatures exceeding 35 ˚C or strong radiation, shading is recommended in order to avoid compromising flower stem quality (Schwab et al., 2018). Another important factor for gladiolus production is the duration of the production cycle. According to Schwab et al. (2018), the cycle is shorter when the plant is grown at high air temperatures in summer and is longer when it is grown at low temperatures in winter (< 5 ˚C). Furthermore, in regions where solar radiation and temperatures are high, the size of the plants may be reduced, stems have a smaller number of buds, and there is a decrease in plant quality (Bosco et al., 2021).

The characterization of phenophases and of the developmental cycle is extremely important for crop management (Silva et al., 2022). Once this information is available, producers can program plantings so that harvests occur in a timely manner to meet demands. The aim of this study was to determine the flowering phenophases and to provide morpho-agronomic data for four gladiolus cultivars grown in shaded and full sun environments using both single or twin-row planting system.

Material and Methods

Study location

The experiment was conducted in Tangará da Serra, Mato Grosso State, Brazil (14º64'93" S and 57º43'25" W), which is located at an altitude of 488 m and has a tropical climate characterized by average annual rainfall of 1,830 mm and an average annual temperature of 24.6 ºC. There are two well-defined seasons, a dry period from May to September and a rainy period from October to April (Dallacort et al., 2011). The soil is classified as dystroferric Red Latosol with a clayey texture, gently undulating relief, and maximum slope of 1% (Embrapa, 2018).

Experimental design and plant material

Two experiments were conducted, one in a shaded environment and one in a full sun environment. A split-plot design in randomized blocks was used, which consisted of the planting system (single rows and twin rows) in the plots and the cultivars (White Goddess, Traderhorn, Peter Pears and Gold Field) in the subplots, with four replicates and 14 plants per plot. Ten central plants were evaluated per plot.

The cultivars studied were purchased from a commercial producer. The selection criteria were color of the flowers and crop cycle. The White Goddess cultivar has white flowers, Traderhorn has red flowers, Peter Pears has orange flowers, and Gold Field has yellow flowers. The crop cycle is intermediate (I), lasting from 71 to 124 days after planting, for the Traderhorn and Peter Pears cultivars; intermediate (II) lasting from 78 to 131 days for White Goddess, and a late cycle with a duration of 85 to 148 days for Gold Field (Schwab et al., 2019).

Planting and conduction

Planting was performed on March 12, 2021, in 1.0 x 15.0 m beds. The soil was prepared by adding bovine manure and 50 g per linear meter of NPK 20-05-20. Chemical fertilization (50 g per linear meter of NPK 20-05-20) was again performed 30 days after planting and at the beginning of flowering. Spacing of 30 cm between rows and 10 cm between bulbs was used for single rows, totaling 333,333 plants ha^{-1}. For the twin-row system, spacing was 15 cm between rows, 30 cm between twin rows and 10 cm between bulbs, totaling 500,000 plants ha^{-1}. The planting depth was 15 cm in both planting systems.

Two experiments were conducted, one covered with a 30% shading screen and the other in full sun. Irrigation was performed with a microsprinkler once a day, for forty minutes, always in the morning.

Tutoring

To avoid the formation of curved and tortuous flower stems, once the plants had reached a height of 30 cm, wooden slats measuring approximately 1.80 m were fixed vertically at the ends of the beds. Nylon threads were placed from one end to the other, every 20 or 30 cm apart, following the growth of the plant.

Evaluation of flowering phenophases and yield

The reproductive phenophases of gladiolus start at R0 when the tip of the spike becomes visible between leaves (Figure 1A). At R1, the spike is completely visible between leaves, allowing visualization of its peduncle (Figure 1B). At R2, the first three florets, from bottom to top, show the color of the corolla (Figure 1C) (Schwab et al., 2015a; Schwab et al., 2019).

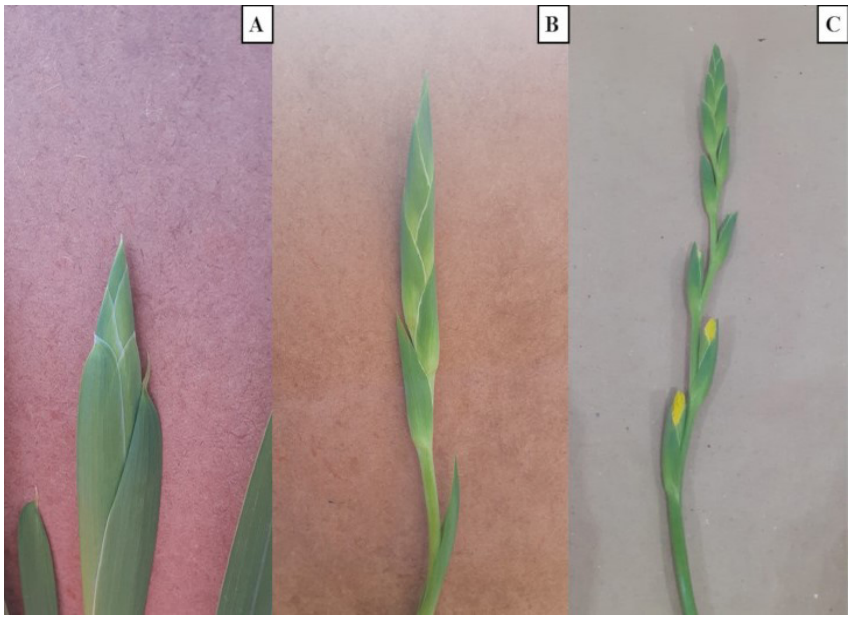

Figure 1. Reproductive phenophases of gladiolus. R0 (A), R1 (B), and R2 (C).

To characterize the development of the plant, the number of days from planting to entry into R0 (DR0), number of days from entry into R0 to entry into R1 (DR1), and number of days from entry into R1 to entry into R0 (DR2) were determined. At each stage, plant height was measured from the ground to the tip of the flower spike with a tape measure (HPR0, HPR1, HPR2). The diameter of the stalk (DS) in each stage (DSR0, DSR1, DSR2) was determined at 1.0 cm from the ground, on the flat side of the stem, using a digital caliper.

Productivity (PROD) in dozens ha^{-1} was estimated from the number of stems produced per plot using the following the formula

$$DHS.ha^{-1} = \frac{DHS\ x\ 10{,}000}{Plot\ area}$$

where *DHS* are the dozens of harvested stems and the plot area is 0.30 m^2 for the single-row system and 0.20 m^2 for the twin-row system.

Morpho-agronomic characterization of flower stems

Stalks at R2 were harvested in the morning. The stalks were harvested 30 cm from the ground so that 4 to 5 leaves remained on the plant for bulb maintenance. The following characteristics were evaluated in stems: inflorescence diameter (ID) measured with a digital caliper below the insertion of the first floret, inflorescence size (IS) measured below the insertion of the first floret to the tip of the stem, and number of flower buds (NFB).

Statistical analysis

The results obtained for the shaded and full sun experiments were analyzed individually. The data were submitted to analysis of variance. According to significance in the F test, means were compared by the Tukey test at 5% probability.

Results

Evaluation of flowering phenophases in shaded and full sun environments

Cultivation in the shaded environment

Analysis of variance did not indicate a significant interaction for the characteristics evaluated in the shaded environment. There was a significant difference ($p < 0.05$) in DR0 and DR2 between the single- and twin-row plantings systems (Table 1). The cultivars differed significantly regarding the characteristics evaluated, except for DSR0.

Table 1. Mean, mean square and coefficient of variation of days to entry into the phenophases R0, R1 and R2 and of plant height and diameter in each floral phenophase of the gladiolus cultivars White Goddess, Traderhorn, Peter Pears, and Gold Field grown in single and twin rows in a shaded environment[1].

Sources of variation plants	DR0 (days)	HPR0 (cm)	DSR0 (mm)	DR1 (days)	HPR1 (cm)	DSR1 (mm)	DR2 (days)	HPR2 (cm)	DSR2 (mm)
…….…… Planting system ……...……									
Single rows	61.03	94.34	11.17	4.62	124.26	11.09	3.3	136.79	11.2
Twin rows	62.98	94.49	10.35	4.99	121.59	10.48	3.06	132.77	10.21
QM	30.55*	0.19^{ns}	5.44^{ns}	1.09^{ns}	57.11^{ns}	2.98^{ns}	0.48*	128.88^{ns}	7.84*
CV (%)	2.3	8.36	8.24	8.19	3.02	6.06	6.44	4.73	6.74
…….. Cultivar……									
White Goddess	61.66b	92.72b	9.95	5.86a	128.01a	9.95c	2.49c	137.09a	10.05b
Traderhorn	63.72a	91.31b	11.05	4.15c	117.42b	11.64a	3.11b	129.25b	11.34a
Peter Pears	58.06c	92.69b	11.16	4.43bc	118.46b	10.65bc	4.39a	137.08a	10.53ab
Gold Field	64.59a	100.94a	10.88	4.77b	127.81a	10.91ab	2.74bc	135.71ab	10.90ab
QM	67.41**	155.44**	2.43^{ns}	4.51**	266.52**	3.89**	5.74**	112.00*	2.40**
CV (%)	2.01	4.85	8.49	7.5	4.5	5.37	11.69	4.07	5.66

DR0: number of days from planting to entry into R0; DR1: number of days from entry into R0 to entry into R1; DR2: number of days from entry into R1 to entry into R2; HPR0: plant height at R0; HPR1: plant height at R1; HPR2: plant height at R2; DSR0: diameter of the stalk at R0; DSR1: diameter of the stalk at R1; DSR2: diameter of the stalk at R2; QM: mean square; CV: coefficient of variation. [(1)] Means followed by the same letter in the column do not differ from each other at 5% probability by the Tukey test; [ns] not significant; [*] and [**] significant at 5% and 1% probability by the F test.

Single-row planting favored the anticipation of DR0 by two days when compared to the twin-row system (Table 1). Entry of the inflorescence into R2 was less than one day in the single-row system.

The number of days to entry into R0 (DR0) ranged from 58.06 to 64.59 for the Peter Pears and Gold Field cultivars, respectively. The mean interval between DR0 and DR2 was about 8 days. Peter Pears was the most precocious cultivar, which started flowering 58 days after planting and entered R2 at 65.5 days, significantly differing from the other cultivars. The remaining cultivars entered R0 between 61.66 and 64.59 days after planting and harvest at R2 occurred between 69 and 72 days.

Plant height ranged from 92.72 to 100.94 cm, corresponding to an average increase of 30% between DR0 and DR2. A plant height at R2 (HPR2) greater than 110 cm was observed for all cultivars evaluated at this phenological stage.

The mean stem diameter at R0 (DSR0) was 10.76 among cultivars. The White Goddess cultivar had the smallest mean stem diameter at the different phenological stages (DSR0 to DSR2). At R2, the stem diameter of the Traderhorn cultivar did not differ significantly from that of the Peter Pears or Gold Field cultivar.

The planting systems significantly influenced the productivity of *Gladiolus* stems in the shaded environment (Table 2). Cultivation in twin rows promoted a 13% increase in cultivar productivity. The highest productivity was observed for the Gold Field cultivar (25,554.03 dozens ha^{-1}), a 21.7% higher average yield than that observed for the other cultivars. The lowest productivity was found for the Traderhorn cultivar, with a mean of 11,805.56 dozens ha^{-1}, significantly differing from the other cultivars evaluated.

Table 2. Morpho-agronomic characteristics of flower stems of the gladiolus cultivars White Goddess, Traderhorn, Peter Pears, and Gold Field grown in single and twin rows in a shaded environment [1].

Sources of variation plants	PROD (dozen ha^{-1})	ID (mm)	IS (cm)	NFB
Planting system				
Single rows	23784.72	7.66	73	10.05
Twin rows	27323.08	7.04	72.28	8.19
QM	100159931.92*	3.05^{ns}	4.17^{ns}	27.75**
CV (%)	9.98	16.56	7.28	9.66
Cultivar				
White Goddess	28778.11a	6.82	71.82	7.02c
Traderhorn	11805.56b	7.08	71.81	10.29a
Peter Pears	28993.56a	7.35	72.2	10.59a
Gold Field	32638.89a	8.15	74.75	8.58b
QM	697166306.67**	2.64^{ns}	15.98^{ns}	21.93**
CV (%)	19.52	17.82	3.81	7.03

PROD: productivity; ID: inflorescence diameter; IS: inflorescence size; NFB: number of flower buds; QM: mean square; CV: coefficient of variation. (1) Means followed by the same letter in the column do not differ from each other at 5% probability by the Tukey test; ^{ns} not significant; * and ** significant at 5% and 1% probability by the F test.

Cultivation in single rows provided a larger NFB, with a significant difference compared to the twin-row system (Table 2). The Traderhorn and Peter Pears cultivars differed significantly from the other cultivars, with a mean number of 10.44 flower buds per stem. The lowest mean NFB was observed for White Goddess (33% lower). There were no significant differences in ID or IS, with mean values of 7.35 and 72.64 cm, respectively.

Cultivation in full sun

There was no significant interaction between planting system and cultivar in the evaluations of gladiolus cultivation in full sun.

Significant differences between cultivars were observed for DR0 to DR2, as well as for DSR0 and DSR2 (Table 3). Spike emergence, determined by DR0, occurred between 63.39 and 69.86 days after planting. Peter Pears was the most precocious cultivar, differing significantly from the other cultivars. Entry into R2 occurred on average 7.8 days after entry into R0, with a variation of approximately 8% between the precocious cultivar (Peter Pears) and the latest cultivar (Gold Field).

Plant height at R2 ranged from 110.46 to 117.87 cm, with no significant difference between cultivars. The Gold Field and White Goddess cultivars exhibited the smallest mean stem diameters at R2 (DSR2) (9.31 and 10.08 mm, respectively). The largest stem diameter was found for the Traderhorn cultivar, which was 7.6% greater than the overall mean DSR2.

There were no significant differences in PROD, ID, or IS (Table 4). Productivity was 25% higher in twin-row planting compared to the single-row system. The average productivity of the Traderhorn and Gold Field cultivars ranged from 17,098.95 to 23,958.33 dozen ha^{-1}, respectively. The mean ID was 6.56 mm and the IS ranged from 64.15 to 68.51 cm among cultivars.

Table 3. Mean, mean square and coefficient of variation of days to entry into the phenophases R0, R1 and R2 and of plant height and diameter in each floral phenophase of the gladiolus cultivars White Goddess, Traderhorn, Peter Pears, and Gold Field grown in single and twin rows in full sun[1].

Sources of variation plants	DR0 (days)	HPR0 (cm)	DSR0 (mm)	DR1 (days)	HPR1 (cm)	DSR1 (mm)	DR2 (days)	HPR2 (cm)	DSR2 (mm)
Planting system									
Single rows	67.45	84.68	11.01	5.04	109.39	10.4	2.91	114.97	10.22
Twin rows	67.16	86.02	10.77	4.97	108.6	10.98	2.7	115.28	10.24
QM	0.70^{ns}	14.31^{ns}	0.47^{ns}	0.04^{ns}	4.99^{ns}	2.70^{ns}	3.33^{ns}	0.76^{ns}	0.002^{ns}
CV (%)	2.7	6.35	8.65	13.81	3.36	20.94	11.78	5.07	10.91
Cultivar									
White Goddess	67.73a	84.63	9.90c	5.94a	111.79	9.66	2.16b	116.52	9.31b
Traderhorn	68.25a	84.75	11.82a	4.64bc	106.68	11.02	2.77b	110.46	11.05a
Peter Pears	63.39b	85.3	10.87b	3.99c	105.72	10.72	3.66a	115.65	10.40a
Gold Field	69.86a	86.75	10.97b	5.43ab	111.81	11.34	2.64b	117.87	10.18ab
QM	61.23**	7.58^{ns}	4.91**	5.92**	84.82^{ns}	4.24^{ns}	3.14**	84.04^{ns}	4.10**
CV (%)	2.69	7.6	5.06	17.17	5.89	15.31	17.43	7.69	6.34

DR0: number of days from planting to entry into R0; DR1: number of days from entry into R0 to entry into R1; DR2: number of days from entry into R1 to entry into R2; HPR0: plant height at R0; HPR1: plant height at R1; HPR2: plant height at R2;DSR0: diameter of the stalk at R0; DSR1: diameter of the stalk at R1; DSR2: diameter of the stalk at R2; QM: mean square; CV: coefficient of variation. (1) Means followed by the same letter in the column do not differ from each other at 5% probability by the Tukey test; ^{ns} not significant; * and ** significant at 5% and 1% probability by the F test.

Table 4. Morpho-agronomic characteristics of flower stems of the gladiolus cultivars White Goddess, Traderhorn, Peter Pears, and Gold Field grown in single and twin rows in full sun [1].

Sources of variation plants	PROD (dozens ha^{-1})	ID (mm)	IS (cm)	NFB
Planting system				
Single rows	17179.8	6.69	67.76	8.19
Twin rows	23105.36	6.43	64.91	7.5
QM	280897794.23^{ns}	0.53^{ns}	64.84^{ns}	3.81^{ns}
CV (%)	32.7	8.24	4.16	22.37
Cultivar				
White Goddess	21631.21	6.14	68.51	5.84b
Traderhorn	17098.85	6.87	66.56	8.90a
Peter Pears	17881.95	6.67	64.15	8.96a
Gold Field	23958.33	6.56	66.14	7.69a
QM	83068683.07^{ns}	0.75^{ns}	25.51^{ns}	17.06**
CV (%)	42.86	7.69	6.78	13.41

PROD: productivity; ID: inflorescence diameter; IS: inflorescence size; NFB: number of flower buds; QM: mean square; CV: coefficient of variation. (1) Means followed by the same letter in the column do not differ from each other at 5% probability by the Tukey test; ^{ns} not significant; * and ** significant at 5% and 1% probability by the F test.

Although no significant difference was observed between planting systems, the NFB was 8.4% higher in the single-row system compared to the twin-row system. The White Goddess cultivar had the lowest NFB (5.84), significantly differing from the other cultivars that exhibited a mean number of 8.51 flower buds per stem.

Discussion

The differences in the parameters evaluated between planting systems in the flower phenophases of the cultivars may be related to the climatic conditions of the southwestern region of Mato Grosso State. During the evaluation period, the mean monthly temperature in the region was 24.6 ºC (INMET, 2023). An increase in the duration of the crop cycle is generally observed for gladiolus grown during colder periods of the year when compared to the warmer months (Schwab et al., 2018). Our results agree with Uhlmann et al. (2017) who observed a shorter cycle of gladiolus development, with a delay in planting, under the climatic conditions of the state of Rio Grande do Sul.

In our study, cultivars grown in the shaded environment started flowering earlier than those grown in full sun. In a study conducted under the environmental conditions of Rio Grande do Sul, Brazil (Schwab et al., 2019), the same cultivars grown in full sunlight started flowering between 71 and 85 days. According to Streck et al. (2003), variations in cycle duration are related to the temperature in day degrees; the duration of the crop cycle increases at low temperatures and decreases at high temperatures.

Temperatures higher than 34 ˚C are considered harmful to gladiolus crops (Uhlmann et al., 2017). The literature reports the need for artificial shading due to the damage caused by the sun to the flower spike (Schwab et al., 2018). The present results corroborate this indication by suggesting that the use of artificial shading during the warmer months of the year or from the beginning of the R0 phase is extremely important for the quality of the flower stems.

The higher crop yield and better stem quality of the Gold Field cultivar, regardless of planting system or environment, may indicate good adaptation to the temperatures and atmospheric conditions of the southwestern region of Mato Grosso State. Studying gladiolus grown in the city Dois Vizinhos in Paraná, Ferron et al. (2021) suggested that high temperatures influenced in inflorescence size (IS) and thus interfered with the commercial quality of the stems. This visible floral damage and the possibility that three or four buds at the apex of the gladiolus flower stem did not open have also been reported by Uhlmann et al. (2017).

Gladiolus plants grown in a shaded environment showed higher fresh mass, NFB and yield, regardless of the number of planting rows. The use of 70% shading for the cultivation of gladiolus under the semi-arid conditions of Serra Talhada, Pernambuco, promoted an increase in the amount of biomass in the aerial part, as well as in plant diameter and height (Sousa et al., 2021). These findings agree with the present study that obtained similar results for plants grown under 30% shading.

In our study, the single-row planting system favored the anticipation of flowering when compared to twin-row planting. On the other hand, Paiva et al. (2000), who evaluated the ideal number of plant rows for intercropping gladiolus with adult coffee crops, observed that the greatest stem length and number of flowers per stem were independent of the use of one or two rows, suggesting that the greater competition for luminosity observed in the twin-row system does not interfere with the agronomic characteristics of gladiolus.

The environmental conditions (sun or shade) exert a greater influence on the development and productivity of *Gladiolus* than the planting system (single or twin rows). According to Shillo and Halevy (1976), cultivars that are more resistant to high solar radiation tend to reduce the NFB on the stem, while more sensitive plants exhibit a reduction in the NFB and in flowering percentage. These results agree with the NFB and flowering results obtained in the present study in the full sun environment.

Plants grown in wider spacing have greater stem diameters (Silva et al., 2021; Silva et al., 2022). A greater flower stem diameter confers higher resistance of the plant to wind damage and reduces the percentage of broken stems during growth in the field or during the harvest and post-harvest periods (Souza et al., 2020).

The White Goddess cultivar showed the smallest plant diameter regardless of planting system or environment, as well as the lowest performance for all characteristics evaluated, and is therefore inadequate for the region. These findings differ from those reported by Souza et al. (2020) who obtained superior results for this cultivar grown in Alto Vale do Jataí, SC, in terms of stem size and diameter, with 100% production of extra stems (110 cm) and 15 to 16 buds per stem. The quality parameters of the stems are influenced by planting season and by cultivar since the conditions to which gladiolus plants are exposed interfere with these variables (Schwab et al., 2015b). Longer flower stems with a greater diameter contain higher carbon reserves, conferring better post-harvest resistance of these stems (Silva et al., 2018).

Our results reveal that each cultivar meets the qualitative standards differently as a result of the local conditions and planting season to which it was subjected (Bosco et al., 2021). One factor that may have influenced the classification of the quantitative pattern of the stems in this study was the absence of extra-large stems (110 cm). However, the standardization adopted in the present study, in which the flower stems were cut 30 cm above the ground, may be responsible for the fact that no extra-large flower stems were obtained. In contrast, Schwab et al. (2015b) suggested cutting the stem at the base of the plant close to the ground.

Conclusions

The shaded environment was more suitable for gladiolus production in the state of Mato Grosso. The Peter Pears and Gold Field cultivars produced the largest number of marketable stems regardless of the planting system (shade

or sun). It is possible to produce quality flower stems that meet the commercial standards of gladiolus cultivation in the southwestern region of Mato Grosso.

Author Contribution

FAF: Experimental execution, evaluation, literature review and writing. **MHMC:** Planning, experimental, field work literature review. **RPAF**: Data analysis, literature review and writing. **LSN:** Data analysis, literature review. **CAS:** Research project coordinator, processing and data analysis, literature review and writing.

Acknowledgments

The authors would like to thank FAPEMAT for the scholarship granted to the first author, the students of the botanical laboratory of the Center for the Study of Agricultural Research and Development (CPEDA) for helping in the field, and the Genetics and Plant Breeding Program (PGMP) of the Mato Grosso State University.

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