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# Yield of Yellow Finger Pepper under Water Replenishment Levels

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The pepper species (*Capsicum baccatum*) have high fruit variability in terms of colour, shape, size and intensity of spicing, with fruit quality depending on the amount of water used during the development phases. In this sense, the objective of this study was to evaluate the yield of yellow finger pepper cultivated in a greenhouse environment under drip irrigation system. The experiment was conducted in a greenhouse located in the experimental area of the Goiano Federal Institute - Campus Ceres, Goias – Brazil, from July 2016 to February 2017. A completely randomized design was used, with four irrigation levels (50, 75, 100 and 125% of Crop evapotranspiration (CET)) and 5 replications. The traits evaluated were plant height; diameter of stem and cup; fresh weight and root dry weight; number of fruit; mass, diameter and length of the fruit; amount of seeds per fruit; pericarp thickness; average productivity; yield per plant and fruit length/diameter ratio. Data were submitted to variance analysis (F Test), at 5% significance level and in the characteristics that presented significance, regression. Differentiation of the treatments ($p < 0.05$) provided linear growth in the characteristics of the yellow finger pepper, with an increase in yield according to the increase of the water replenishment levels.

## 1. Introduction

Population growth on the planet Earth and global climate change require constant research and discoveries that will ensure the production of healthy food with limited natural resources, such as soil and water (Cosic et al., 2015). In view of the fact that water is a limited resource, the general goal of research should be to seek out various water-saving measures and approaches that produce cost-effective yields (Cosic et al., 2017). Drip irrigation results in water savings in two ways: first, less water is lost as a result of the completely closed pipeline system; and second, only a part of the soil surface is wetted, whereas the rest remains dry which is especially significant for crops with wide row spacing (Koksal et al., 2017).
Another way to mitigate drought, as well as save water, in agriculture is to apply deficit irrigation (DI), with the objective of reducing the irrigation water demand, increasing water use efficiency (WUE) and optimizing yields (Ismail, 2010). The effect of DI on yields and fruit quality depends on the type of crop, agronomic practices, evapotranspiration rate, type of soil and available soil moisture (Cosic et al., 2015; Akıncı and Lösel, 2012). Extensive research has been conducted to study the variation in sweet pepper yield as a function of water stress, corroborating a considerable decline in yield as the water deficit increased (Sezen et al., 2014). DI should be applied in phenophases least vulnerable to water stress. In the case of crops like the sweet pepper, water stress should be avoided at flowering and yield formation stages. This is a very difficult task, given the length of these phenophases of most pepper cultivars (González-Dugo et al., 2007). Recently, there is a demand to enhance vegetable production and develop ways through which maximum benefits can be obtained from the limited available water resources. The plant response to a given amount of soil water varies as a function of evaporative demand (Sezen et al.,

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2019). Moreover, determining the local/regional sensitivity of chili peppers to water stress at various growth stages is required to help growers adopt improved irrigation schedules to achieve better yields in conjunction with less water consumption, increasing the farm incomes (Yang et al., 2017).
Thus, because of varied effects of water replenishment level, on fruit quality and growth of the pepper plants, this study was conducted to evaluate the effects of water replenishment level on morphological and fruit parameters, growth, and yield of "yellow finger pepper". We aimed also at determining irrigation level for good growth, and fruit yield, of this cultivar, grown in a greenhouse environment under a drip irrigation system.

## 2. Materials and Methods

The experiment was conducted from July 2016 to February 2017, in a greenhouse located in the experimental area of the Goiano Federal Institute, Campus Ceres, Goias, Brazil (Latitude: 15°20'59.89"S, Longitude: 49°35'54.60"O and altitude of 580 m a.s.l). The climate of the region, according to the Koppen-Geiger classification, is type Aw, i.e. a tropical climate with a dry season in winter.
The greenhouse used has a low air density, transparent polyethylene cover, and a structure in an arch form. The hybrid of the pepper used was the IFET 1572 (yellow finger pepper) (Capsicum baccatum). One seed per cell was planted in an expanded polystyrene tray with 200 cells containing commercial Plantmax® substrate. At 30 days after sowing (DAS), when the seedlings had around four developed leaves, they were transplanted to 12 L flexible vessels. The substrate used was composed of ravine soil (red latosol) and bovine manure, at a ratio of 3:1, respectively. The physical and chemical composition of the soil used of the experiment is presented in Table 1.

*Table 1. Physical and chemical characteristics of the soil*

| in $H_2O$ | g dm$^{-3}$ | ------------------cmol dm$^{-3}$-------------- | | | | | | ---mg dm$^{-3}$--- | | -%- | mg dm$^{-3}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | OM | Ca | Mg | Al | H+Al | K | T | K | P | V | Cu |
| 7.0 | 14.2 | 4.1 | 1.8 | 0.00 | 1.0 | 1.0 | 7.9 | 410.0 | 160.0 | 87.3 | 1.7 |
| Texture (%) | | | | | | | | | | | |
| Sand | | | Silt | | | | Clay | | | | |
| 35.2 | | | 6.7 | | | | 58.1 | | | | |

An experimental design was randomized completely blocks with 5 repetition was used. The plots were composed of four treatments with different levels of water replenishment, namely 50, 75, 100 and 125% of crop evapotranspiration (CET), estimated through the daily reading of a evaporimetric pan with dimensions of 60 cm x 28 cm, installed inside the greenhouse. The different water volumes applied were controlled by the application time.
The blocks were composed of rows of flexible 12 L vessels, totalling 20 pots per block and 80 pots in the experiment, spaced at 0.80 m between rows, and 0.65 m between plants.
The experiment was conducted by using a drip irrigation system with a flow rate of 8 L/h, push-button drippers, and a self-compensating flow. The temperature and air humidity data were obtained by using a thermo-hygrometer, which was installed in a meteorological shelter inside the greenhouse.
During the transplanting, the moisture of the substrates contained in the vessels was elevated to vessel capacity moisture (VCM), based on the methodology used by Gamareldawlla et al. (2017). The volumetric water content in the vessels was maintained during the acclimatization of the seedlings, which occurred before the differentiation of the treatments and was performed at 30 days after transplanting (DAT).
The evaluations were performed fortnightly, from 15 DAT to 200 DAT. The morphological characteristics of plant height (PH, cm), stem diameter (SD, mm), and cup diameter (CD, m) were evaluated. The yellow finger pepper fruits were counted and weighed, and then evaluated average productivity (PROD, t ha$^{-1}$), considering a population of 19,231 plants ha$^{-1}$; productivity per plant (PPROD, g plant$^{-1}$); fruit mass (FM, g planta$^{-1}$); total number of fruit (TNF); fruit length (FL, mm); diameter fruit (DF, mm); pericarp thickness (PT, mm); relationship FL/DF, and number of seedling per fruit (NSF). Root fresh weight (RFW, g seedling$^{-1}$) and root dry weight (RDW, g seedling$^{-1}$) were also evaluated.
The values obtained for PH; SD and CD were quantified at 200 DAT, using the arithmetic mean of the values observed in 10 plants, while the values presented for DF, CF, ESP, NSF were quantified by the arithmetic mean of the five harvests. For the characteristics FL, DF, PT and NSF were considered 10 fruits, randomly selected, in each of the evaluations performed.

The data were analysed through one-way analysis of variance, using the F test, at the 5% probability level. For the variables in which there were significant treatment effects ($p < 0.05$), applied regression analysis.

## 3. Results and Discussion

### 3.1 Climatic data

The temperature and relative humidity (Figure 1a and 1b, respectively) inside the greenhouse was very variable throughout the experimental period, and ranged from a minimum of 11.1°C to a maximum of 55.3 °C to temperature and from 10% to 77% to relative humidity.

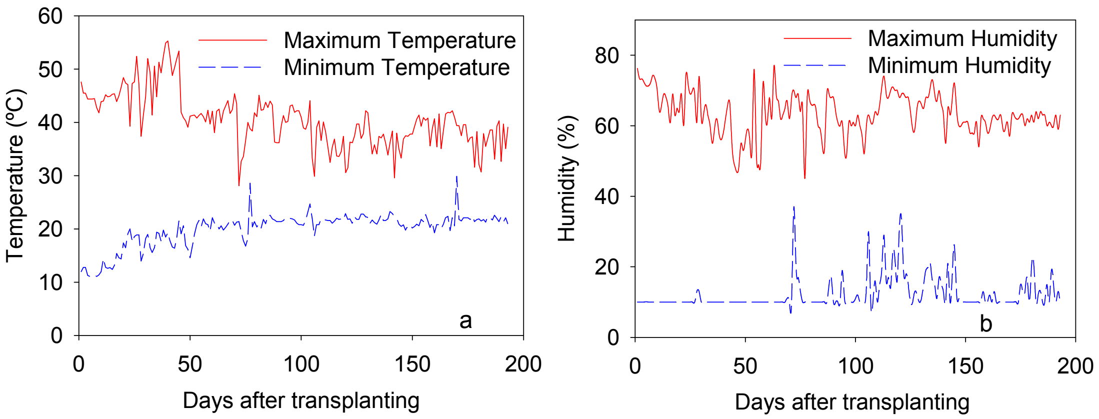


*Figure 1. Temperature (a) and humidity (b) inside the greenhouse throughout the experimental period*

Marinho et al. (2016) mention that during flowering and fruit development it is essential that the relative humidity of the air oscillate between 50 and 70% and for the seedlings the best growth is reached with temperatures between 26 and 30 ° C.

### 3.2 Morphological characteristics of plant

Table 2 presents the Fisher's F test at $p < 0.05$ for the morphological characteristics of the pepper plants: plant height (PH, cm), stem diameter (SD, mm), cup diameter (CD, cm), root fresh weight (RFW, g seedling$^{-1}$) and root dry weight (RDW, g seedling$^{-1}$) as a function of water replenishment levels (WRL) (50, 75, 100 and 125% of CET) at 200 days after transplanting (DAT).

*Table 2. Variance analysis for morphological characteristics as a function of WRL.*

| | PH (cm) | SD (mm) | CD (cm) | RFW (g seedling$^{-1}$) | RDW (g seedling$^{-1}$) |
|---|---|---|---|---|---|
| F Test | | | | | |
| WRL | 25.86* | 25.96* | 73.44* | 2.54$^{NS}$ | 2.58$^{NS}$ |
| CV% | 5.07 | 7.44 | 6.09 | 41.67 | 52.20 |

*Significant at the 5% level of significance ($p<0.05$); $^{ns}$No significant ($p>0.05$);
WRL – Water Replenishment Level; CV - Coefficient of Variation;
PH - Plant Height; SD - Stem Diameter; CD - Cup Diameter;
RFW - Root Fresh Weight; RDW - Root Dry Weight.

The morphological characteristics PH, SD and CD were significantly affected ($p < 0.05$) by the WRL. These characteristics, presented an increasing linear trend (Figure 2), from the lowest to the highest WRL value. Already, RFW e RDW were not influenced by the WRL.
Lima et al. (2012) in a study with chili plants found a higher value of PH and SD of 106.4 cm and 14.1 mm, respectively, for a 125% replacement leaf in relation to crop evapotranspiration (CET) Class A.

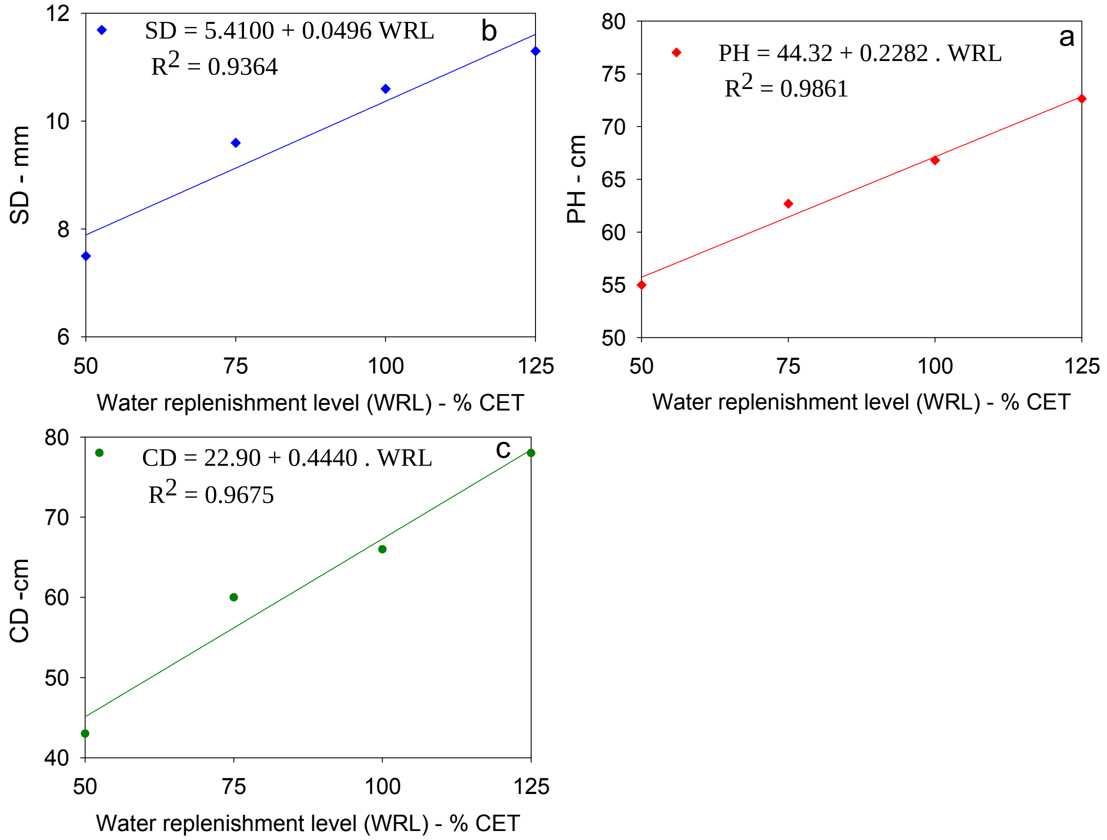


*Figure 2. Morphological characteristics, PH (a); SD (b) and CD (c) as a function of WRL*

### 3.3 Fruit analysis

Table 3 presents the Fisher's F test at $p < 0.05$ for the productive characteristics of fruit length (FL, mm); fruit diameter (FD, mm); pericarp thickness (PT, mm), number of seedling per fruit (NSF), relationship FL/DF, productivity per plant (PPROD, g $plant^{-1}$), total number of fruit (TNF), fruit mass (FM, g $planta^{-1}$), average productivity (PROD, t $ha^{-1}$) as a function of water replenishment levels (WRL) (50, 75, 100 and 125% of CET) at 200 days after transplanting (DAT).

*Table 3. Variance analysis for productive characteristics as a function of WRL.*

| | FL (mm) | FD (mm) | PT (mm) | NSF | FL/DF | PPROD (g $plant^{-1}$) | TNF | FM (g) | PROD (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| F Test | | | | | | | | | |
| WRL | 21.68* | 3.41$^{NS}$ | 17.10* | 2.27 $^{NS}$ | 1.29 $^{NS}$ | 48.66* | 68.5* | 11.65* | 48.74* |
| CV% | 13.34 | 44.04 | 11.84 | 60.00 | 20.23 | 28.25 | 18.63 | 25.58 | 28.23 |

*Significant at the 5% level of significance; $^{ns}$No significant.
FL - Fruit Length; FD - Fruit Diameter; PT - Pericarp Thickness; NSF - Number of Seedling per Fruit;
PPROD - Productivity per Plant; TNF - Total Number of Fruit; FM - Fruit Mass; PROD - Average Productivity

Regarding the fruits, the statistical analysis indicated there were significant differences ($p < 0.05$), for FL, PT, PPROD, TNF, FM and PROD as presented in Table 2.

The Figures 3a and 3e shows the quadratic adjustment obtained for the characteristics FL and FM. For these characteristics, the estimated optimum WRL were 125.00 and 122.33 %, respectively. The characteristics PT, PPROD, TNF and PROD presented an increasing linear trend, from the lowest to the highest WRL value (Figure 3).

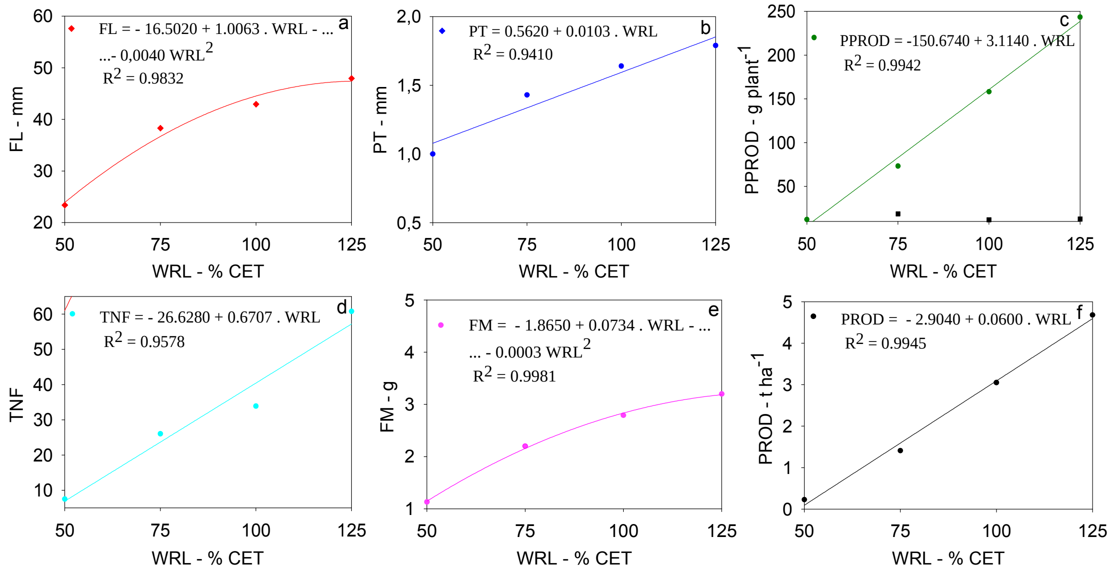


*Figure 3. Productive characteristics FL (a); PT (b); PPROD (c); TNF (d); FM (e) and PROD (f) of yellow finger pepper as a function of WRL*

According to the equations shown in Figures 3b, 3c, 3d and 3f, each 1 % increase in the water replenishment level, corresponding to an increase of 0.01 mm; 3.14 g plant$^{-1}$; 0.67 fruits and 0.06 t ha$^{-1}$ in PT, PPROD, TNF and PROD, respectively.

The estimated maximum and minimum PROD were 4.60 and 0.10 t ha$^{-1}$, respectively. The comparison shows, under the conditions of the study, a 97.82 % reduction in productivity when using 50 % WRL (% CET) in relation to the treatment with maximum WRL.

Barroca et al. (2015) studying the effect of irrigation depths (40, 70, 100, 130 and 160% of Penman Monteith reference evapotranspiration (ETO)) in yellow finger peppers observed for the productive characteristics, FL and FD, values of 67.75 mm and 15 mm in irrigations depth between 112, 42 and 94.75% of reference evapotranspiration (ETo), respectively. These characteristics are important factors in the commercialization of the fresh peppers, because the improved looking, the greater the value paid for them. Carvalho et al. (2011) obtained a maximum PPROD of 164.4 g of irrigated pepper fruits, in the depth water corresponding to 100% of ETO.

In study conducted to analyse the physiological response of red pepper (Capsicum annuum L.) to different irrigation regimes, Sezen et al. (2019) found that the highest yield was obtained from the drip full irrigation (DFI) treatment followed by deficit irrigation (DI-75% and DI-50% of DFI) treatments.

Shammout et al. (2018) conducted experiment to assess the effect of deficit irrigation (100, 80 and 60% of Crop evapotranspiration - CET) on pepper yield and observed the yields were higher under 100% of CET, but there was no difference in water use efficiency between treatment with 100 and 80 % of CET. Therefore, the authors recommended irrigating at 80% of CET.

Ahmed et al. (2014) studying the increasing irrigation deficiency (100, 85, 70, and 55% of water-holding capacity) found a reduction in vegetative growth, fruit parameters, and yield. Yang et al. (2017) studying the effects of regulated deficit irrigation on the yield of drip-irrigated chili pepper plants in a typical arid environment of Northwest China concluded that full irrigation is recommended, first for achieving the highest yield, and a water deficit of 25-50% during the late stage is also recommended if considering economic benefits.

In the study of Gadissa and Chemeda (2009) a 50% reduction in irrigation level caused a reduction in yield of about 48.3 and 74.4% under the normal and paired-row planting methods, respectively, whereas, a 25% reduction in irrigation level caused a reduction in yield of about 22.8 and 47.7% under the same planting methods.

## 4. Conclusions

1. This study show that the effects of water replenishment level is important in order to obtain higher yields of field grown yellow finger pepper under the climatic condition in central region of Brazil.

2. Differentiation of the treatments provided linear growth in the morphological characteristics and in the productivity of the yellow finger pepper, with an increase in yield according to the increase of the water replenishment levels.
3. The results revealed that drip irrigation, which was irrigated with 125% of crop evapotranspiration was recommended under greenhouse conditions in order to obtain higher yellow finger pepper yield in the central region of Brazil.

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