Available online at: http://proceeding.rsfpress.com/index.php/ ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 445-452

Early vegetative growth of tomatoes cultivated under different types and dosages of fertilizer applied in the drip irrigation system

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Abstract

Nutrient availability will affect plant growth, especially at the early development of the plant. Organic and inorganic fertilizer provides a different level of the nutrient. This research aimed to study the early growth of tomato cultivated under different fertilizer types and dosages. The greenhouse experiment was set in a Randomized Completely Block Design. The treatments were various types of fertilizer (Liquid Organic Fertilizer/LOF, inorganic fertilizer, LOF+AB Mix), and different dosages per day (225 mL, 450 mL, 675 mL 900 mL). Tomatoes were planted in polybags in a greenhouse and with treatments according to the experimental design, each treatment was repeated three times. Fertilizer was applied together with irrigation water, as drip fertigation, and automatically set as to irrigate at 06.00 am. 12.00 pm, at 06.00 pm. The liquid fertilizer concentration applied was 5 mL/L. Plant height and number of leaves were observed every two days for two weeks. The results showed there was no interaction between fertilizer type and fertilizer dosage in affecting plant height and number of leaves during early vegetative growth of tomato plant, except for plant height at 8 daps (days after planting) and 10 dap. Until 6 daps, application of inorganic fertilizer and 225 mL liquid fertilizer/day resulted in significantly higher plant height than other treatments. However, at 8 daps until 16 daps, the application of LOF+ NPK Mix and 450 mL liquid fertilizer/day resulted in significantly higher plant height and a higher number of plant leaves than other treatments. This result indicating that mixed between inorganic and organic fertilizer support better growth of tomato plant at their early stage. Further study, examining the effect of types of fertilizer and fertilizer dosage supplied in drip irrigation on the yield and quality of tomato is needed to confirm the recent results.

Keywords: dosage, drip irrigation, inorganic fertilizer, liquid organic fertilizer, tomato

I. INTRODUCTION

The availability of fertile soil for agriculture has been reduced significantly due to changes in land use. Agricultural activities have then shifted on suboptimal land, including in karst areas. The karst area is dominated by porous carbonate rocks with a thin solum, causing marginal or critical land to occur. Runoff from rainwater collects in underground water without any filtering process (Sweeting, 1968; Simms, 2005). This has the potential for underground water pollution. If at the top the farmers cultivate horticultural crops intensively using excessive doses of chemical fertilizers and pesticides, the leaching water will enter underground water. Proper nutrient and water management are very

important in an effort to improve soil quality. The fertigation system is very appropriate as a solution to the above problems. Fertigation is a system where fertilizer is supplied through irrigation. Drip irrigation is a common method applied to the fertigation system. This system will save water and fertilizer and resulted in higher yield with better quality (Kafkafi, & Kant, 2005).

Every crop responds differently toward the availability of nutrients and water. Tomato is a horticultural crop that is known for its sensitivity against nutrient and water availability. Tomato growth and yield are affected by water stress and nutrient supply (Nuruddin et al., 2003; Harmanto et al., 2005; Mahajan and Singh, 2006; Ismail et al., 2008; Pires et al., 2009).

There were much research has been conducted to study the effects of the application of various nutrient and water availability on the growth and yield of tomato. However, little is known about the early development of tomato if organic or inorganic fertilizer is used to supply the nutrient at different dosages in drip irrigation. The specific objectives of this study were to examine the early vegetative growth of tomato grown with different dosages of inorganic fertilizer, liquid organic fertilizer, or mixed of inorganic and organic fertilizer supplied in drip irrigation. Different dosage of liquid fertilizer applied in drip irrigation means the different volume of irrigation water given. Better early vegetative growth is expected to support better later growth stages during flowering and fruit developing, and subsequently produced higher yield with better quality. This study will help to evaluate the effectiveness of fertigation systems using various compositions of liquid organic fertilizer and inorganic-organic fertilizers using tomato as a test plant.

II. LITERATURE REVIEW

II.1. Plant growth on sub-optimal land

Suboptimal land is characterized by low productivity due to the influence of internal and external factors that occur naturally, such as drought stress (Mulyani & Sarwani, 2013). Drought stress causes changes in plant anatomy, morphology, physiology, and biochemistry that will affect plant growth and yield (Totok & Rahayu, 2004). The response of plants to drought stress is determined by the level of stress experienced, the length of stress, the phase of plant growth when experiencing stress. The influence of different levels and duration of drought stress will cause changes and different responses during the plant growth process (Naswir *et al*., 2009; Soepiandie, 2013).

Drought stress in plants can result in a direct decrease in cell division and enlargement. Water is used by plants for cell division and enlargement at the vegetative stage of growth, which is indicated in the increase in plant height, enlargement of diameter, leaf multiplication, and root growth. Drought causes the water potential of plant cells to decrease so that turgor in plant cells decreases and results in decreased physiological processes (Subantoro, 2014; Setiawan, 2016). The low turgor pressure results in the closing of the stomata so that CO2 diffusion is reduced, this results in low CO2 concentrations in the cell which results in low photosynthate produced. Research has shown that drought has mixed effects on agricultural output. Infield experiments, mycorrhizal, and vermicompost increased crop yields at water availability of 80, 60, and 40%. At 40% available water, vermicompost 12 tonnes/ha accompanied by mycorrhizal 6 and 8 tonnes/ha the yield was higher than 80% available water (Mustadjab, 2000). The frequency of irrigation once every three days on tomatoes can increase the average yield by 10% compared to the highest yield of one-day irrigation frequency. Moderate drought (75% irrigation) to severe drought (50%) significantly decreased tomato fruit yield by 40% (Ismail *et al*., 2007).

II.2. Fertigation and Drip Irrigation

In conventional agriculture, fertilizers and irrigation are applied separately. In modern agriculture, especially in precision farming, fertilizers are applied through the irrigation system. This application is termed fertigation and is considered an efficient way of applying fertilizer and irrigation water (Kafkafi, & Kant, 2005; Sureshkumar *et al*., 2016). In fertigation, nutrients are dissolved in irrigation water at a certain concentration and applied using a micro-irrigation system. Water and nutrients are supplied near the rooting area, so they can be absorbed timely as required (Sureshkumar *et al*., 2016). Types of fertilizer used in fertigation should be carefully selected, so it can be totally dissolved in the irrigation water. The fertigation is scheduled to meet the crop need, so the fertilizer and water are used efficiently to produce optimum yield and quality (Kafkafi, & Kant, 2005).

Fertigation can be applied using sprinkle irrigation or drip irrigation. However, drip irrigation is considered more efficient than other types or fertigation. The advantages of drip irrigation compare to other method are (1) nutrient is applied only on the weekend soil near the root, so leaching is reduced and fertilizer is used more efficient; (2) crop leaves do not get wet to hinder pests and diseases infestation and prevent leaves injury; (3) influence of wind and runoff is eluded (Kafkafi, & Kant, 2005). Tomato yield increased by 66.5% when cultivated using a subsurface drip irrigation system with 50% of crop evapotranspiration (ETc) compared with the surface treatment. On the other hand, total fruit yield was significantly different between a tomato grown with surface or subsurface drip irrigation system at 100% ETc (del Amor & del Amor, 2007).

III. RESEARCH METHODOLOGY

The experiments were conducted in a greenhouse in Karangnongko Hamlet, Maguwoharjo Village, Depok District, Sleman Regency. The experiments were arranged in a Split Plot Design with two factors and repeated 3 times. The first factor was the types of fertilizer, i.e. liquid organic fertilizer (LOF), inorganic fertilizer (NPK Mix=16:16:16), LOF + NPK Mix; the second factor was the fertilizer dosages per day, i.e. 225 mL, 450 mL, 675 mL 900 mL. Liquid organic fertilizer was own formulated from fermented fruit waste. Karst soil collected from Kampung Hamlet, Ngawen District, Gunung Kidul Regency was used as planting media in polybags. Fertilizer and irrigation water was applied as fertigation. Fertigation was conducted in a drip irrigation surface system and operated automatically using information technology via the internet. The concentration of liquid fertilizer was 5mL/L. Fertigation was applied three times per day at 06.00 am, 12.00 pm, and 06.00 pm, and the amount of volume was adjusted to the experimental dosage.

The tomatoes grown were the F1 Pendants hybrid variety. Seedlings were planted in 30 cm-sized polybags which were given soil from Gunung Kidul mixed with compost in a ratio of 2: 1. Maintenance was carried out by controlling weeds manually. Pest and disease control was not carried out. Observation of plant height and number of leaves was carried out every two days from 2-16 days after planting (dap). The observed data were analyzed for their diversity and continued with Duncan's multiple range test using SPSS for Windows version 15 ($\alpha = 5\%$).

IV. FINDING AND DISCUSSION

Results showed that there was no interaction between types of fertilizer and fertilizer dosages in affecting tomato plant height at 2 daps, 4 daps, 6 daps, 12 daps, 14 daps, and 16 daps (Table 1). However, there was an interaction between types of fertilizer and fertilizer dosages in affecting tomato plant height at 8 daps and 10 daps (Table 2 & 3). Tomato plant treated with inorganic fertilizer (NPK Mix) significantly resulted in higher plant height at 2 daps, 4 daps, 6 daps than those treated with liquid organic fertilizer (LOF), although they were not significantly different from those treated

with LOF+ NPK Mix. Tomato plant treated with LOF+ NPK Mix significantly grew higher at 12 daps, 14 daps, 16 daps than those treated with LOF or NPK Mix (Table 1).

Table 1. Tomato plant height at 2-16 days after planting (dap) grew under various fertilizer types and dosages (cm)

Treatments	2 dap	4 dap	6 dap	12 dap	14 dap	16 dap
Fertilizer Type						
Inorganic NPK Mix	6,26 a	7,05 a	8,48 a	14,19 b	17,15 b	20,59 b
LOF+ NPK Mix	5,97 ab	6,91 ab	8,38 a	15,38 a	18,85 a	22,77 a
LOF	5,84 b	6,61 b	7,98 b	14,01 b	16,81 b	20,14 b
Fertilizer Dosage/day				14,55 pq	17,32 q	20,44 r
225 mL	6,23 p	7,07 p	8,46 p			
450 mL	6,07 q	6,89 q	8,39 p	14,69 p	17,99 p	21,79 p
675 mL	5,77 r	6,57 r	8,03 r	14,34 q	17,46 q	21,35 PQ
900 mL	6,03 q	6,91 q	8,23 q	14,54 PQ	17,65 PQ	21,09 q
Interaction	-	-	-	-	-	-

The mean followed by the same letter in one column shows no significant difference according to Duncan's Multiple Range Test ($P \leq 0.05$); (-) indicates that there is no interaction between treatment combinations; LOF = Liquid Organic Fertilizer

Tomato plant treated with 225 mL fertilizer/day significantly resulted in higher plant height at 2 daps, 4 daps than those treated with other dosages. Tomato plant treated with 450 mL fertilizer/day were significantly resulted in higher plant height at 6 daps, 12 daps than those treated with 675 mL or 900 mL, but not significantly higher than those treated with 450 mL fertilizer/day. Tomato plant treated with 450 mL fertilizer/day were significantly resulted in higher plant height at 14 daps than those treated with 225 mL, 675 mL, but not significantly higher than those treated with 900 mL fertilizer/day. Tomato plant treated with 450 mL fertilizer/day significantly resulted in higher plant height at 16 daps than those treated with 225 mL or 900 mL, but not significantly higher than those treated with 675 mL fertilizer/day (Table 1).

In the fertigation system, when inorganic fertilizer (NPK Mix) or Liquid Organic Fertilizer (LOF) was used, dosages of fertilizer did not significantly affect the plant height at 8 daps and 10 daps. However, when LOF+ NPK Mix was used, fertilizer dosage at 225 mL/day resulted in significantly higher plant height than those treated with 675 mL/day, although it was not significantly different from those treated with 450 mL/day or 900 mL/day. The application of LOF+ NPK Mix resulted in higher plant height at 8 daps and 10 days when it was applied at 225 mL/day than those treated with NPK Mix or LOF alone, although it was not significantly different from those treated with LOF at 450 mL, NPK Mix at 900 mL/day or NPK Mix or LOF alone at 675 mL/day (Table 2 & 3).

Table 2. Tomato plant height at 8 days after planting (dap) grew under various fertilizer types and dosages (cm)

Treatment	**Fertilizer Dosage /day**				
FertilizerType	225 mL	450 mL	675 mL	900 mL	Mean
Inorganic NPK Mix	10,02 a q	9,61 a q	9,89 a p	10,07 a p	9,89
LOF+ NPK Mix	11,29 a p	10,39 ab p	9,83 b p	10,18 ab p	10,42
LOF	9,22 a r	10,19 a p	9,57 a p	9,50 a q	9,62
Mean	10,18	10,05	9,76	9,91	**(+)**

The mean followed by the same letter in one column (a,b,c) or rows (p,q,r) shows no significant difference according to Duncan's Multiple Range Test (P≤0.05); (+) indicates that there is an interaction between a combination of treatments; LOF = Liquid Organic Fertilizer

Table 3. Tomato plant height at 10 days after planting (dap) grew under various fertilizer types and dosages (cm)

Treatment	**Fertilizer Dosage/day**				
FertilizerType	225 mL	450 mL	675 mL	900 mL	Mean
Inorganic NPK Mix	12,04 a q	11,57 a q	11,84 a p	12,04 a PQ	11,88
LOF+ NPK Mix	13,66 a p	12,84 ab p	12,18 b p	12,37 ab p	12,76
LOF	11,11 a r	12,34 a p	11,61 a p	11,76 a Q	11,71
Mean	12,27	12,25	11,88	12,06	**(+)**

The mean followed by the same letter in one rows (a,b,c) or column (p,q,r) shows no significant difference according to Duncan's Multiple Range Test (P≤0.05); (+) indicates that there is an interaction between a combination of treatments; LOF = Liquid Organic Fertilizer

Furthermore, the results showed that there was no interaction between types of fertilizer and fertilizer dosages in affecting the number of tomato leaves at 2 daps until 16 daps (Table 4 & 5). The number of tomato leaves at 2 daps was not significantly affected by types of fertilizer or fertilizer dosages. The number of tomato leaves at 4 daps was not significantly affected by types of fertilizer but those treated with fertilizer dosages at 225 mL/day or 450 mL/day had more leaves than those treated with 675 mL/day or 900mL/day. The number of tomato leaves at 6 daps and 8 daps, plants that were treated with LOF produced more leaves than those treated with NPK Mix or LOF+ NPK Mix (Table 4).

Table 4. Number of tomato leaves at 2-8 days after planting (dap) grew under various fertilizer types and dosages

Treatments	2 dap	4 dap	6 dap	8 dap
Fertilizer Type				
Inorganic NPK Mix	2,00 a	2,56 a	3,47 c	4,36 c
LOF+ NPK Mix	2,00 a	2,72 a	3,67 b	4,47 b
LOF	2,03 a	2,69 a	3,83 a	4,64 a
Fertilizer Dosage/day				
225 mL	2,00 p	2,74 p	3,63 p	4,41 q
450 mL	2,00 p	2,81 p	3,67 p	4,59 p
675 mL	2,04 p	2,56 q	3,70 p	4,48 pq
900 mL	2,00 p	2,52 q	3,63 p	4,48 pq
Interaction	-	-	-	

The mean followed by the same letter in one column shows no significant difference according to Duncan's Multiple Range Test (P≤0.05); (-) indicates that there is no interaction between treatment combinations; LOF = Liquid Organic Fertilizer

The application of LOF+ NPK Mix resulted in significantly more tomato leaves at 10 daps until 16 daps than other treatments. The application of 450 mL liquid fertilizer/day resulted in more leaves than the application of 225 mL, although it was not significantly different from that of 675 mL fertilizer/day. The application of 900 mL fertilizer/day resulted in less number of leaves at 14 daps and 16 daps than those treated with450 mL fertilizer/day (Table 5).

Table 5. Number of tomato leaves at 10-16 days after planting (dap) grew under various fertilizer types and dosages

Treatments	10 dap	12 dap	14 dap	16 dap
Fertilizer Type				
Inorganic NPK Mix	5,31 c	6,42 b	7,33 b	8,31 c
LOF+ NPK Mix	5,78 a	6,67 a	7,64 a	8,64 a
LOF	5,61 b	6,31 c	7,50 a	8,50 b
Fertilizer Dosage/day				
225 mL	5,52 q	6,33 q	7,37 q	8,15 r
450 mL	5,74 p	6,59 p	7,63 p	8,67 p
675 mL	5,56 q	6,48 PQ	7,52 PQ	8,70 p
900 mL	5,44 q	6,44 PQ	7,44 q	8,41 q
Interaction	-	-	-	-

The mean followed by the same letter in one column shows no significant difference according to Duncan's Multiple Range Test (P≤0.05); (-) indicates that there is no interaction between treatment combinations; LOF = Liquid Organic Fertilizer

These results indicated that in their very early stage of vegetative growth, the provision of inorganic NPK Mix fertilizer was sufficient to support the plant nutrient needs. However, in their later growth state, a mixture between inorganic and organic fertilizer provided a better nutrients supply to the tomato plant. Inorganic NPK Mixed only supply macronutrient nitrogen, phosphate, and potassium (Kalium), whereas organic fertilizer provided not only macronutrients but also micronutrients that are needed by the plant in a small quantity. NPK macronutrients found in organic fertilizers and inorganic fertilizers have the same function in plant growth. Nutrient N is needed for protein synthesis in the formation of plant cells and supported the vegetative growth of plants (Lawlor, 2002). The nutrient P is required in the formation of energy, nucleic acid synthesis, photosynthesis, glycolysis, respiration, membrane synthesis and stability, activation/inactivation of enzymes, redox reactions, carbohydrate metabolism, and nitrogen fixation (N) (Vance et al., 2003). Potassium plays a role in biochemical and physiological processes that affect plant growth and plant metabolism. Potassium also functions to increase plant resistance to environmental stress, such as drought, salinity, pests, and diseases (Wang et al., 2013). Potassium helps enzyme activation and absorption of nutrients and water from the soil and transport of photosynthate from leaves to other plant tissues (Marschner, 2012).

Vegetative growth occurs after germination until just before flower production. During this period plant collecting photosynthates needed for the reproductive stage. Plant with vast vegetative growth is expected to have better reproductive growth thus produce a higher yield. Vegetative growth can be measured from plant height and number of leaves. The higher the plant and more leaves it produces, this will allow the plant to accumulate more photosynthates in the sink. This result findings suggest that in the early stage of vegetative growth tomato cultivated under drip irrigation can be fertilized with inorganic fertilizer NPK with a lower dosage as much as 225 mL/day. However, after 8 daps a mix of inorganic NPK and organic fertilizer should be applied to provide more complete nutrients to support tomato growth with a higher dosage of 450 mL/day.

V. CONCLUSION AND FURTHER RESEARCH

Fertilizer type and fertilizer dosage performed independently in influencing plant height and number of leaves during early vegetative growth of tomato plant, except for plant height at 8 daps (days after planting) and 10 daps. Until 6 daps, application of inorganic fertilizer and 225 mL liquid fertilizer/day resulted in significantly higher plant height than other treatments. However, at 8 daps until 16 daps, the application of LOF+ NPK Mix and 450 mL liquid fertilizer/day resulted in significantly higher plant height and a higher number of plant leaves than other treatments. This result indicating that mixed between inorganic and organic fertilizer support better growth of tomato plant at their early stage. Further study, examining the effect of types of fertilizer and fertilizer dosage supplied in drip irrigation on the yield and quality of tomato is needed to confirm the recent results.

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