Management of corm size and soil water content for gladiolus flower production[1]

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ABSTRACT

Gladiolus grandiflorus Andrews, in the family Iridaceae, is one of the most produced and marketed flowers in the world. In general, however, research results on gladioli production factors are scarce and divergent. The objective of this work was to evaluate the influence of corm size and soil water content on gladiolus flower production. The experimental design, using the early maturity cultivar 'White Friendship', was entirely randomized, arranged in a 5 x 2 factorial scheme (five soil water contents: 25; 50; 75; 100; and 125% field capacity, combined with two corm sizes: medium and big), with four replications per treatment. Each replication, composed of one pot, comprised three corms, totaling 40 pots and 120 plants. Both vegetative and flowering characteristics were evaluated. Gladiolus cultivation at 80% soil field capacity presents best results for commercialization, generating longer flower stems with greater diameter and flower number, plus larger flowers. Furthermore, such soil water content promotes the shortest cultivation period.

Keywords: *Gladiolus grandiflorus*, field capacity, cut flower, floriculture.

RESUMO

Manejo do tamanho do cormo e conteúdo de água no solo para a produção de flores de gladíolo

Gladiolus grandiflorus Andrews, da família Iridaceae, é uma das flores mais produzidas e comercializadas no mundo. De maneira geral, no entanto, resultados de pesquisa acerca dos fatores de produção dessa espécie são escassos e divergentes. O objetivo do trabalho foi avaliar a influência do tamanho do cormo e conteúdo de água no solo na produção de flores de gladíolo. O delineamento experimental, usando a cultivar de ciclo precoce 'White Friendship', foi inteiramente casualizado, arranjado em esquema fatorial 5 x 2 (cinco conteúdos de água no solo: 25, 50, 75, 100 e 125% da capacidade de campo, combinados com dois tamanhos de cormo: médio e grande), com quatro repetições por tratamento. Cada repetição, composta por um vaso, foi formada por três cormos, totalizando 40 vasos e 120 plantas. Tanto as características vegetativas como as reprodutivas foram avaliadas. O cultivo do gladíolo feito a 80% da capacidade de campo promoveu os melhores resultados para comercialização, com hastes florais mais longas, de maior diâmetro e com mais flores, além de flores maiores. Além disso, esse conteúdo de água resultou no menor período de cultivo.

Palavras-chave: *Gladiolus grandiflorus*, capacidade de campo, flor de corte, floricultura.

1. INTRODUCTION

It is known that the state of Mato Grosso, in Brazil, is not traditional on flower production, concentrating most of its agricultural production on cotton, maize, and soybean. However, it presents potential to incorporate the floriculture sector, since it has available areas and appropriate climate. Furthermore, it is located far from the largest Brazilian distribution centers, located in São Paulo State, what results in more expensive products arriving there besides limiting access to many consumers. Nonetheless, for floriculture development in the state, studies are necessary to define the best species to be cultivated in each region and its respective production factors, such as irrigation.

Among the most cultivated and marketed cut flowers, gladiolus (*Gladiolus grandiflorus* Andrews, in the family Iridaceae) is highlighted both in the domestic and export markets. In Brazil, commercial corms are classified and commercialized according to their perimeter (BARBOSA et al., 2011a); the most marketed ones fall among the 12-14 and 14-16 cm perimeter groups. They are used to produce both flowers and cormels, the latter, in turn, are again planted to produce new plants. According to Rosa et al. (2014), corm size does influence a successful cultivation, while Barbosa et al. (2011a) mentions that there is a direct relationship between flowering quality and corm size, but corms greater than 16 cm perimeter produce more flowers of lower quality. In fact, Rosa et al. (2014) testified that corm size does influence plant and flower stem length, however, further experimental studies related to corm size effects on gladiolus cultivation were not found.

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Although gladiolus plants are not soil-specific, they should not be cultivated in clayey soils subjected to waterlogging, as the water excess may cause flowering delay and corm decay. On the other hand, Pereira et al. (2009) mentioned that gladioli are quite susceptible to water shortage, resulting in uneven, shorter, and low-quality flower stems, while Tombolato et al. (2004) and Paiva et al. (2012) reported that water deficit may cause leaf burn and accelerate flowering. Water should then be often provided so that the soil is kept moist, thus plants may produce flower stems of appropriate length and matter (PAIVA et al., 2012). Furthermore, there is an increasing global concern on the use of irrigation water because of water shortage forecasts, so it is necessary to study the actual plant water requirements by certain species and whether it is able to maintain its production even when submitted to water deficit.

Cut flower species are generally cultivated directly in soil. In Brazil, gladioli cultivation is also primarily performed in the field, although it may also occur under protection due to low temperatures, high humidity, and operational/financial responses (BARBOSA et al., 2011b). However, many flower growers have been changing their usual crop production for container or pot cultivation under protection, once this system favors plant management and water control. Furthermore, it virtually eliminates attacks of soil pathogens as soil is replaced by substrates. However, there are no standard substrates among properties, which are usually composed of different materials at varied rates according to the grower own experience, tests, and plant species cultivated.

In general, research results on gladiolus production factors are scarce and divergent. This study differs from others because it combines research on both corm size and water use for a potentially productive region of cut flowers. The objective of this work was then to evaluate the influence of corm size and soil water content on gladiolus flower production.

2. MATERIAL AND METHODS

The experiment was conducted from April to July 2014 (14 weeks) in a greenhouse built at the east-west direction with 6 m height and 450 m^2 total area. It is coated with 200 µm translucent plastic. Average air temperatures along the experimental period inside the greenhouse were 23.1 ^oC minimum, 28.4 ^oC mean, and 34.7 ^oC maximum.

The experimental design was entirely randomized, arranged in a 5 x 2 factorial scheme [five soil water contents: 25; 50; 75; 100; and 125% field capacity (FC), combined with two corm sizes: medium and big], with four replications per treatment. Each replication, composed of one pot, comprised three corms, totaling 40 pots and 120 plants. Soil field capacity was studied prior to the experiment implementation by the gravimetric method. Medium corms had 13 cm perimeter and 25.99 g mean dry matter, while big ones had 14 cm perimeter and 32.26 g mean dry matter; both are usually marketed as belonging to the same group.

Plants were cultivated from corms of gladiolus ‘White Friendship’ bought from a commercial producer, which were planted at 10 cm depth in pots of 8 L, where remained up to the end of the experimental period. According to Paiva et al. (2012), gladiolus ‘White Friendship’ is an early maturity cultivar that flowers from 60 to 65 days after planting. The substrate used for corm planting, popularly called “black soil” in the region, is commonly employed for flower production and garden implementation. It was previously analyzed as described by Raij et al. (2001), resulting in the following characteristics: pH 5.6 ($CaCl_2$); P = 3.3 mg dm^{-3}; K = 301.0 mg dm^{-3}; S = 10.0 mg dm^{-3}; Ca = 3.7 $cmol_c$ dm^{-3}; Mg = 1.2 $cmol_c$ dm^{-3}; Al = 0.9 $cmol_c$ dm^{-3}; H + Al = 12.7 $cmol_c$ dm^{-3}; SB = 5.7 cmol dm^{-3}; CEC = 18.4 cmol dm^{-3}; V% = 30.9; Zn = 0.2 mg dm^{-3}; Mn = 23.4 mg dm^{-3}; Cu = 0.5 mg dm^{-3}; Fe = 19 mg dm^{-3}; B = 0.30 mg dm^{-3}; O.M. = 39.5 g kg^{-1}; 375 g kg^{-1} clay; 150 g kg^{-1} silt; and 475 g kg^{-1} sand. According to Barbosa et al. (2011a) and Paiva et al. (2012), the recommended pH range for gladiolus cultivation is 5.5 to 6.5. There was no additional fertilization along the experimental period and nutrient deficiency symptoms were not observed. Pots were daily weighted for water replacement, which was performed whenever necessary to maintain the proposed treatments (% FC) along the experimental period (Figure 1).

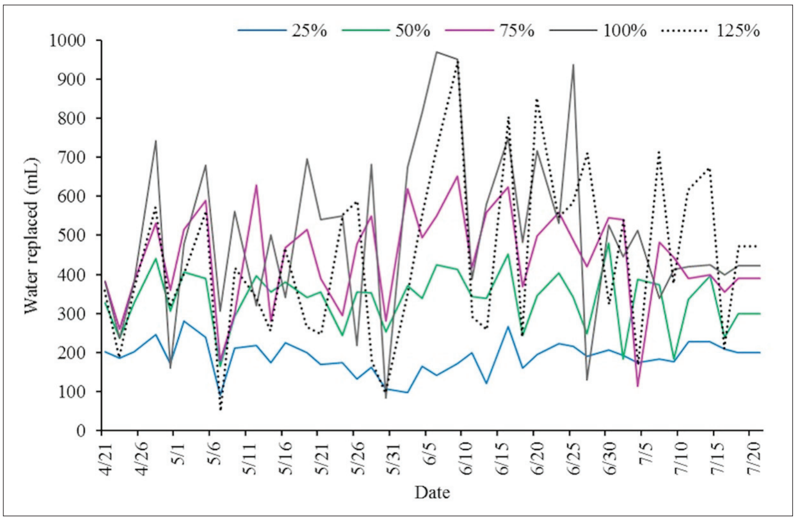

Figure 1. Water replaced for cultivation of *Gladiolus grandiflorus* 'White Friendship' along the experimental period (14 weeks) according to soil water contents (25, 50, 75, 100, and 125% field capacity).

Plant growth and development were weekly observed, from shooting to opening of the first basal flower, when it was considered harvest time. According to Paiva et al. (2012), gladiolus flower stems may already be harvested when the first basal flower shows its petal color. Vegetative plant characteristics were studied to analyze plant response to the treatments as they directly influence flowering, while flowering ones were defined based on important aspects considered for commercialization by the most accepted Brazilian gladiolus classification (VEILING HOLAMBRA, 2016). The following variables were evaluated at the end of the experimental period: sprout number per corm; plant height (cm), measured from the substrate surface to the highest leaf tip; leaf number; flower stem number; flower stem length (cm), measured from the substrate surface to the last flower tip; flower stem diameter (cm), measured immediately below the first basal flower; flower number; flower diameter (cm), measured at the central flower area parallel to the substrate surface; dry matter of leaves (g) per corm; dry matter of flower stems per corm (g); number of days from planting to flower harvest; dry matter used from the planted corms (%); and number of decayed corms.

Data were submitted to variance analysis and, when significant, means were compared by the Tukey test ($p < 0.01$). Regression analyses were also performed to verify variable behavior according to soil water contents. Data of flower stem diameter and decayed corms were transformed to arcsine $(x+1)^{1/2}$ for statistical analysis only.

3. RESULTS

There were no significant interactions among soil water contents and corm sizes for all variables, except dry matter of flower stems (Table 1). For this variable, medium corms at 75 and 125% field capacity (FC), as well as big corms at 100% FC achieved best results. In general, medium corms showed better performance than big ones, while 75, 100, and 125% FC presented superior results to 50% FC. The treatment of 25% FC was not considered for analysis because plants did not produce flowers.

Table 1. Dry matter of flower stems of *Gladiolus grandiflorus* 'White Friendship' according to corm size and soil water contents.

Dry matter of flower stems (g)			
Field capacity	Corm size[1]		Means
	Medium	Big	
25%[2]	---	---	---
50%	2.68 Ac	2.19 Bc	2.44 b
75%	5.16 Aa	3.73 Bb	4.44 a
100%	3.88 Bb	5.12 Aa	4.50 a
125%	4.64 Aa	3.73 Bb	4.18 a
Means	3.27 A	2.95 B	
C.V. 10.29 %			

[1]Medium = 13 cm perimeter, and Big = 14 cm perimeter.
[2]Plants cultivated under 25% field capacity did not produce flowers.
Means followed by different upper case letters in the line and lower case letters in the column differ from each other by the Tukey test ($p \leq 0.01$).

For all the other variables, there were isolated effects promoted only by the soil water contents. The exception were sprout number (from 1.04 to 1.22 sprouts per corm) and dry matter used by the plant from planted corms (from 37.50 to 42.16%, i.e., the planted corms at the end of the experimental period were that lighter than at the beginning), which had non-significant results from both soil water contents and corm sizes.

For the vegetative part, best results were obtained by 81% FC for both plant height (63.61 cm) and leaf number (6.94 leaves), while greater dry matter of leaves was achieved by 125% FC, resulting in 36.87 g per plant (Figure 2).

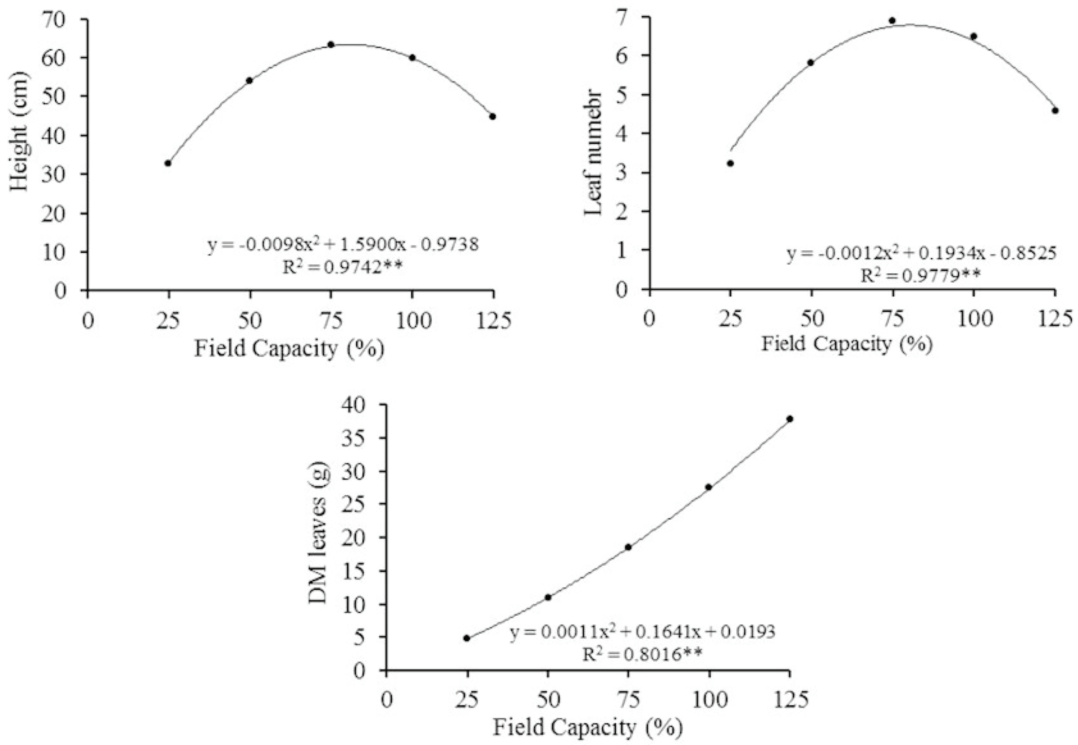

Figure 2. Variations of plant height, leaf number, and dry matter of leaves (DM leaves) of *Gladiolus grandiflorus* 'White Friendship' cultivated under different soil water contents (% field capacity). **Significant at $p \leq 0.01$.

Regarding the flowering characteristics, the 25% FC treatment was disregarded from the regression analysis, as flowering was not achieved from plants cultivated under such conditions. Best results were obtained when plants were cultivated under 80 to 81% FC, resulting in 1.08 flower stems per corm (80% FC) of 111.16 cm length (81% FC) and 7.67 mm diameter (80% FC), with 9.28 flowers per flower stem (81% FC) of 11.49 cm diameter (80% FC) (Figure 3). For dry matter of flower stems, results obtained from the regression analysis indicated that, for both corm sizes, 99% FC was the most appropriate soil water content to reach highest dry matter (Figure 3).

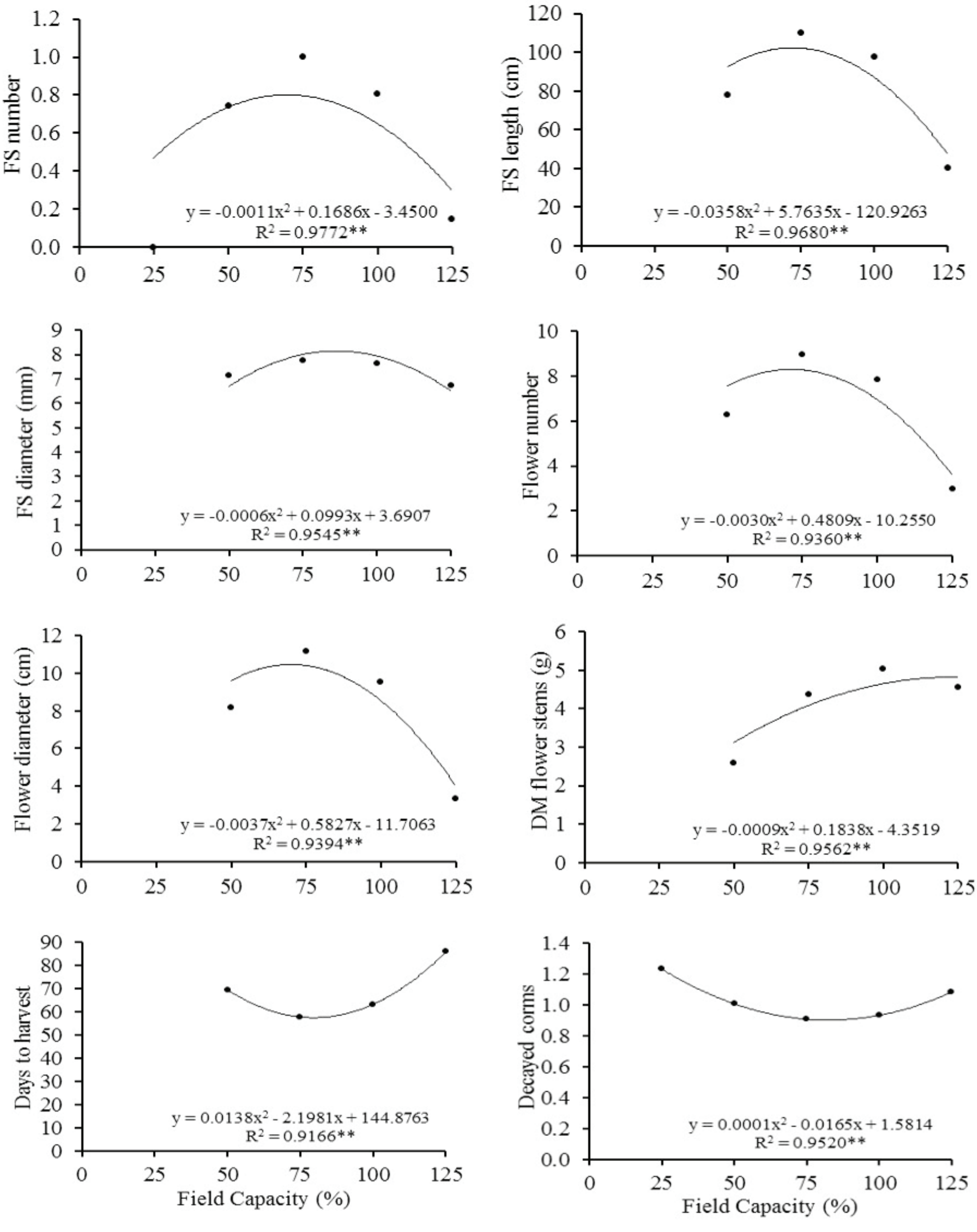

Figure 3. Variations of flower stem (FS) number, length, and diameter; flower number and diameter; dry matter of flower stems (DM flower stems); days from corm planting to flower harvest; and number of decayed corms of *Gladiolus grandiflorus* 'White Friendship' cultivated under different soil water contents (% field capacity). **Significant at $p \leq 0.01$.

Regarding the plant cultivation period, i.e., number of days from corm planting to flower harvest, minimum was 57.5 days, achieved under 79 and 80% FC (Figure 3). The treatment of 125% FC promoted the longest period, reaching 86.2 days.

There were no decayed corms from plants cultivated under 50, 75, and 100% FC. However, the regression analysis indicated that 76% FC is the treatment that would result in no decayed corms at all (Figure 3). Both 25 and 125% FC promoted death of 20.8% planted corms.

4. DISCUSSION

Differently to what happened in this study, Rosa et al. (2014) reported that corm size is responsible for gladiolus cultivation success, since flower stem quality is directly related to it. In addition, the authors mentioned that big corms promoted more and longer leaves. Corroborating such statement, Thompson et al. (2011) claimed that, for *Watsonia* spp. Mill., another Iridaceae plant that produces corms, leaf number increased according to greater corm dry matter, but flower number remained similar regardless corm size. However, for that species, the authors concluded that flowering was not related to corm size but directly to environmental conditions, what is not established for gladiolus.

According to Du Toit et al. (2004), big reserve organs, with greater dry matter, have higher starch concentration. In fact, bulbs, tubers, and corms are known to be rich in starch sources (CASTRO et al., 2005). Thus, together with what is produced during plant life cycle by photosynthesis, starch is used as an energy source for shoot growth that, after maturation, will also accumulate starch from photosynthesis. However, medium and big corms used in this study may be traded within the same commercial group, so that should be natural that no differences were found among them, otherwise sales of such group could infer in losses to growers. Therefore, inferences in this regard should be applicable to those corms that are very much different in size and dry matter.

Regarding the used dry matter by the plant, another variable that was not influenced by the studied treatments, Du Toit et al. (2004) stated that, for bulbs, starch concentration in the mother bulb started to increase due to photosynthesis performed by active leaves until flowering, decreasing during senescence and death of the aerial part. Considering the data obtained in this study, reasonable results would demonstrate that taller plants with more leaves and longer inflorescences would have used more reserve than others. However, more leaves also mean that more photoassimilates were produced via photosynthesis, so matter was probably replaced this way, resulting in no final differences among corms of different sizes.

According to Porto et al. (2014), the appropriate water content, obtained in this study by 81% FC, promoted greater assimilation of carbohydrates by the plant, which is used as an important component of photosynthesis, resulting then in increased development what was demonstrated by plant height and leaf number. From 81% FC, thus increase in soil water content, values of both variables started to decrease. Under waterlogged conditions, oxygen in the soil becomes rare and plant metabolism is altered via stomata closure, reducing photosynthesis, carbohydrate translocation, and mineral absorption (KOZLOWSKI, 1984). This condition, then, minimizes growth, what explains the obtained results.

For dry matter of leaves, as the regression analysis resulted in an increasing line from 25% FC, with no curve peak, such result could change if soil water contents above 125% FC were tested. However, it would not make sense to test or cultivate plants under water contents above 125% FC since such condition does not represent producers' reality. On the other hand, Kozlowski (1984) reported that there is a reduction in the translocation rate of photosynthetic products from leaves in plants cultivated under oxygen deficiency in the soil caused by high water content. This may be, then, a possible explanation for such result, so perhaps most of the dry matter produced because of photosynthesis was fixed in the leaves. That author also mentioned that, in flooded soils, root growth is reduced more than shoot growth, so leaves would carry on with growth until a certain limit when overwatering would be fatal.

Overall, the treatment of 25% FC presented the lowest results for the vegetative part (Figure 2), corroborating with Pereira et al. (2009), who reported that gladiolus plants are very sensitive to water deficit, showing poor growth and flowering when submitted to these conditions. In addition, Wright and Burge (2000) observed that symptoms of water stress include lower growth, what is much apparent in this study. Furthermore, Shillo and Halevy (1976b), Bastug et al. (2006), and Pereira et al. (2009) mentioned that gladiolus vegetative development and flower stem initial growth are the most sensitive stages to soil water shortage. In fact, water deficit permanently affected plant development as, although plants remained alive, such treatment did not promote any flowering, as also reported by Shillo and Halevy (1976a) for gladioli cultivated under low soil moisture. According to the same authors, low soil moisture is even more detrimental when temperature is high, as it implies in higher vapor pressure deficit. Indeed, there were periods of high temperature during the experimental period. Positive results obtained for the vegetative parts of plants cultivated under 81% FC, therefore, directly influenced development of reproductive parts. According to Pereira et al. (2009), gladiolus flowering is directly affected by an either vigorous or poor vegetative growth.

According to Begum et al. (2007), greater water availability may facilitate root growth and nutrient uptake, therefore resulting in higher flower yield. Furthermore, Bastug et al. (2006) reported that every millimeter of water increases gladiolus flowering percentage at around 0.3% according to irrigation treatments and varieties. However, the highest moisture (125% FC) tested in this study promoted the lowest results for all flowering variables, with the exception of dry matter of flower stems. Number of flower stems, for instance, was 67.3% lower than the best result obtained under 80% FC (1.08 flower stem per corm). Therefore, there is a water supply limitation for gladiolus growth and development as, according to Bastug et al. (2006), the irrigation water applied affected all characteristics of flowering and flower quality. On the other hand, for calla (*Zantedeschia* sp. Spreng.), Wright and Burge (2000) concluded that irrigation had no effects on flower stem number, but did increase flower size, as it also happened with the gladioli.

Regarding the number of days from corm planting to flower harvest, the minimum period (57.5 days) achieved under 79 and 80% FC shows that such treatment anticipated the normal cultivar cycle, which, according to Paiva et al. (2012), falls between 60 to 65 days from planting to flowering. The treatment of 125% FC, which promoted the longest period from planting to harvest (86.2 days), should be disregarded once as longer plants remain under cultivation as more expensive becomes their production for the grower.

With respect to number of decayed corms, according to Pereira et al. (2009), water excess favors rot besides inducing plant cycle delay, what we also found. However, 25% FC also promoted an equal number of decayed corms. Such water deficiency usually promotes poor growth, observed in this study. However, such condition, when persistent for a long time, may even cause plant death, according to the species.

In the literature, however, there are divergences on recommended irrigation for gladiolus, as Porto et al. (2014) found optimum soil water content at 134.41% FC for the same cultivar, and obtained much longer flower stems reaching up to 137.60 cm at harvest time. On the other hand, Pereira et al. (2009) observed that FC close to 100% resulted in longer gladiolus flower stems with more flowers; the latter studied a medium maturity cultivar that might present different responses than early maturity ones.

5. CONCLUSIONS

Gladiolus cultivation at 80% soil field capacity presents best results for commercialization, generating longer flower stems, with greater stem diameter and flower number, plus larger flowers. Furthermore, such soil water content promotes the shortest cultivation period.

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AUTHORS CONTRIBUTIONS

R.B.M.G.: Experiment idealization, implementation, and conduction; data analysis; manuscript writing. **O.G.F.:** Experiment implementation; manuscript writing and review. **E.M.B.S.:** Experiment idealization; manuscript review. **J.C.C.C.:** Experiment implementation and conduction; data collection. **M.T.J.P.:** Experiment conduction and discussion. **T.J.A.S.:** Experiment idealization; manuscript review.

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