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Effects of Nitrogen Fertilization and Water Replacement Level on the Production of Gladiolus Corms in a Protected Environment

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Abstract

The objective of this study was to evaluate the effects of water replacement levels (50, 75, 100, 125 and 150%; for the 100% level, the water replacement volume was at field capacity) and nitrogen doses (0, 30, 60, 90, and 120 mg dm^{-3}) on the production of gladiolus (*Gladiolus grandiflorus* L.) corms, White Friendship variety. The project was developed in a protected environment using a randomized complete block design witha 5x5 factorial scheme (water replacement levels × nitrogen doses). The evaluated variables werecorm diameter and weight and cormel number and weight. The data were assed using analysis of variance F-test at 5% probability and a regression analysis using the Sisvar statistical program. There was no nitrogen fertilization effect on the analyzed variables. The water replacement levels had a significant effect. For corm weight, the water replacement level that led to the highest weight was 128.96%. The weight and number of cormels were fit using an increasing linear regression model. According to Brazilian commercial corm standards, quality corms with diameters that suggest good potential for floral stem production were observed starting at the 50% water replacement level.

Keywords: *Gladiolus grandiflorus* L., soil moisture, tensiometer, water management

1. Introduction

The commercial focus of gladiolus cultivation is both the production of cut flowers and the production of corms. Gladiolus can be cultivated in small areas for a quick financial return because they have a short time to produce flowers, they are easy to grow and has a low implementation cost.

From 2000 to 2008, Brazilian exports of rhizomes and corms corresponded to 46.31% of flower and ornamental plant exports, for a total of $13.28 million USD (Junqueira & Peetz, 2011).

In Brazil, gladiolus corms are the most frequently exported parts of the plant, and the bulbous plant market generated a total export value of $13-14 million USD in 2010 (Tombolato et al., 2010).

The gladiolus needs well-drained, sandy soils with good aeration for its development, and it primarily requires nitrogen, potassium and calcium (Tombolato, 2004).

During gladiolus cultivation, the critical moisture content of the soil that reduces production differs according to the developmental stage and the purpose of the crop, *i.e.*, for flower or corm production (Halevy, 1962).

In a gladiolus experiment, Pereira et al. (2009) found that the best results with regards to the plant height, floral stem length and number of flowers were obtained by maintaining the soil water tension close to field capacity and by not allowing the soil water tension to exceed 15 kPa.

According to Halevy (1962), when a gladiolus is grown for corm production, its critical moisture corresponds to the water tension in the soil from 60 to 80 kPa during the emergence period. It lasts until the final height of the fifth leaf is reached and, during the flowering period, until the end of the cycle.

Sasso (1962) obtained positive responses for corm weight by maintaining the soil moisture at ranges between 20 and 60, 50 and 90, and 80 and 100% of the field capacity. Bastug et al. (2006) and Maggio (1993) did not obtain significant results for corm weight under irrigation treatments with three different water replacement levels.

Lahiji et al. (2012) evaluated the irrigation intervals effects 7, 10 and 15 days, on gladiolus plants and observed significant differences in the corm and cormel weights and the number of cormels.

Nitrogen is one of the most important nutrients for gladiolus growth and production responses (Leghri et al., 2011). Time of planting and fertilization management affect the production and quality of gladiolus flowers as well as corms and cormels. Inadequate plant nutrition causes serious disorders and may eventually lead to a decline in plant vigor and production (Hossian et al., 2011). Despite positive responses to nitrogen fertilization, Fernandes et al. (1974) observed that nitrogen top dressing had no effect on the mean weight of gladiolus corms.

The size of the corm is important for the success of gladiolus cultivation. Large-sized corms produce more uniform flowering, shorter cultivation periods, and stronger plants with heavier spikes. Therefore, the quality of the flower is directly related to the size of the corm, and during each generation, one corm is capable of producing 20-50 cormels (Tombolato, 2004).

Because irrigation and nitrogen fertilization management during gladiolus corms production is not frequent, there is a need for studies that measure the water availability effects and nitrogen fertilization on gladiolus corms production in protected environments. The purpose of this research was to assess the effects of the water replacement levels and nitrogen fertilization on the production parameters of gladiolus corms from the White Friendship variety when cultivated in a protected environment.

2. Method

This project was conducted from April to September of 2012 in a protected environment at the Institute of Agricultural Science and Technology, Federal University of Mato Grosso (UFMT), Rondonópolis Campus, in Rondonópolis city, Mato Grosso (MT), Brazil. This campus is located at 281 meters altitude, 16°28′ S latitude and 54°38′ W longitude.

The air temperature and humidity were measured by a thermo-hygrometer inside the greenhouse. Temperatures were from 17.4 to 40 °C and an average of 27.47 °C and humidity were from 45 to 99% and an average of 74.04%.

The soil collected for the experiment was from a native Cerrado area(Brazilian savannah) that was defined as Dystrophic Red Latosol with a sandy loam texture (Embrapa, 2006), and the 0.0-0.20 m layer was passed through a 2 mm aperture sieve. The soil analysis revealed the following chemical and textural characteristics (Table 1).

Table 1. Chemical and textural characteristics of an oxisol collected from the 0-20 cm layer in a native vegetation area

Particle size distribution			pH ($CaCl_2$)	Phosphorus	Potassium	Organic matter
Sand	Silt	Clay				
------ $g\ kg^{-1}$ ------				------ $mg\ dm^{-3}$ ------		$g\ dm^{-3}$
549	84	167	3.8	1.2	24	23.4
Calcium+Magnesium		Calcium		Magnesium	Aluminum	Hydrogen
------ $cmolc\ dm^{-3}$ ------						
0.2		0.1		0.1	0.9	4.8
Sum of bases		Cation exchange capacity		Base saturation	Aluminum saturation	
------ $cmolc\ dm^{-3}$ ------				------ % ------		
0.3		6.0		4.4	77.4	

The soil base saturation was increased to 70% with liming (Ribeiro et al., 1999). Phosphorus fertilization (P_2O_5) was done in all the plots using 200 mg dm^{-3} in the form of simple superphosphate on the same day as the bulb planting. Potash (K_2O) was applied at 75 mg dm^{-3} in the form of potassium chloride 24 days after planting (DAP) (Ribeiro et al., 1999).

The experimental design was a randomized block in a 5 × 5 factorial scheme with four replications. The treatments consisted of five nitrogen doses (0, 30, 60, 90, and 120 mg dm^{-3}), with urea as a nitrogen source, and five water replacement levels (50, 75, 100, 125 and 150% of the water replacement volume of the field capacity).

The nitrogen doses were divided into three applications that were made at 20, 31 and 40 DAP. The micronutrient fertilizer consisted of 0.5 mg dm^{-3} boron in the form of H_3BO_3 and 1 mg dm^{-3} zinc as $ZnCl_2$ (Ribeiro et al., 1999) at 24 DAP. Each experimental unit consisted of one pot with dimensions of 230 × 240 × 240 mm.

The species used for the experiment was the *Gladiolus grandiflorus* L., White Friendship variety. It has a has a short period of cultivation of 60-65 days (Severino, 2007). Two corms with perimeters of 12-14 cm (4.4 to 4.8 cm in diameter) were planted in each pot to a depth of 12 cm.

To evaluate soil moisture, the characteristic curve parameters of the soil water retention were obtained with the aid of Soil Water Retention Curves software (SWRC, version 2.0). According to the Van Genutchen model (1980) that was developed by Dourado Neto et al. (2000), the characteristic curve describes the behavior of soil moisture as a function of the tension (Equation 1) (Figure 1).

$$\theta = \frac{0.468}{[1 + (0.0573|\psi|)^{0.3545}]^{0.5724}} \tag{1}$$

where, θ: soil moisture, $cm^3\ cm^{-3}$; ψ: Matric potential, kPa.

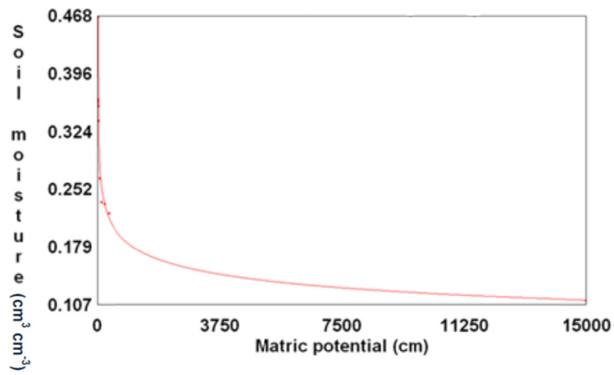

Figure 1. Soil Water Retention Curve (SWRC)

For each observed soil water tension value, the corresponding amount of moisture was calculated from the characteristic water retention curve in the soil. After accounting for the volume of soil in the plots, this moisture value and the one corresponding to the field capacity were used to calculate the water replacement volume for each treatment (Equation 2).

$$V = (\theta cc - \theta f) \times 13000 \tag{2}$$

where, V: volume of water, cm^3; θcc: soil moisture at field capacity, $cm^3\ cm^{-3}$; θf: moisture from the retention curve according to the observed tension, $cm^3\ cm^{-3}$.

The water tension equivalent to the soil moisture at field capacity was defined as 6 kPa, and according to Bernardo et al. (2009), it is normal to find field capacity values of up to 5 kPa in typical savannah soils.

To determine the volume of water in the plots, one puncture tensiometer was installed per block for a total of four tensiometers. The installation depth of the tensiometers, which was measured from the soil level to the center of the capsule, was 12 cm; the capsule´s position was supposed to be close to the developing roots of the crop.

Water was applied manually to each plot using a measuring cylinder. Using the methodology used by Koetz (2006), the water replacement volume for each treatment was obtained from the average reading of the tension observed in the four tensiometers and then added to the experimental units, with 100% of the recommended replacement water in the soil and a reference dose of 60 mg dm^{-3} nitrogen.

Daily readings were taken from the tensiometer at 9 a.m.and 3 p.m., and the moment of watering was said to occur when the average tension obtained from the four tensiometers reached a value close to 15 kPa. Until 20 DAP, when all of the corms had emerged, all the treatments were irrigated with the same amount of water to ensure corm emergence and seedling establishment. After this period, the application of the water replacement volume to the soil began in accordance with established treatments.

After gladiolus floral stems were produced, irrigation was maintained until 132 DAP, and 23 days after irrigation was suspended, the corms and cormels were harvested when it was clear that the corms in the pots were not wet. The analyzed variables were corm weight and diameter and cormel weight and number. The corms harvested were classified according to their diameter and weight (Table 2).

Table 2. Gladiolus corms classification, White Friendship variety, according to the corm perimeter and its relationship to the diameter and weight

Perimeter class (cm)	White Friendship Variety	
	Diameter (cm)	Weight (g)
7-8	2.1-3.0	3.1
8-10	3.1-3.5	7.3
10-12	3.6-4.3	13.6
12-14	4.4-4.8	21.0
14-16	4.9-5.7	31.3
>16	> 5.7	48.8

Source: Adapted from Barbosa (2011).

3. Results and Discussion

During the experiment, 59 irrigations were performed, and the mean irrigation during the entire treatment period was 2.24 days (Table 3), for a mean tension of 17.27 kPa.

Table 3. Water replacement levels, total water applied to each treatment and mean water used by the crop over a 132-day cycle

Water replacement levels (%)	Total water applied (L)	Average crop water use(L day^{-1})
0	16.49	0.1249
75	24.73	0.1873
100	32.98	0.2498
125	41.23	0.3123
150	49.47	0.3747

The corm weight results were significant only for the water replacement levels, and the data fit a quadratic regression equation (Figure 2). For maximum corm weight, a value of 56.88 g pot^{-1} was obtained for a water replacement level of 128.96%.

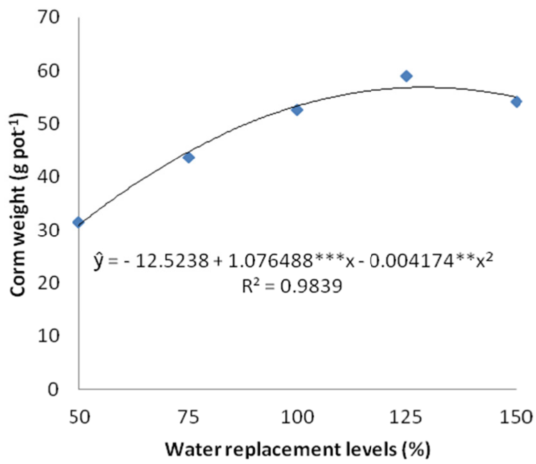

Figure 2. Corm weight as a function of water replacement levels. ** Significant at 1%

Sasso (1962) maintained the soil moisture at ranges between 20 and 60, 50 and 90, and 80 and 100% of field capacity, and they also found that increased soil moisture content increased corm weight. Lahiji et al. (2012) evaluated the effects of the three irrigation intervals on gladiolus plantsand also obtained significant responses in corm and cormel weights.

Unlike those results, Bastug et al. (2006) and Maggio (1993) did not obtain significant results for corm weight under irrigation treatments with three different water replacement levels.

In the present study, the cultivated corms ranged from 4.4 to 4.8 cm in diameter, and therefore, they had sufficient reserves for plant development. Thus, there were no significant differences among the nitrogen doses.

There were significant responses in corm diameter only for the water replacements levels, and those data were represented using a quadratic regression model (Figure 3). Thus, an increase in corm diameter is observed up to the maximum water replacement level of 122.21%, after which a decrease in corm diameter is observed. Thus, both water deficit and water excess decrease corm diameter. Sasso (1962) also observed an increase in corm diameter with increasing soil moisture, as well like this study. Lahiji et al. (2012) however, did not observe a significant response in corms diameter in study of irrigation intervals on gladiolus plants.

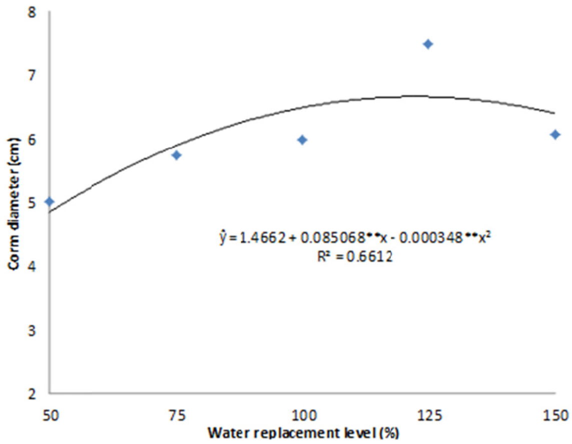

Figure 3. Corm diameter as a function of water replacement levels. ** Significant at 1%

According to Barbosa (2011), the corm perimeter is the most commonly used parameter for Brazilian commercial classifications of gladiolus corms. In observing the means at the 50% water replacement level, the corms are already within the 14-16 cm perimeter, or 4.9-5.7 cm in diameter.

The North American Gladiolus Council recommends medium-sized corms with diameters ofgreater than 3.1 cm or jumbo-sized corms with diameters of greater than 5.1 cmfor the production of floral stems (Tombolato, 2004). Fernandes et al. (1974) report that large corms with perimeters of greater than 16 cm (> 5.7 cm in diameter) and corms with smaller diameters (2.1-3.0 cm) or 7-8 cm in perimeter produce poorer-quality stems.

According to the means observed here, even though corms with larger diameters are obtained with increased water replacement levels, at the 50% level, corms with 4-5 cm diameters favored good floral stem production capacities (Table 4).

Table 4. Corm diameter and commercial perimeter as functions of water replacement level

Water replacement level	Observed	Commercial perimeter
	---------------------------- Mean	----------------------------
50	5.01	14-16
75	5.73	>16
100	5.99	>16
125	7.48	>16
150	6.06	>16

Therefore, it should be emphasized that when a gladiolus is grown exclusively for corm production, the water replacement level may be lower. According to Porto et al. (2014) and Pereira (2009), when the purpose is solely the production of floral stems, the applied water replacement levels should be higher.

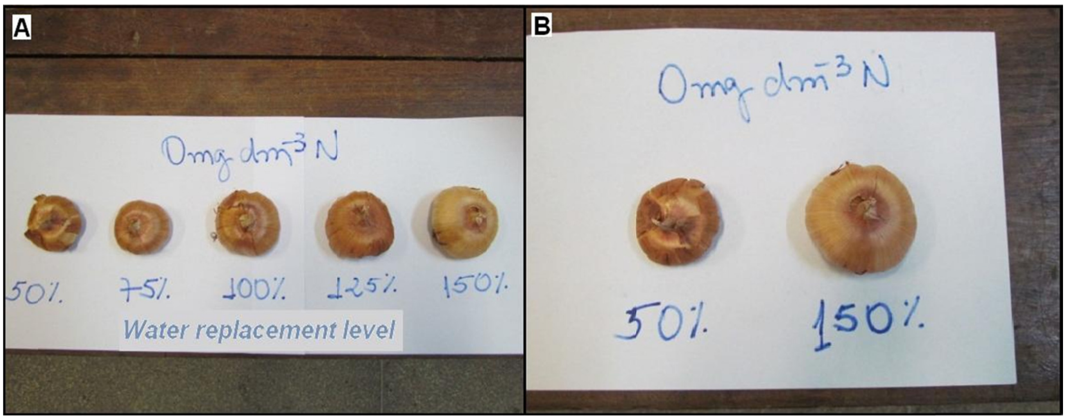

Figure 4. (A) Corms produced without nitrogen fertilization and at five different water replacement levels (50, 75, 100,125 and 150%). (B) There is a visible difference between the corms produced at the lower water replacement level (50%) and the highest water replacement level (150%), without nitrogen fertilization

The water replacement levels significantly affected cormel weight, and the data were fit to a linear equation in which the maximum water replacement level (150%) led to a cormel weight of 13.94 g pot^{-1} (Figure 5A).

Lower water replacement levels are recommended to form corms that provide better-quality flowers, but in terms of cormel production, the water replacement levels that led to heavier cormels were closer to the water replacement levels used for producing floral stems (Porto et al., 2014).

The water replacement levels significantly influenced the number of corms, as demonstrated by a linear regression model. The maximum number of corms found here (58.88) was obtained for the 150% water replacement level (Figure 5B). Sasso (1962) also observed an increase in the number of corms with increasing soil moisture, but the number of corms was not significant. Lahiji et al. (2012) obtained significant responses on the weight and numbers of corms in an experiment to analyse irrigation intervals effects on gladiolus plants.

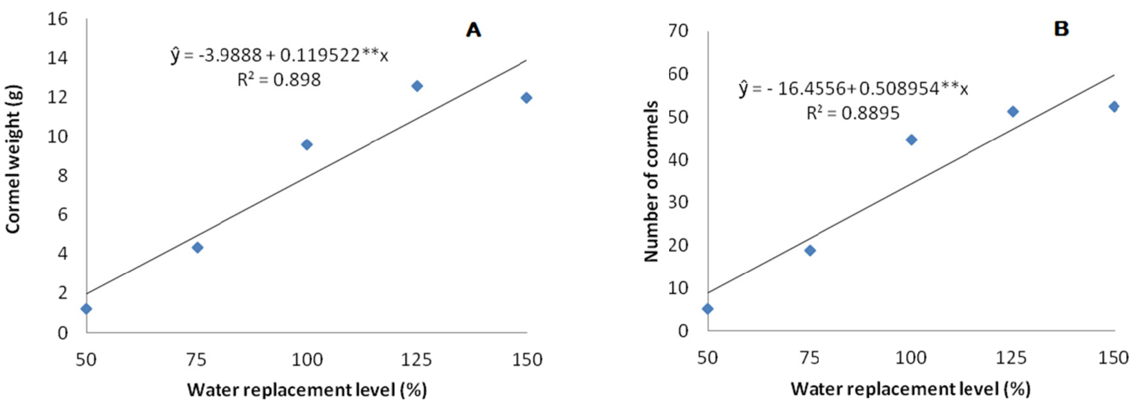

Figure 5. Weight (A) and number (B) of cormels as a function of the water replacement level.

** Significant at 1%

For nitrogen fertilization, the lack of significant responses in the analyzed variables may be related to the corm size because it can influence the response to fertilization. The corms used in the present experiment were medium-sized, with 12-14 cm perimeters and 4.4 to 4.8 cm diameters. According to Rosa et al. (2014), small corms benefit more from nitrogen fertilization, likely because of their lower nutrient reserve.

The increase in flower production, flower quality and corm and cormel production varies according to corm size (Hossian et al., 2011). The initial growth and vigor are determined by the amount of feed provided for plant growth by the corm (Pant, 2005).

According to Lehri et al. (2011), the cultivar and corm and cormel sizes also influence the fertilization requirements of the gladiolus. Smaller corms require more fertilizer than larger corms, primarily because of their lower stored reserves and in part because of the greater feeding capacity of the root system produced by larger corms (Pal, 2000). Moreover, the production of flowers from medium-sized corms is not influenced by fertilizer applications (Tamura & Mega, 1959).

Fernandes et al. (1974) evaluated the N dose effects on gladioli grown from three different corm sizes. They observed that, in general, the greatest nitrogen fertilization effects on the production of flowers, corms and cormels were observed in plants grown from the smallest corms (3 cm in diameter) because they had a higher nutrient requirement, given their lower nutritional reserve.The same trend was also found in plants grown from jumbo corms (6 cm in diameter) because they have less vitality and are in the final stage of life.

Fernandes et al. (1974) also reports that for plants grown from medium-sized corms (4 cm in diameter), there was no response to nitrogen fertilization due to the corm's nutrient reserve combined with the capacity of the more extensive root system, and even though the 4 cm corms did not respond to fertilization, the corm weight, number of corms, stem length and number of floral buds per stem were higher than those of the other corm sizes, indicating that the medium-sized corms had greater vigor. Pant (2005) also states that the initial growth and vigor are determined by the amount of food provided by corms for plant growth.

5. Conclusions

Gladiolus grown to produce corms are obtained starting at the 50% water replacement level to produce corms with diameters indicative of good potential for floral stem production.

There is no response to nitrogen fertilization with regards to the production of gladiolus corms, when using medium sized corms.

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