J. Agric. Food. Tech., 2(1) 16-20, 2012

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ISSN 2090 – 424X
Journal of Agriculture and Food Technology
www.textroad.com

Effect of Water Management on Yield of Tomato Plant (*Lycopersicon esculentum* Mill)

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ABSTRACT

A green house experiment was conducted to study the effect of water management on the growth and yield of tomato (*Lycopersicon esculentum* Mill.) plant. The treatments included the amount of irrigated water and the growth phase at which the watering was done. The amount water addition was calculated based on the percentage of crop factor (kc) to evapotranspiration, and the combination treatments were: (1) the amount of water addition the same with the evapotranspiration throughout the growth of tomato crop, 100% kc; (2) 100% kc at vegetative growth and 70% kc at generative growth; (3) 70% kc at vegetative and 100% kc at generative growth; (4) 70% kc at vegetative and 70% kc at generative growth: (5)) 100% kc at vegetative and 40% kc at generative growth; (6) 40% kc at vegetative growth and 100% kc at generative growth; and (7) 40% kc at vegetative and 40% kc at generative growth. The experimental results showed that addition of water at the combination level of 70% kc at vegetative and 100% kc t generative growth reduced the number of fruit yield, the number of healthy fruits and the number of marketable fruits. The addition of water at a combination level of 40% kc at vegetative growth and 40% kc at generative growth decreased plant height, leaf number and total fruit yield. The addition of water at a combination level of either 100% kc at vegetative growth and 70% kc generative growth or 40% kc at vegetative growth and at 100% kc generative growth was enough to produce a high yield (1307 g/plant and 1320 g/plant) which were not significantly different with that of the plants had no suffer from water shortage (100 % kc)..
Keywords: water stress, irrigation, crop factor, evapotranspiration

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the important horticultural plants which can be consumed as either vegetable or fruit crops. In line with increasing population and income, the demand for tomato in Indonesia increase from year to year. However, tomato production is still low with average yield of 15.27 t/ha [1]. This is far below the potential yield of tomato crop which can reach 60 t/ha [2]. In Indonesia, mostly tomato is planted in upland area; on the other side, tomato is known as the crop that sensitive to water stress [3]. Therefore, it is suggested that one of the reason for the low yield of tomato crops in Indonesia was the inadequate of water supply during tomato growth.

As far as there no other limiting factor, any crop will growth normally and produce maximum yield if there is enough water availability. Therefore, on upland agriculture water supply is an important agronomic practice to obtain a high yield. The most common practice in water management is to give back the water loss with irrigation water. In upland area, water is very valuable natural resources, and therefore it should be utilized efficiently. The supply of water continuously to compensate water loss might be not necessary, and has been omitted in water management practices. It would be more efficient to supply water at a period in which the crop need enough water, or in which the lack of water will result in the worst effect. Usually damaging effect of water stress in the plant tissue is very visible in the periods of rapid growth, and based on this phenomenon some workers suggest that there are certain growth periods in which the crops development is very sensitive to water stress [4].

Water stress on vegetative phase tends to reduce the dry weight of the larger canopy, but increase the number of bunches of flowers, the number of bunches of fruit and fruit number. Stress that occurs at the beginning of growth allows the plants to recover more quickly, so in the end will have no effect on reducing the weight of the fruit harvest [5]. Some workers have found that for tomato plants, the period of flower formation and fruit enlargement are very sensitive to water stress [6]. The response, however, depends on the level of stress. Moderate water stress occurs before flowering can accelerate flowering and fruit formation. Severe water stress slows down the rate of flower initiation, inhibit fruit formation, and hence reduce the number of flowers and fruits [7]. Water stress during the phase of fruit enlargement is causing blossom end-

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rot disease [8]. In their experiment on *Capsicum annuum* L., Koesriharti *et al*. [9] showed that the number of harvested fruit per plant varied depends on the level of water stress and the growth phase at which the water stress occurred. Supply of irrigation water at 40% field capacity from planting to flowering phase, and from flowering phase until fruit formation phase did not influence the number of harvested fruit. However, water supply at 60% or even 40% field capacity during the fruit formation phase until harvesting time decreased the amount of harvested fruit up to 37.90% (compared to the control treatment).
The objective of the experiment described here was to explore the method of increasing the efficiency of water irrigation for tomato growing. This was done by arranging water supply at the period where the growth of tomato crops is very sensitive to water shortage.

MATERIALS AND METHODS

A green house experiment was done at Pasuruan, East Java, Indonesia (at elevation of 1200 m above sea level, $7^0$59' South, 110^0 East). The experiment was carried out from May to October 2009, during which the average daily temperature are 20-34 ^{0}C and relative humidity are 70-90%.

The experimental treatment was the amount of irrigated water and growth phase. The amount of irrigated water was determined based on the crop factor (kc) multiplied with daily potential evapotranspiration (ETo). The kc factor employed was the crop factor (kc) was defined as the ratio of the maximum evapotranspiration (ETm) to the potential evapotranspiration (ETo). The experimental treatments were: {1} the amount of water addition the same with the evapotranspiration throughout the growth of tomato crop, 100% kc; {2} 100% kc at vegetative growth and 70% kc at generative growth; (3) 70% kc at vegetative growth and 100% kc at generative growth; (4) 70% kc through out the tomato growth: (5)) 100% kc at vegetative growth and 40% kc at generative growth; (6) 40% kc at vegetative growth and 100% kc at generative growth; and (7) 40% through out the tomato growth. These 7 treatments were arranged in Completed Randomized Design with 3 replications.

Tomato plant, Marta cultivar, was grown in a plastic poly bag of 25 cm diameter and 30 cm height with capacity of about 15 kg growth medium. The poly bag was filled with 10 kg growth medium containing a mixture of soil and cattle manure with a ratio of 3:1. The plant was fertilized with 2.5 g plant^{-1} ammonium sulphate; 5 g plant^{-1} urea; 10 g plant^{-1} super phosphate; and 10 g plant^{-1} K Cl. Ammonium sulphate and superphosphate were given t one week after planting, and urea and K Cl were given at 21 and 35 days after planting. In addition the plat was sprayed with Calcium 80 WP (5 g L^{-1}) at 52, 59 and 66 days after planting. To control plant pest and diseases, the plant was sprayed with insecticide which active ingredient of Karbofuran 3% and Deltamethrin 25 g L^{-1}; and with fungicide which active ingredient of propineb 70%.

Potential evaporation was measured with open pan evaporation. Crop factor (kc) varies depend on the growth phase, in this study the kc employed was (10): kc = 0.75 during the development phase (25 days), kc = 1.15 during the maximum vegetative growth (40 days), and kc = 0.85 during the generative growth (60 days). Water addition was done every day.

The data collected include: plant height, leaf number, the date of flowering and fruiting, number of flowers, number of fruits, and the date of the first harvesting. The harvested fruit was parted in: healthy fruit; blossom end-rot fruit; and marketable fruit.

The data were analyzed by ANOVA, and if there was a significant difference, the data was further compared with LSD test at 5% level.

RESULTS AND DISCUSSION

The growth of tomatoes plants was significantly influence by the amount of applied water and the growth phase at which the water applied (Table 1). Reduce the amount of water supply up to 70% kc during vegetative growth did not significantly influenced plant height, however, it significantly decreased leaf number (at 63 days measurement). The deleterious effects of water stress in plants are usually most pronounced in tissues and organs which are in the stages of most rapid growth and development [10]. This implies that there are periods of growth in plants when there is relatively greater or lesser sensitivity to water stress. The result in Table 1 show that the tomato plants watered with 100 kc at vegetative phase and 40 % at generative phase had the lower of plant height and leaf number compared to that of 40 kc at vegetative phase and 100 % at generative phase. This result indicated that generative growth phase was more sensitive to water stress.

Table 1 Plant height and leaf number of tomato plant at various water management practices

Treatment	42 days		63 days	
	Plant height (cm)	Leaf number	Plant height (cm)	Leaf number
1. Water added equal to ETm through out tomato growth	119.60 d	28.27 c	146.95 c	37.67 d
2. 100% kc at vegetative growth; 70% kc at generative growth	113.47 cd	26.13 ab	136.00 bc	34.93 c
3. 70% kc at vegetative growth; 100% kc at generative growth	109.80 abc	26.47 b	127.73 ab	34.67 c
4. 70% kc through out the tomato growth	110.67 abc	26.47 b	122.60 ab	34.20 bc
5. 100% kc at vegetative growth; 40 kc at generative growth	112.27 bcd	26.93 bc	123.23 ab	32.13 ab
6. 40% kc at vegetative growth; 100% kc at generative growth	105.70 ab	26.00 ab	134.58 bc	34.60 c
7. 40% kc through out the tomato growth	103.66 a	24.67 a	117.67 a	31.07 a
LSD 5%	**7.42**	**1.58**	**16.50**	**2.28**

The numbers followed by the same letters in the same column is significantly different (p = 0.05).
NS: not significantly different

The date of flowering, fruiting, and the first harvesting was not significantly influenced by the system of water management (Table 2). It seems that time of flowering, fruiting and harvesting tomato plants are determined by the genetic rather than environmental factor. In this experiment tomato plants start to flower at 29 -32 days after planting, and fruit formation occurred at 43 -45 days after planting. The first harvest varied from 66 to 70 days after planting can be harvested at number of fruit crops

Table 2The date of flowering, fruiting, and the first harvest on tomato plant at various water management systems

Treatments	Date of flowering (days after planting)	Date of fruiting (days after planting)	Date of the first harvest (days after planting)
Water added equal to ETm through out the tomato growth	30.00	43.67	68.80
100% kc at vegetative growth and 70% kc at generative growth	31.67	43.67	69.60
70% kc at vegetative growth and 100% kc at generative growth	29.33	44.00	67.33
70% kc through out the tomato growth:	29.33	44.00	66.87
100% kc at vegetative growth and 40% kc at generative growth	29.00	44.67	66.33
40% kc at vegetative growth and 100% kc at generative growth	31.00	44.33	68.93
40% kc through out the tomato growth	29.67	45.00	69.73
LSD 5%	Ns	Ns	ns

The numbers followed by the same letters in the same column is significantly different (p = 0.05).
NS: not significantly different

The number of flower, number of harvested fruit, weight of fruit, and fruit yield were influenced by water management system (Table 3). The result presented in Table 3 show that reduce the amount of water addition significantly decreased the number of flowers and the number of fruits. From point of view of flower and fruit numbers, the worst negative effect observed in the treatment of 40% kc at vegetative growth and 100% kc at generative growth, and then followed by the treatment of 100% kc at vegetative growth and 40% kc at generative growth. According to Doorenbos and Kassam [11], the highest demand for water supply on tomato plants occurs at the flowering phase. Izzeldin *et al*. [12] explains that the impact of drought before the time of flowering affects the reproductive system with the increasing sterility of flowers, so that flowering and fruiting will fail if prolonged water shortage. In this experiment, the tomato planted on the treatment of 40% kc at vegetative growth and 100% kc at generative growth produced an average of 50.27 flowers/ plant with an average of 40.53 fruits/plant. If the stress occur during the generative growth (100% kc at vegetative growth and 40% kc at generative growth), the tomato plant produced an average of 49.33 flowers/plant with an average of 28.53 fruits/plant.

It is interesting to notice the date presented in Table 3. The treatment 40% kc at vegetative growth and 100% kc at generative growth produced the biggest fruits (31.47 g/fruit), although it was not significantly different with the treatment of water added equal to evapotranspiration through out tomato growth, 100% kc at vegetative growth and 70% kc at generative growth, and 70% kc at vegetative growth and 100% kc at generative growth. This is significantly bigger than the treatment of 70% kc at vegetative growth and 70% kc at generative growth, and 100% kc at vegetative growth and 40% kc at generative growth. This data indicate that if the tomato plants experience water shortage during vegetative growth, indeed it will reduced flower and fruit numbers, but if then there was enough water during generative growth

Table 3 The average number of flowers, number of fruit harvest, weight per fruit and fruit weight per plant on tomato plants caused by the treatment of water

Treatments	Number of flowers	Number of fruit harvest	Weight per fruit (g)	Fruit weight per plant (g)
Water added equal to evapotranspiration through out tomato growth	63.87 e	49.73 d	29.68	1461.00
100% kc at vegetative growth and 70% kc at generative growth	58.87 d	43.60 cd	29.07	1307.00
70% kc at vegetative growth and 100% kc at generative growth	54.53 cd	40.27 c	17.57	723.33
70% kc through out the tomato growth:	52.53 bc	32.07 b	13.45	431.33
100% kc at vegetative growth and 40% kc at generative growth	49.33 b	28.53 ab	19.59	566.33
40% kc at vegetative growth and 100% kc at generative growth 40% kc	50.27 bc	40.53 c	31.47	1320.67
through out the tomato growth	36.27 a	23.87 a	24.29	580.67
LSD 5%	4.81	7.71	Ns	Ns

The numbers followed by the same letters in the same column is significantly different (p = 0.05).
NS: not significantly different

Water management system significantly influenced the quality of tomato fruit classification based on the quality (Table 4). If there was no water shortage (Water added equal to evapotranspiration throughout tomato growth) produced 37.73 healthy fruit/plant; which was significantly higher compared to the water shortage plant (70% kc at vegetative growth and 70% kc at generative growth; 100% kc at vegetative growth and 40% kc at generative growth; 40% kc at vegetative growth and 40 % kc at generative growth). If a shortage of water availability occurred during vegetative growth only (40% kc at vegetative growth and 100% kc at generative growth) did not significantly influenced the number of healthy fruit, and marketable fruit.

Table 4 The average number of healthy and diseased fruit (blossom-end rot) and the number of marketable fruit and weight of marketable fruit in tomato plant caused by the treatment of water

Treatments	Number of healthy fruit per plant	Number of blossom-end rot fruit	Number of marketable fruit per plant	Weight of marketable fruit (g/plant)
Water added equal to evapotranspiration throughout tomato growth	37.73 d	12.00	29.87 d	1219.00
100% kc at vegetative growth and 70% kc at generative growth	33.60 cd	10.00	28.33 cd	1065.67
70% kc at vegetative growth and 100% kc at generative growth	27.53 bc	12.73	19.87 abc	492.33
70% kc through out the tomato growth:	23.20 b	8.87	17.00 ab	270.33
100% kc at vegetative growth and 40% kc at generative growth	19.40 ab	9.13	15.73 a	414.67
40% kc at vegetative growth and 100% kc at generative growth 40% kc	32.33 cd	8.20	26.00 bcd	1148.33
through out the tomato growth	15.00 a	8.87	12.13 a	383.33
LSD 5%	8.19	Ns	9.07	Ns

The numbers followed by the same letters in the same column is significantly different (p = 0.05).
NS: not significantly different

CONCLUSION

The experimental result presented and discussed in section 3 showed that the water requirement of tomato plants could be minimized by arrangement of water supply. Reduced water supply at vegetative growth, as far as there was enough water during vegetative growth (70% kc at vegetative growth and 100% kc at generative growth; or 40% kc at vegetative growth and 100% kc at generative growth) was enough to produce high yield. The yield of these two treatments were 1307 g/plant and 1320 g/plant which were not significantly from that of tomato plant without water shortage, kc 100 %, (1461 g/plant).

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