Research article

Effect of Drip-Fertigation Intervals and Hand-Watering on Tomato Growth and Yield

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Abstract Irrigation is vital to increase the crop yield or crop productivity. The research was conducted in Royal University of Agriculture (RUA), Phnom Penh, Cambodia, in order to compare the influence of different irrigation intervals and methods on plant development and yield of tomatoes. As replicated three times, the treatments designed in the experiment layout included daily drip irrigation without fertilizer (T_0), daily drip fertigation (T_1), drip fertigation in every two days (T_2), and (T_3) daily hand-watering by applying the same amount of fertilizer before planting. In the study, the quantity of water applied in each treatment was equal to 5.22 m^3, or 20.88 m^3 as a whole. The chemical fertilizers, 46-0-0 and 20-20-15, were only applied for three treatments (T_1, T_2 and T_3), and the total amount of fertilizers used was 7,662 g, or 2,554 g for each treatment, whereas T_0 was not added with any fertilizer. The result illustrates that T_0, T_1, T_2 and T_3 yielded 10.4 t/ha, 42.25 t/ha, 27.45 t/ha and 29.95 t/ha, respectively. The average numbers of tomatoes in each treatment were 8, 22, 18 and 17 fruits per stem for T_0, T_1, T_2 and T_3 respectively. Moreover, the stem growth rate and diameter growth rate was 63.36 cm and 9.38 mm (T_0), 84.81 cm and 12.03 mm (T_1), 75.96 cm and 10.50 mm (T_2) and 79.33 cm and 11.10 mm (T_3). Based on the experiment, it could be concluded that the application of water and nutrients to meet the crop needs without interrupting irrigation, as seen in T_1, had optimal effects on the growth and yield of tomatoes. Therefore, growers should irrigate crops by focusing on the real crop needs for water and nutrient and should choose drip-fertigation methods, which offers multiple benefits such as providing water effectively, reducing erosion and loss of nutrients in the soil, making the ground slower in density, reducing grass, saving time and water and increasing crop growth and yield.

Keywords drip-fertigation, hand-watering, effect, tomatoes, growth, yield, fertilizer

INTRODUCTION

Supplying an adequate amount of water is very important for plant growth; especially, when rainfall is not sufficient, the plants must receive additional water from irrigation. There are various irrigation methods that can be used to supply water to the plants. Each irrigation method has its own advantages and disadvantages, so these should be taken into account when choosing the irrigation method which is best suited to the local circumstances. A simple irrigation method is to bring water from the source of supply, e.g. a well, to each plant with a bucket or a watering can (FAO, 2001). The drip irrigation system is one of the most effective irrigation systems which can controll the water supply to the rootzone of the crops before the water is evaporated or run-off. This irrigation method is able to save water and time, providing a certain amount of water to suit crop requirements. However, water content in the soil must be taken into consideration before supplying the irrigation water as non-uniformity of the soil water content could lead to different crop productions (Hargreaves et al., 1998). Drip irrigation is currently a suitable irrigation method for reducing the impact from drought to the agricultural productivities. It can diversify and maximize crop productions through effective water management (GDA, 2016). Moreover, in the irrigation process, proper irrigation interval is very important to strengthen the effective water use and crop productivities by providing a particular amount of water based on the crop water need (Ismail et al., 2009).

Tomato is one of the most popular vegetable crop which is widely grown in the world. It belongs to the genus *Lycopersicon* which is grown for its edible fruit (Jones, 1990). The fruit contains high levels of vitamin A, B, C, E and nicotinic acid and is therefore an important source of vitamins. On the average, the fruit contains 8% protein, 34% minerals (mainly K + Ca + and P), 48% total soluble sugars, 9% citric acid and 0.5% vitamin. Tomato has a higher acreage than any vegetable crop in the world and it requires a high water potential for both optimal vegetative and reproductive development stages (Jones, 1990). The crop tolerates fairly acid soil and liming is unnecessary unless the soil pH is below 5. Well drained sandy loam is preferred by the crop. No horticultural crop has received more attention and detailed study than tomato (Lycopersicon esculentum). Water deficit decreases tomato growth, yield and quality (Byari and Al-Sayed, 1999). Therefore, proper water management is vital for sustainable crop production. In Cambodia, drip irrigation system is mainly used for fruit tree plantations and some vegetable cultivation. Tomato is one of the crops which is suitable for drip irrigation to produce a better yield (Sy, 2004).

OBJECTIVE

The research aims to compare the influence of different drip fertigation intervals and irrigation methods with the diversed application of fertilizers on plant development and yield of tomatoes.

MATERIALS AND METHOD

Study area: The study was carried out at the Faculty of Agricultural Engineering, Royal University of Agriculture (RUA), which is located at latitude of $11^0$30'40.91" and longitude of $104^0$54'01.24" from January 01, 2016 to April 30, 2016. Soil samples at the study area were taken to the laboratory to determine pH = 7.10, Organic matter (OM) = 0.85%, Ec = 137.00 $\mu S\ cm^{-1}$, Nitrogen (N) = 530.00 mg/kg, Phosphorus (P) = 109.60 mg/kg, and Potassium (K) = 180.00 mg/kg. Flow rate and operating pressure before and after irrigation were measured with flow meters and a pressure gauge. The amount of water and fertilizers were applied equally in all treatments/plots. The total amount of irrigated water was 20.88 m^3, from which each treatment consumed 5.22 m^3. The chemical fertilizers, 46-0-0 and 20-20-15, were only applied for three treatments (T_2, T_3 and T_4), and the total amount of fertilizers used was 7,662 g, or 2,554 g for each treatment, whereas the control treatment (T_0) was not tested with any fertilizer.

Experimental design: A Randomized Complete Block Design (RCBD) was applied. There were 12 plots and each plot size was 1 x 2.8 m. There were two rows in each plot with plant spacing of 0.4 x 0.8 m and plant population per plot was 16 plants. The experimental plots were divided into 4 treatments as the following:

- Treatment T_0 = Drip irrigation with no application of fertilizer (Control treatment)
- Treatment T_1 = Drip irrigation with daily application of fertilizers
- Treatment T_2 = Drip irrigation with every two days application of fertilizers
- Treatment T_3 = Daily hand-watering with application of fertilizer at the land preparation

All treatments were irrigated in the morning and evening when the irrigation schedules were required.

Sample collection: Some parameters selected to analyze plant development/growth and yield were collected during the experiment such as blooming period, stem diameter, stem height, and yield including good and bad yields of the fruits.

Statistical analysis: Analysis of Variance (ANOVA) was conducted on the data using XLSTAT statistical package. The means were compared by applying Least Significant Difference (LSD) at test 5% probability level.

RESULTS AND DISCUSSION

Blooming 50% and 100% of Tomatoes

The duration of 50% blooming was counted when the 6 plants per plot flowered and the period of 100% blooming was also counted when all plants reached full flowering..

Table 1 Effect of irrigation method on blooming period of tomatoes

Treatment	50% Blooming	100% Blooming
Treatment T_0	56.33a	63.66a
Treatment T_1	47.33b	50.66b
Treatment T_2	53.66ab	58.33ab
Treatment T_3	50.00ab	54.33ab
F-test probability	0.03	0.03
CV (%)	3.50	2.70

Note: Different used alphabets indicate measurement is significantly different ($p<0.05$) from each other

Table 1 shows that the average blooming period of tomato plants in each treatment was significantly different. For the number of 50% blooming days, T_1 could produce the flowers within 47 days, which was faster compared to the other treatments. Meanwhile, T_2 and T_3 took 52 days, whereas 56-day flowering period was recorded in T_0, and this period was the longest and differed significantly with T_1. Aside from these, the tomato plants took 51-64 days in order to produce 100% blooming period. Based on the observation, the 100% blooming period were the same as the 50% blooming period did. The different irrigation system could affect the blooming period of the tomatoes. T_1 had quick flowering, but T_2 had slower flowering, 6 days for 50% flowering and 7 days for 100% flowering. Similarly, the research conducted by (Sionit, 1977) and (Kramer, 1983) on soybean found that if we retard the water to the plants, it might prolong the blooming period but also cause more flower drop.

Stem Diameter and Height

Figures 1 and 2 illustrate the stem growth rate (stem height) and diameter growth rate (stem diameter) of all treatments: T_0, T_1, T_2 and T_3 which there were 63.36 cm and 9.38 mm, 84.81 cm and 12.03 mm, 75.96 cm and 10.50 mm and 79.33 cm and 11.10 mm, respectively. When the tomato plants were 30-40 days old (5 days after applying fertilizer), each stem diameter and height in all treatments were not much significantly different. However, after 25 days of fertilizer application, the stem diameters and height were steeply increased because it was the development stage of the crop, but the stem diameters and height increased slightly at the age of 70-90 days (flowering stage), which was the mid-season of the crops. Moreover, irrigation systems highly affected the stem diameter and height of tomato crops, as shown in figures below. After 45 days of planting, the stem diameter and height of tomatoes in T_1

were the greatest in comparison to the other treatments. This illustrates that the development of plant diameter is parallel with the increase in stem height if the adequate amount of water and fertilizers are applied regularly. Moreover, the differences in average stem diameter measured in each treatment remained significant until the end of the harvesting time. The stem diameter grew rapidly in the development stage, but from the flowering stage till the end of harvesting time, its growth was retarded.

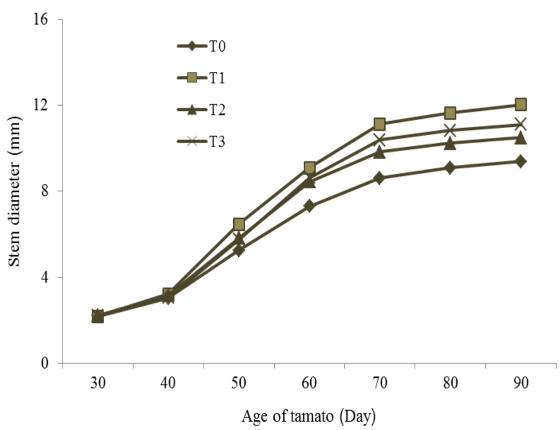

Fig. 1 Effect of irrigation on stem diameter

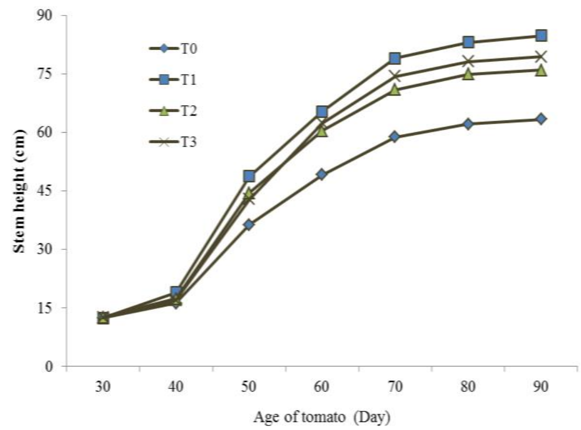

Fig. 2 Effect of irrigation on stem height

Having compared the average stem heights in all treatments, the findings show that T_2 had greater stem height than T_3, but from day 60, the plants grown in T_3 was 2 cm higher than in T_2. Cevik et al., (1996) and Yazar et al., (1991) showed that insufficient irrigation scheduling based on the crop water requirements can reduce partly the development of plant growth. Moreover, Srinivas et al., (1989) carried out the research on plant water relations, canopy temperature, yield and water-use efficiency of water melon Citrullus lanatus indicates that while the plants cannot be able to intake enough water, the moisture at the root zone is reduced, resulting in retardation of the plant development.

Yield of Tomatoes

a. Number of fruits: The count of tomato fruits per stem was done at the harvesting time by counting the numbers of fruits out of 6 tomato stems in each treatment. Each fruit was identified and totaled considerately. The average numbers of tomatoes in each treatment were 8, 22, 18 and 17 fruits per stem for T_0, T_1, T_2 and T_3 respectively. These tomato fruits per stem collected from each treatment were affected by different irrigation as it was indicated in the Fig. 3 that T_1 could yield 22 fruits/stem, compared to other treatments.

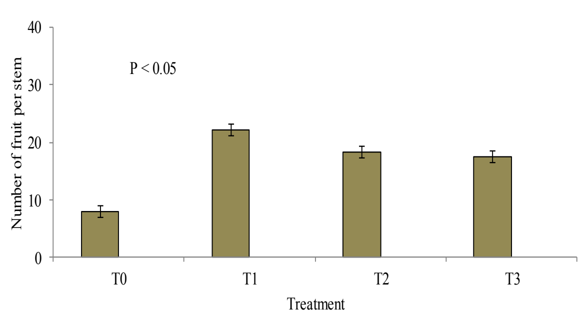

Fig. 3 Effect of irrigation on number of fruits

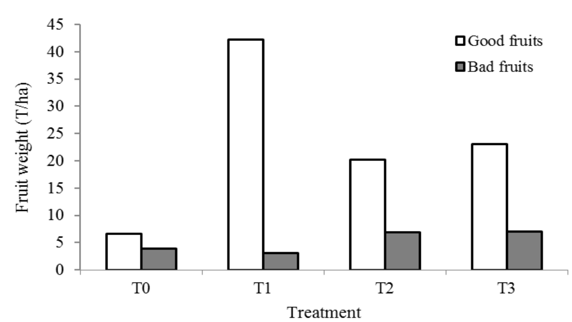

Fig. 4 Effect of irrigation on fruit yields

However, there was no significant difference in tomato fruits per stem between T_2 and T_3, while the T_0 yielded the lowest numbers of fruits which was only 8 fruits/stem and it was significantly different in comparison to the other three Treatments. Candido et al., (1999) studied the effect of irrigation regime on yield and quality of processing tomato cultivars found that inadequate application of water could retard the plant development and fruit size. Moreover, low soil moisture can cause irregularity to plant physics as a result of dropping flowers and producing less flowers. Furthermore, Ponce et al., (1996) indicated that all crops with stress problems may encounter stunted growth, lessening flowers to produce the fruit set.

b. Total tomato yield: Total tomato yield (Fig. 4) included good and bad yields of fruits which were collected from all treatments. The Table 2 below illustrates the total yield of tomatoes during the experiment, and the result indicates that different irrigation methods and irrigation intervals could dramatically affect the yield of tomatoes.

Table 2 Effect of irrigation method and interval on tomato yield (t/ha)

Irrigation method	Tomatoes yield (t/ha)	SE
Treatment T_0	10.40c	0.08
Treatment T_1	42.25a	0.56
Treatment T_2	27.45b	0.31
Treatment T_3	29.95b	0.28
F-test probability	74.59	
CV (%)	1.79	

Note: Different used alphabets indicate measurement is significantly different ($p<0.05$) from each other

The results show that T_0, T_1, T_2 and T_3 yielded 10.4 t/ha, 42.25 t/ha, 27.45 t/ha and 29.95 t/ha, respectively. The highest yield of tomatoes (42.25 t/ha) obtained from the experiment was the T_1, whereas the lowest yield (10.40 t/ha) obtained was the T_0, while the T_2 could produce the same yield as the T_3. Zhai, et al., (2010) studied the effects of drip irrigation regimes on tomato fruit yield and water use efficiency found that the more the irrigation interval is prolonged or not often irrigated, the lower the yield would be. Moreover, the other research findings of Pasternak, et al., (1995) also indicated that drip irrigation systems with daily fertilizer application provide higher yields, compared to the same drip irrigation method with the application of fertilizer for 2-3 days per time.

CONCLUSION

Based on the experiment, it could be concluded that the drip-fertigation system is an effective irrigation method to promote tomato growth and yield and it is easy to control the amount of fertilizer and water applied to the crops. The application of water and nutrients to the crop needs without interrupting irrigation as in T_1 had optimal effects on growth and yield of tomatoes while it highly affected not only the stem diameter, but also the height of tomatoes which after 45 days of planting, were the greatest in comparison to the T_0, T_2 and T_3. Moreover, the tomato fruits per stem collected from each treatment were also affected by different irrigation methods as T_1 could yield 22 fruits/stem. Furthermore, the highest yield, 45.30 t/ha, could be obtained, if compared to the other Treatments and the average yield of bad fruit was only 3.05 t/ha as the yield of T_3 was 29.95 t/ha and the yield of its bad fruit was 6.9 t/ha. Therefore, growers should irrigate crops by focusing on the real needs of the crop requirement and should choose drip-fertigation methods, which offers multiple benefits such as providing water effectively, reducing erosion and loss of nutrients in the soil, making the ground slower in density, reducing grass, saving time and water and increasing crop growth and yield. Thus, farmers should apply this irrigation technique for their own cultivations and stop using the conventional hand-watering as it may waste water and obtain low yields.

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