

THE EFFECTS OF DIFFERENT IRRIGATION DEPTHS ON RADISH CROPS

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1 ABSTRACT

The aim of this study was to analyze the performance of the radish crop under different levels of water replacement. The experiment was carried out at the Department of Rural Engineering, College of Agricultural Sciences - UNESP/Botucatu – SP. The experimental design was randomized blocks with five irrigation depths (25%, 50%, 75%, 100% and 125% Etc) and 10 replicates. A total of two crop cycles were conducted to analyze the crop performance. The following parameters were evaluated: number of leaves; root, bulb and above-ground green phytomass; bulb length and diameter and root length. Similar performance was observed for both cycles, characterized by a quadratic increase in irrigation depths with an optimal point from 60% to 80% Etc.

Keywords: management, optimization, efficiency, evapotranspiration.

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**EFEITOS DE DIFERENTES LÂMINAS DE IRRIGAÇÃO NA CULTURA DO
RABANETE**

2 RESUMO

O objetivo do presente do presente trabalho foi analisar o comportamento da cultura do rabanete submetido em diferentes taxas de reposição hídrica. O experimento foi realizado no Departamento de Engenharia Rural, da Faculdade de Ciências Agrônômicas, FCA-UNESP, na cidade de Botucatu – SP, em que adotou-se o delineamento em blocos casualizados, onde foram adotadas 5 lâminas de irrigação (25%, 50%, 75%, 100% e 125% da ETc) e foram utilizadas 10 repetições. Foram conduzidos 2 ciclos da cultura para constatar o comportamento da cultura. Foram realizadas as avaliações do número de folhas, fitomassa verde da parte aérea, raiz e bulbo, comprimento e diâmetro do bulbo e comprimento de raiz. Pôde-se constatar que foi verificado o comportamento semelhante em ambos os ciclos, sendo que responderam de forma

quadrática o aumento das lâminas de irrigação, em que o ponto ótimo obtido foi na faixa de 60% a 80% da ETc.

Palavras-chave: manejo, otimização, eficiência, evapotranspiração.

3 INTRODUCTION

Agriculture has been undergoing great impacts because of droughts, climatic changes and pests, with the consequent reduction of food supplies. On the other hand, increase in the buying power of consumers has caused people to eat more quality food. Due to the above facts, water consumption in irrigation has increased excessively to meet water necessities caused by lack of rain.

Irrigation is widely used to supply the plants' water needs. When irrigation is undertaken correctly, it has several advantages, ranging from an increase in production to an improvement in food quality. In spite of costs in its installation and maintenance, irrigation is an economically viable technology (FINGER; HEDIGER; SCHMID, 2011).

The radish culture has low resistance to water deficit (WAN et al., 2013), where in due to the short cycle can not occur lack of water (XU et al., 2014). It should be noted that due to its short cycle, the culture has strong absorption of nutrients, mainly nitrogen (SHAFIQ; AKRAM; ASHRAF, 2015; TAKAHASHI et al., 2013; KIM et al., 2015; PETOUSI et al., 2013)

However, if irrigation is not done correctly, it may jeopardize production. In fact, several research works have been performed for better reposition rates to determine the water volume to be irrigated and thus complying with the sustainability of the rational use of water (PAREDES et al., 2014; RODRIGUES et al., 2013; EL-GAFYA et al., 2014).

In the area of agricultural sciences, several studies using mathematical modeling in the management of orchids (PUTTI et al., 2014), determination of slaughter cattle (GABRIEL FILHO et al., 2011), chicken welfare (PEREIRA et al., 2008) and energy consumption (CREMASCO et al., 2008).

Water deficit may cause a decrease in production. This is especially true for the culture of radish (*Raphanus sativus*) of the family Brassicaceae, which is highly sensitive to lack of water (BREGONCI et al., 2008). Current assay assesses the effect of different water depths for the culture of radish in two cycles.

4 MATERIALS AND METHODS

Current assay was performed between January and April, in two cycles, with the subsequent start of lettuce crop in a protected place in the Department of Rural Engineering of UNESP, Faculty of Agronomic Sciences, in Botucatu SP Brazil, 22° 51' S and 48° 26' W, at 786 m above sea level. Following Köppen's classification (KÖPPEN; GEIGER, 1928), the region's climate is Cfa, with a humid subtropical climate.

Climate parameters were registered by an automatic meteorological station. Table 1 gives climate details throughout the experiment.

Table 1. Climatic parameters during the experiment.

Parameters		Cycle 1	Cycle 2
Temperature (°C)	Minimum	14 ± 3.19	16.99 ± 2.18
	Maximum	28.98 ± 4.90	32.38 ± 4.74
	Mean	21.49 ± 3.02	24.69 ± 9.17
Humidity (%)	Minimum	32.02 ± 17.30	29.19 ± 12.58
	Maximum	79.14 ± 11.33	74.77 ± 10.76
	Mean	55.5 ± 13.09	51.98 ± 9.17
Evaporation (mm)		114.2	135.2

According to Carvalho, Espíndola, Paccola (1983), the soil of the greenhouse was Dystrophic Red Latisol Nitosol with a moderate clayey structure. The soil had the following chemical characteristics: pH (CaCl₂) = 5.9; M.O. = 24 g dm⁻³; P (resin) = 191 mg dm⁻³; K = 4.8 mmolc dm⁻³; Ca = 68 mmolc dm⁻³; Mg = 25 mmolc dm⁻³; H+Al = 17 mmolc dm⁻³; SB = 67 mmolc dm⁻³; B = 0.51 mmolc dm⁻³; Cu = 4.8 mmolc dm⁻³; Fe = 20 mmolc dm⁻³; Mn = 10.10 mmolc dm⁻³; Zn = 8 mmolc dm⁻³ CTC = 114 mmolc dm⁻³; V = 85%.

The assay comprised two independent drip irrigation systems, with a main line, Amandani type, manufactured by Petroísa Irrigações Ltd, and directly inserted drip bands. Further, there was a 0.30 m space between drips, with a mean discharge of 1.47 L.h⁻¹, at a pressure of 10 m.c.a.

Irrigation and reading of Class A tank was done daily at 8 a.m., with irrigation time determined as follows:

$$Ti = 6000 \cdot \frac{Kc \cdot Kp \cdot Eca \cdot Sl \cdot Sg \cdot TR}{Ei \cdot Vg} \quad (1)$$

where, *Ti* is irrigation time; *Kc* is the coefficient of crop; *Kp* is the coefficient of the tank; *Eca* corresponds to the evaporation of Class A tank (mm dia-1); *Sl* is the space between sides (m); *Sg* is the space between drips (m); *Ei* is the efficiency of irrigation (%); *Vg* is the discharge of the drips (L h⁻¹).

Total water depth of irrigation was calculated according to Snyder (1992) where evaporation (*Kp*) is given by the equation below:

$$Kp = 0.0482 + 0.024 \ln(B) - 0.00376 \cdot V + 0.0045 \cdot R, \quad (2)$$

where *Kp* is the coefficient of the tank; *B* is the border area of vegetation around the tank (m); *V* is the speed of the wind at a height of 2 m (m.s⁻¹); *UR* is the mean relative humidity (%).

Kc rates followed FAO 56 (1998) in which 0.6 are used at the start; 1.15 at the middle and 0.8 at the end of the season.

Variables comprised number of leaves (NL); green (GPAS) and dry (GPAS) phytomass of the aerial segment; green (FRG) and dry (FRD) phytomass of the root; length of root (CR), diameter (DB) and length of bulb (LB); green (FVB) and dry (FSB) phytomass of the bulb.

Data collected underwent Anderson-Darling's normality tests and Bartlett's homogeneity tests of variance; analysis of regression was applied with Sigmasat and Minitab (BANZATTO; KRONKA, 1989), as it has done for (GABRIEL FILHO, et al., 2011).

In the case of mathematical models from a quadratic polynomial regression of the type $ax^2 + bx + c$, with significant p rate ($p < 0.05$) and $a < 0$, the maximum point and associated rate

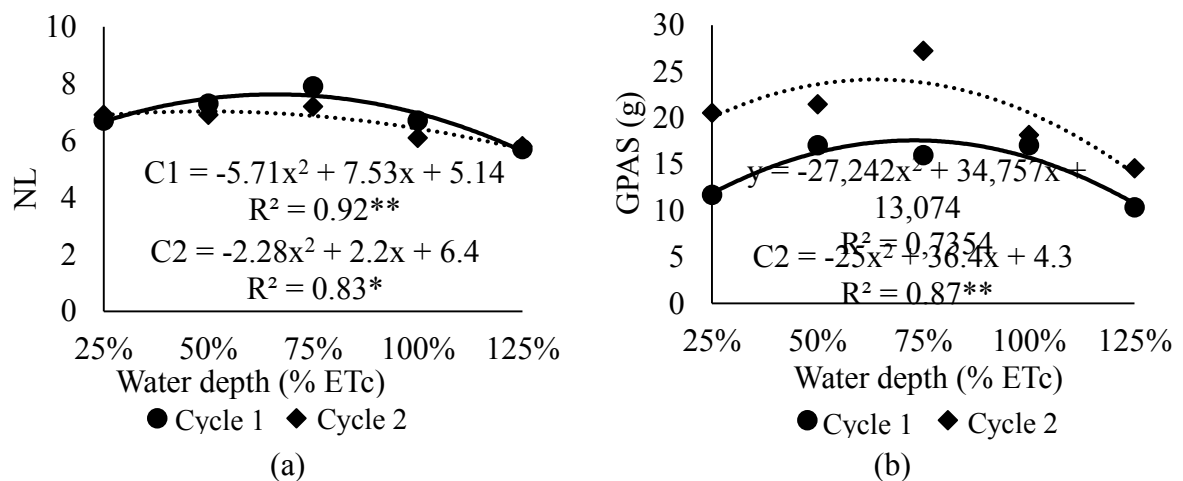
were calculated. They were equivalent to irrigation water depth and to the rate of the related variable in current assay. A second degree graph vertex formula (parable) was employed:

$$Vertex = \left(-\frac{b}{2a}, \frac{-b^2+4ac}{4a} \right).$$

5 RESULTS AND DISCUSSION

A negative effect on the number of leaves and green phytomass of the aerial segment occurred in radish crops under different water depths at a determined water reposition rate (Figure 1).

Figure 1. Number of leaves (NL) and green phytomass of the aerial segment (GPAS) for radish crop at different reposition depths (% ETc).



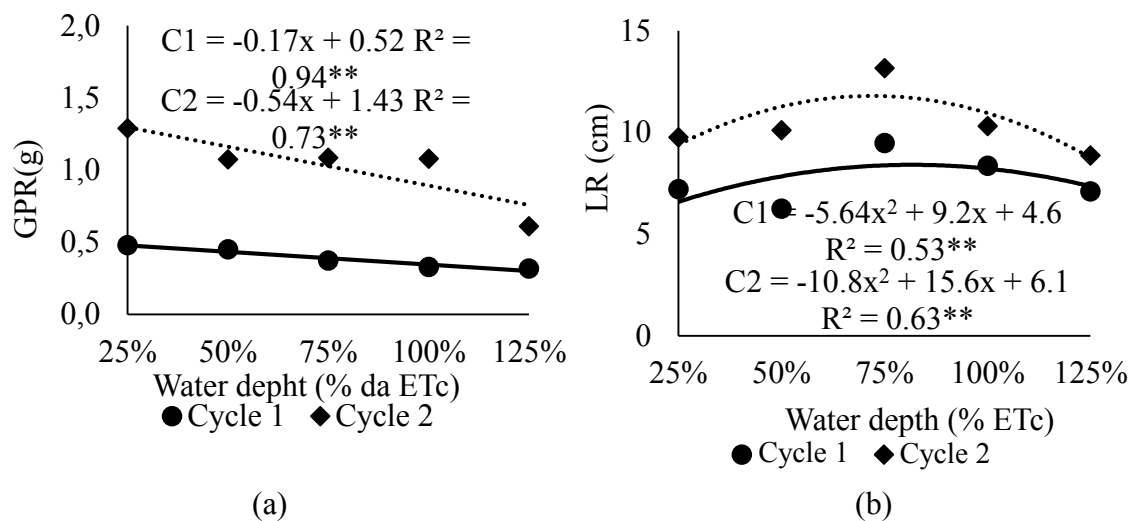
The number of leaves provided the best adjustment in a second degree polynomial model, with a similar behavior in the two cycles. The correlation between the factors was 0.92 and 0.83, respectively for the 1st and 2nd cycle. The negative effect of the reposition rates occurred with reposition rates of 65% ETc in the 1st cycle and 48% ETc in the 2nd cycle. Mean number of leaves was thus reduced.

The green phytomass of the aerial segment is directly related to the number of leaves. The same effect occurred as an adjustment of a second degree polynomial model. However, as a general rule, a decrease in mass occurred from the 1st to the 2nd cycle which may have been due to the mean decrease of temperature. The maximum accumulation of mass occurred close to 63% ETc in the 1st cycle, whereas rate was 72% ETc in the 2nd cycle, with correlation rates respectively at 0.83 and 0.87.

Pereira et al. (1999) reported a linear response for the accumulation of green phytomass of the aerial segment, which was also registered by Santos et al. (2014).

A negative effect in the increase of water depths occurred in the root development of radish (figure 2).

Figure 2. Green phytomass of the root (GPR) and length of root (LR) for radish crop with different water reposition depths (% ETc).

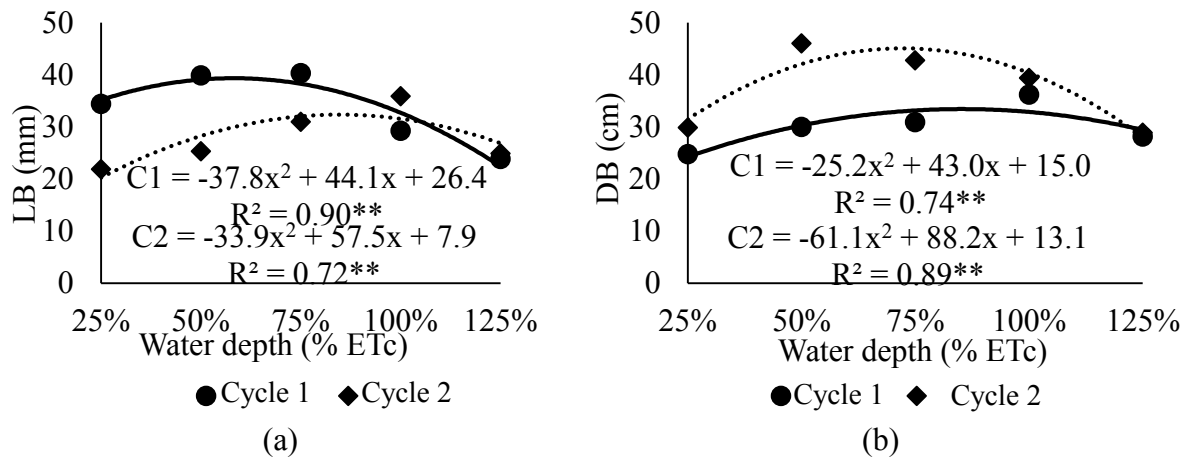


The root's green phytomass responds to the linear increase of the water depth when it is adjusted linearly to the model of the two cycles. Co-relationship is respectively 0.94 and 0.73 for the 1st and 2nd cycles. When the root's length was analyzed, adjustment occurred through a second degree polynomial model in the two cycles, with co-relationship at 0.53 and 0.63 respectively for the 1st and 2nd cycles. A greater development of the root system occurred due to the low availability of water in the soil for the lowest depths, with a linear decrease of mass as a result of the reposition rate measured by the green phytomass of the root (WAN; KANG, 2006; KANG; WAN, 2005). Maximum length of root occurred at depth 81% and 72% ETc respectively for the 1st and 2nd cycles.

Balkhair et al. (2014) reported that the root's length and green phytomass had a negative effect on the different rates of water reposition, corroborating results by Bregonci et al. (2008) and Minchinton et al. (2013). Isaac et al. (2009) registered that, since radish crops have a fast cycle, their root development is intensive and requires constant water availability at the best rates.

Water reposition for the development of bulbs had an inverse effect where, at a certain point, a decrease in length and diameter occurred.

Figure 3. Length (LB) and diameter (DB) of bulb for radish crops under different water reposition depths (% ETc).



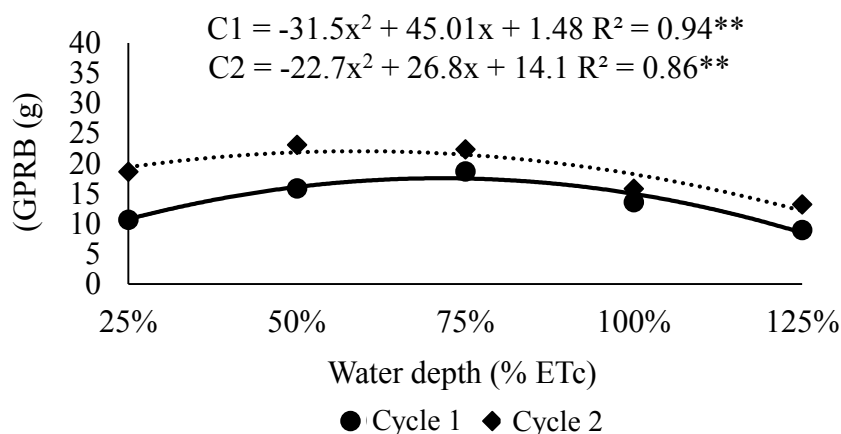
In the case of the variable bulb length, the effects of the two cycles were similar. Adjustment occurred through a second degree polynomial model, with correlation 0.90 and 0.72, respectively for the 1st and 2nd cycles. Great length occurred for water depth 58% in the 1st cycle and 84% for the 2nd cycle.

Bulb diameter adjusted to a second degree polynomial model in the two cycles, with correlation 0.74 and 0.89, respectively for the 1st and 2nd cycles. Equations showed that the greatest diameter occurred in the 1st cycle with a water reposition rate of 85% ETc and at 72% ETc in the 2nd cycle.

Santos et al. (2014) reported similar results. The effect of different water reposition rates for the bulb's length and diameter had a quadratic adjustment, corroborating results by Balkhair et al. (2014), Minchinton et al. (2013), Chatoo et al. (2013), Kang and Wan (2005), Karim et al. (2006) and Isaac et al. (2009).

The radish's bulb green phytomass had a negative effect with different water levels (Figure 4).

Figure 4. Green phytomass of radish bulb (GPRB) under different water reposition depths (% ETc).



Similar behavior occurred in the two cycles where the adjustment was reported by second degree polynomial models, with correlation rates at 0.94 and 0.86 for the 1st and 2nd

cycles, respectively. Water depths with the greatest phytomass occurred at the reposition rates of 71% and 60% ETc respectively for the 1st and 2nd cycles.

Results in current assay corroborate those by Minchinton et al. (2013), Chattoo et al. (2013) and Kang and Wan (2005). On the other hand, Slomp et al. (2011) did not report any significant differences in productivity in Erechim, RS, Brazil, in the same season of the year. Pereira et al. (1999) registered that production responded linearly to the climatic conditions of Lavras MG Brazil, due to the soil's water availability.

It should be underscored that several other crops, such as lettuce (PUTTI et al., 2015), carrot (LIMA JUNIOR et al., 2012), sunflower (SILVA et al., 2011), sugarcane (VIEIRA et al., 2014), red pepper (ARAGÃO et al., 2011) and sweet potato (MANTOVANI et al., 2013) provided a quadratic response to different reposition rates.

6 CONCLUSIONS

Radish crops provide a quadratic response for all the variables analyzed and in the two cycles. A lower rate of the bulb's green phytomass has been highlighted in the first cycle, probably due to a mean lower temperature during the cycle.

Results also show that a 100% ETc reposition is not necessary in the Botucatu region to obtain the best results in production. Water reposition depth ranging between 60% and 80% ETc is recommended.

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