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Assessment of improving irrigation efficiency for tomatoes planted in greenhouses in Lam Dong Province, Vietnam

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ABSTRACT

This study was conducted to investigate the developmental processes of tomato plants in greenhouses covered with polyethene agricultural film that applied a smart irrigation system. The study tested applying different irrigation water levels (IWLs) of 60, 80, 100, and 120% of crop evapotranspiration (ETc). Based on the findings for the tomato rows sampled to collect information about leaf area, biomass, and yield, maximal growth of tomatoes varied from 80 to 90 days after transplanting (DAT) for all IWLs. Among the applied IWLs, approximately 80% of ETc was recorded as the most appropriate for the crop growth rate (CGR), leaf area index (LAI), and yield, while the IWLs with 60%, 100%, and 120% of ETc also gave an equivalent output. The results of this work can provide useful information for farmers to make the right decisions about the amount of irrigation water to use.

Key Words: Drip irrigation, greenhouse, tomato, leaf area, yield

The tomato is the second most important vegetable after the potato (Gad and Hassan, 2013; Oke and Ojediran, 2015) and it faces high risks due to pests, diseases, and local weather conditions(Gad and Hassan, 2013; Monte *et al.,* 2013). According to Oke and Ojediran (2015), the tomato plant is very sensitive to water stress; it therefore, requires the availability of irrigation water throughout its life cycle for good productivity. Although drip irrigation has a high initial cost, it is considered the best technique to provide water to vegetables(Oke and Ojediran, 2015; Harmanto *et al.,* 2005). According to Al-Omran *et al.* (2010), about 70% of global freshwater resources are used for irrigation operations, leading to a lack of irrigation water and a need to find suitable solutions to replace traditional farming and irrigation practices. For modern agriculture, irrigation water is one of the most important factors to ensure sustainable and profitable production; it must be provided in adequate amounts (Singh *et al.,* 2019; Lee and Dang, 2019; Kumar, 2017) and at appropriate times(Casanova *et al.,* 2009; Naidu and Majhir, 2019).In the Don Duong cultivation region, tomatoes are planted all year round, with a growing area of up to 22,000 ha, and 70% of the growing area applies the drip irrigation method in greenhouses (Genova *et al.,* 2013; Harmanto *et al.,* 2005). Drip irrigation in greenhouses has become very popular in the Da Lat vegetable-growing region,which offers the most profitable business opportunities that have been applied in recent decades. For these reasons, the aim of this study was to evaluate the effect of established IWLs and define the optimal amount of irrigation water through drip irrigation under greenhouse conditions.

MATERIALS AND METHODS

Experimental setup

An experiment was designed for applying the drip irrigation method in greenhouses between 11°41'24" – 11o41'50" N and 108°33'48" –108°37'21"E. The weather in the study area is mild and cool all year round, with an average air temperature ranging from 18 to 25°C. The annual sunshine is up to 2500 hours, which is suitable for agricultural activities and especially for tomato plants.The greenhouse was designed to be 140 m long and 10 m wide, with the roof covered by a polyethene agricultural curtain. The control unit of the drip system consisted of a 2000-liter tank, screen filter, main, sub-mains, laterals, drippers, flow meters, control valves, and other accessories required for drip irrigation. The experimental space was 1400 m^2 with 50,000 tomato cuttings planted 0.3 m apart in rows 1.2 m apart. The trial was conducted with 57.8% sand, 30.4% silt, and 11.8% clay, in the surface soil layer (0.2 m deep),with the soil water content at saturation 38 vol %, field capacity 15 vol %, permanent wilting point 7.0 vol %, and saturated

Table 1: Measured results of number and weight of fruit tomatoes with irrigation water levels

Irrigation water levels	Number of fruit tomatoes	Fruit tomato weight (gram)		
		Mean	Maximum	Minimum
MDI (60% ETc)	59	62.5	77.2	50.0
SDI (80% ETc)	79	72.7	81.0	50.2
OI (100% ETc)	67	68.7	78.5	50.0
FI (120% ETc)	65	68.6	75.6	52.2

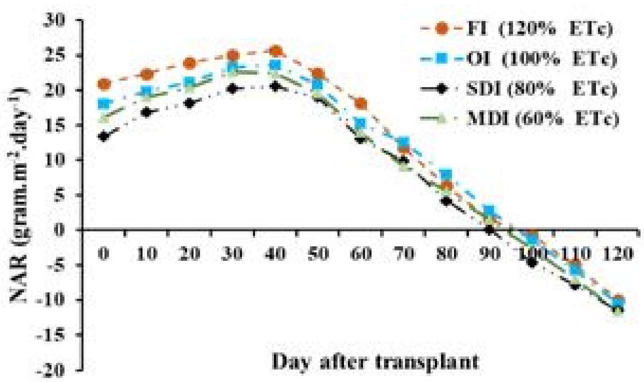

Fig.1: Net assimilation rate of tomato samples corresponding to different IWLs

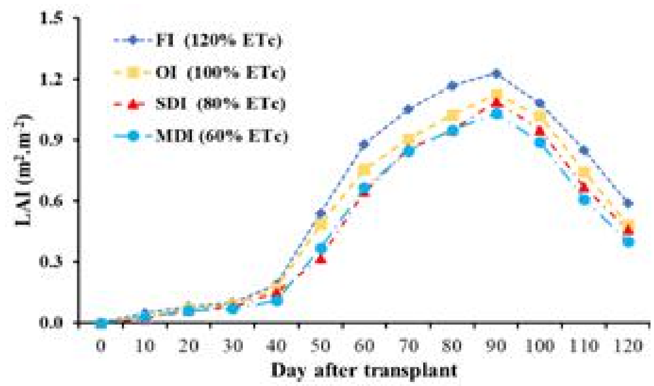

Fig.2: The leaf area index of the tomato crop with applied different IWLs

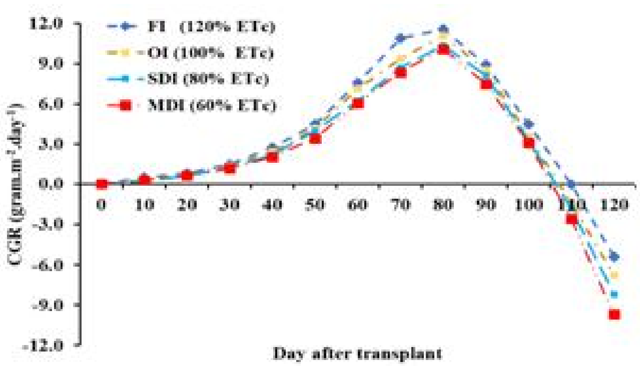

Fig.3: Crop growth rate (CGR) corresponding to different irrigation water levels

hydraulic conductivity 2200 mm.day^{-1}. Four IWLs were applied, including full irrigation (FI), which corresponded to 100% of ETc; over-irrigation (OI), 120% of ETc; slight deficit irrigation (SDI), 80% of ETc; and moderate deficit irrigation (MDI), 60% of ETc. To study tomato growth processes based on the different IWLs applied, leaf weight and tomato fruits were collected during the tomato cycle from 15 to 120 DAT. The samples were randomly collected to evaluate growth rate from each plot to determine the change in the canopy and fruit weight over time. Samples were then brought to the laboratory, after which they were taken to the forced ventilation oven at 90ºC to pre-dry until they reached a consistent amount of dry matter.

Crop growth rate determination

To adjust growth data over time, an exponential polynomial was widely applied to study the crop growth rate (Olaniyi *et al.,* 2010; Monte *et al.,* 2013).

The exponential polynomial was determined as follows:

$$Y = e^{(a+bx+cx^2)} \quad (1)$$

where Y is total dry matter (TDM) and leaf area (LA); x is days after transplanting (DAT); and a, b, and c are the constants to adjust the second-degree polynomial.

Net assimilation rate (NAR) is defined as the balance between the material produced by photosynthesis and that lost by respiration. In most studies, NAR is often measured in grams of phytomass per square meter of leaves per day. The NAR was given as follows:

$$NAR = \frac{\{[b+2cx]/[e^{(a+bx+cx^2)}]\}}{[e^{(a'+b'x+c'x^2)}]} \quad (2)$$

where a', b', and c' are the constants to adjust the polynomial regression of the second degree of the Napierian logarithm of leaf area.

Leaf area index (LAI) is defined by the relationship between plants' LA and surface area (Monte *et al.,* 2013).

LAI was defined based on dividing the mean leaf area of one plant, in square meters,by the surface area occupied by the plant, in square meters, while CGR was defined as a physiological variable that indicates the quantity of phytomass accumulated per unit of area under cultivation during a period and was measured in grams per square meter of ground per day.

RESULTS AND DISCUSSION

During the experiment,from when tomato cuttings were planted until the tomatoes were harvested, the observed ETc in the greenhouse was about 392.9 mm, which implies the necessity of irrigation for evaporated water availability. Therefore, a certain amount of irrigation water is needed to provide and not negatively impact the growing processes and quality of tomatoes. The calculated results of the NAR for the tomato crop are presented in Fig.1.

Fig.1 shows that a distinction was found between the different IWLs from the first to the 40^{th} DAT, whereas a similar NAR was also recorded from the 40^{th} to 120^{th} DAT. The highest value of the NAR is approximately 20.8–25.7 $g.m^{-2}.day^{-1}$ for applying IWLs at 40 DAT.

An initial increase in LAI was recorded with all treatments shown, until maximum values from 1.02 to 1.23 $m^2.m^{-2}$were reached around 90 DAT; then, LAI decreased to minima (varied from 0.40 to 0.59 m2.m-2) around 120 DAT (Fig.2). The LAI peak values found by Monte *et al.* (2013) (approximately 1.20) were similar to those in this experimental case.

Similarly, the crop growth rate (CGR) at different IWLs (Fig.3) shows that CGR was the lowest (less than 3.0 $g.m^2.day^{-1}$) in theinitial stage up to the 40^{th} DAT. Then, it increased gradually from 10.1 to 11.6 $g.m^{-2}.day^{-1}$ around 85 DAT. Often, a decreasing trend was recorded in all IWL treatments from 90 DAT until the end of the cycle (120 days). Monte *et al.* (2013) also reported similar trends.

The results of tomato fruit weight corresponding to IWLs show that for moderate deficit irrigation (60% ETc), the number of tomato fruits were 59, and the maximum, mean, and minimum weights were 73.2, 62.5, and 50.0 g, respectively (Table 1). The number of tomato fruits was low and fruit weight was small perhaps because the amount of irrigation water did not meet the growing needs of the tomato plants.

Zegbe Domíngues *et al.,* (2003) stated that IWL of 50% of ETc resulted in lighter tomato fruits. For SDI (80% ETc), the number of tomato fruits was up to 79, and the maximum, mean, and minimum weights obtained were 81.0, 72.7, and 50.2 g, respectively. These results are similar to those of Marouelli and Silva (2006),who found a higher tomato yield when 75% of ETc was provided. Otherwise, for the higher IWLs, the number of tomato fruits only reached approximately 65–67, and the mean weight of tomato fruits reached 68.5 g (Table 1). This may be due to the fact that the higher vegetative growth of the aerial part led to higher humidity inside the plant canopy, favoring the emergence of diseases and injuries caused by insects.

CONCLUSION

Evaluation of growth processes and tomato yield applied in the Dai Tho experimental garden in Lam Dong Province, Vietnam, was conducted based on different irrigation water levels. The results showed that the maximal growth of Rita tomatoes was recorded around 80 to 90 DAT for all irrigation water levels. Based on the findings from this work, among the applied irrigation water levels, slight deficit irrigation of 80% of ETc was the most appropriate for CGR, LAI, and tomato fruit yield. The results also showed that Rita tomatoes reached theirbest CGR at 85 DAT, compared to 75 DAT for other varieties.

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