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Foliar iron application on growth and yield of tomato

A T Sakya and Sulandjari

Department of Agrotechnology, Sebelas Maret University, Jl. Ir. Sutami 36A, Kentingan, Surakarta, 57126, Indonesia

E-mail: amaliatetrani@staff.uns.ac.id

Abstract. Fertilizers provides important nutrients for plants growth and production. One of micronutrient needed is Iron (Fe) which plays an important role in various enzymatic activities. Research on Fe fertilization in tomato is rarely done due to the low Fe requirement. This study was conducted to investigate the application of Fe on tomatoes' growth and production. The experiment used tomato 'Permata' variety, and was designed as completely randomized design with 2 factors. The fist factor was frequency of ferrous sulphate ($FeSO_4$) spraying (1 and 2 times spraying after transplanting). The second factor was $FeSO_4$ concentration: 0.25, 0.5, 0.75, and 1% with six replications. The observation covered plant height, number of leaves, chlorophyll content, amount and weight of fruit per plant in the third harvest. Plant height and number of leaves at 54 days were not different in all treatments with an average height of 123-155 cm and 27-39 strands of leaves. The chlorophyll content ranged between 0.89-1.24 mg g^{-1} of fresh weight. Application of $FeSO_4$ influenced number and weight of fruit. Application of 1% $FeSO_4$ spraying twice at 15 and 30 days after transplanting produced the highest number and weight of fruit until the third harvest.

1. Introduction

There is an increasing consumption of tomato as a source of antioxidants due to the increasing in health awareness. The efforts to ensure tomato production is to balance the optimum growth and production, one of which is through fertilization both macronutrients and micronutrients. Micronutrients are indeed only present in very small amounts both in soil and plants, however, its role is as important as both primary and secondary macronutrients. At present the role of micronutrients in plant nutrition and soil productivity increases significantly. The use of superior variety and application of high macronutrient continuously, resulting the lack of micronutrients in the soil. Iron (Fe) is one of the micronutrient that plays an important role in plant metabolism, including respiration, photosynthesis, chlorophyll development, energy transfer, components of various enzymes and proteins, and involved in nitrogen fixation [1,2,3].

Many studies reported that Fe application on both through leaves and soil had a positive effect on growth and yield [4,5,6]. The inefficiency of Fe application on fruit plants can cause chlorosis as well as decreases vegetative growth and fruit productivity (7,8,9). Fe fertilizer can be applied through leaves to improve the Fe efficiency in plants, because the distance and length of Fe transportation also affect the efficiency of Fe application. Also, the application through leaves is a more efficient in providing nutrients for plants than application through soil, particularly when soil conditions are not suitable for Fe availability [10,11,12]. Recently, only few studies have focused on the Fe application on plants growth and yield, especially tomato. Therefore, this experiment was conducted to evaluate the foliar Fe application on growth and yield of tomato plants.

2. Material and method

The experiment was conducted in the greenhouse of Faculty of Agriculture, Sebelas Maret University. The experiment was designed as a factorial completely randomized design with 2 factors. The first factor was spraying frequency consisted of 1 time spraying (at 15 days) and twice spraying (at 15 and 30 days) after transplanting. The second factor was ferrous sulfate ($FeSO_4$) concentration, namely 0 (control), 0.25, 0.5, 0.75 and 1%. For control, spraying was done with pure water. All applications were done in the morning. Each treatment combination was repeated 6 times. The growing media of tomato plants was ‘Regosol’.

The 3-week-old tomato seedlings were transplanted on growing media that have been fertilized with super phosphate (SP-36 100 kg ha^{-1}). Urea ($CO(NH_2)_2$ 200 kg ha^{-1}) and potassium chloride (KCI 100 kg ha^{-1}) were given in the first and fourth weeks after transplanting. Watering was done every day; weed and pest management was done manually. The observation variables included plant height, number of leaves, chlorophyll contents, numbers and fruits weight per plants. Plants height and number of leaves were measured and counted once every 2 weeks. Chlorophyll contents were measured from fully expanded leaves when the plants was 6 week after transplanting (wat). Chlorophyll content was analyzed using a method described by Islam et al. [13], in which 1 g of leaf samples was cut into pieces and crushed with a mortar and then added with 20 ml of 80% acetone. The solution was left aside for a while, then filtered with Whatman no. 24 filter paper. The filtrate was inserted into the cuvette until the boundary line, and then the absorbance was measured with spectrophotometer at λ 645 and 663 nm. The calculation of chlorophyll content was determined by the formula: Chlorophyll a content = (12.7 × A663 – 2.69 × A645) × (20 ml/1000 × 1 g); Chlorophyll b content = (22.9 × A645 – 4.68 × A663) × (20 ml/1000 × 1 g) and total chlorophyll content = (20.2 × A645 + 8.02 × A663) × (20 ml/1000 × 1 g). Harvesting was done every 4 days. The number and weight of fruit were calculated by summing the whole first to the third harvest, which.

The data obtained was analyzed using analysis variance continued with Duncan’s test at α=5% with Minitab 17 programme.

3. Result and discussion

3.1. Plant height and number of leaves

Table 1 shows the average increase of tomato plants height with the observation up to 8 weeks after transplanting. The first to fourth week was the vegetative growth phase of tomato plants, indicated by the rapid growth. Plants will enter the generative phase after the flowers appear and the plant height only increases slightly or no further increase. This is showed in Table 1 that increasing plant height was smaller than the first to fourth week.

Concentrations of $FeSO_4$ and spraying frequency did not affect plant height and number of leaves at 8 weeks after transplanting. At 8 weeks after transplanting, plant height ranged from 126 to 155 cm with 27 to 38 strands of leaves (Table 2). Number of leaves affects the photosynthesis process. If a plant has more leaves, the photosynthesis process is higher which leads to higher photosynthate produced, resulting to a high the plant growth. Therefore, the energy needed by the plants will be translocated to all plant tissues in a greater amount. The number of leaves is related to plant height, since the leaves grow in the segments of the stem. Tomato plant height is proportional to the number of leaves formed, which shows the relationship between the two variables. The absence differences in plants height and number of leaves following $FeSO_4$ application may also due to the Fe availability in the soil which sufficient to supply Fe for metabolism process. The plants without Fe application did not show any Fe deficiency, namely chlorosis in young interveinal leaves [14], similarly, the Fe fertilizer application with 1% concentration also did not show any toxic symptoms.

Table 1. Plant height and number of tomato leaves from transplanting until 8 weeks after transplanting

Treatment		Week after transplanting				
		0	2	4	6	8
T1K0	PH (cm)	14.27	47.77	93.67	125.83	134.63
	NL	2.3	7.4	18.6	25.1	31.9
T1KI	PH (cm)	15.47	51.97	72.53	109.13	132.47
	NL	2.3	7.7	21.3	23.6	28.0
T1K2	PH (cm)	14.67	54.33	91.87	116.23	126.83
	NL	2.4	8.2	15.9	25.0	27.3
T1K3	PH (cm)	14.37	56.17	113.10	123.20	128.30
	NL	2.4	7.9	22.3	28.0	33.1
T1K4	PH (cm)	14.20	51.47	92.77	129.57	155.63
	NL	2.5	7.8	18.3	27.8	38.7
T2K0	PH (cm)	15.47	39.50	117.53	127.43	129.93
	NL	2.5	6.7	21.2	28.0	31.4
T2K1	PH (cm)	14.60	56.63	99.90	132.43	132.13
	NL	2.1	8.5	19.2	29.2	35.6
T2K2	PH (cm)	14.17	53.40	107.73	127.40	143.70
	NL	2.5	7.8	19.5	32.7	30.3
T2K3	PH (cm)	16.13	52.87	99.13	121.30	123.17
	NL	2.6	8.5	18.5	26.0	28.9
T2K4	PH (cm)	16.37	54.77	104.43	117.77	125.30
	NL	2.5	8.6	22.6	29.8	31.9

Note: T= application frequency (1× and 2× spraying); K = concentration of $FeSO_4$ (0;0.25;0.5;0.75 and 1 %); PH = plant height; NL= number of leaves

Table 2. Plant height and number of tomato leaves at 8 weeks after planting

$FeSO_4$	Concentration (%)					Mean
	0	0.25	0.5	0.75	0.1	
Plant height (cm)						
1×	121.0	132.5	136.8	135.0	155.6	136.2
2×	129.9	132.1	143.7	129.8	135.3	134.2
Mean	125.5	132.3	140.3	132.4	145.5	
Number of leaves (strand)						
1×	32	28	27	33	39	31.8
2×	31	36	30	29	32	31.6
Mean	31.6	31.8	28.8	31.0	35.3	

3.2. Chlorophyll Content
Measurement of chlorophyll content was done when the plant is at 6 weeks after transplanting. A variety of fertilizers and concentration given did not affect the chlorophyll a and chlorophyll b, but the concentration affects the total chlorophyll content. Chlorophyll content in tomato leaves ranged between 0.87 and 1.245 mg g^{-1} fresh weight on the $FeSO_4$ application with 0.25 to 1% concentration. The highest chlorophyll content was found in twice spraying 0.5% $FeSO_4$ (1.245 mg g^{-1} of fresh

weight), which was not significantly different with 0.25% $FeSO_4$ twice spraying and 0.5% $FeSO_4$ one time spraying. Twice spraying of 0.5% $FeSO_4$ increased chlorophyll content by 17% compared to control. Fe is very important in the formation of aminolevulenic acid (ALA) during chlorophyll synthesis [1,15]. Additionally, Fe also plays a role in the structure porphyrin of chlorophyll, and is a major component of chloroplasts [15].

Increasing in chlorophyll content due Fe application was also reported by Medawar et al [16] in the HBED-Fe and FEDDHA-F application in tomatoes and cucumbers. Effendi et al. [7] showed that chlorophyll content in pineapple with 50 ppm concentration of Fe is higher compared to 100-250 ppm concentration of Fe.

Table 3. Chlorophyll content (mg g^{-1} fw) of tomato leaves on foliar $FeSO_4$

$FeSO_4$		Chl-a ^{ns}	Chl-b ^{ns}	Chl total *
Frequency	Concentration (%)			
	0	0.407	0.463	0.870^{a}
	0.25	0.526	0.644	1.171^{ab}
1	0.5	0.554	0.653	1.206^{b}
	0.75	0.520	0.633	1.152^{ab}
	1	0.516	0.598	1.114^{a}
	0	0.433	0.509	0.942^{c}
	0.25	0.563	0.633	1.195^{b}
2	0.5	0.580	0.664	1.245^{b}
	0.75	0.524	0.561	1.086^{a}
	1	0.519	0.559	1.078^{a}

Note: ns : non significant; * significant.
^{a,b,c} Number followed by the same letter in one column shows no significant difference in the Duncan test 5%

Figure 1 illustrates a polynomial regression analysis between chlorophyll content and $FeSO_4$ application. Regression equation of one spraying was $y1 = 1.0201 + 0.644x - 0.5658x^2$ and the equation on twice spraying is $y2 = 1.1018 + 0.449x - 0.5014x^2$ and each with $R^2 = 0.91$ and 0.66, respectively. High R^2 both in one and twice spraying shows $FeSO_4$ contribution to large variations in chlorophyll content.

3.3. Number and weight of tomatoes

The results of variance analysis showed an interaction between frequency of Fe application and concentration on the number and weight of tomato in the third harvest. This shows a different pattern response of number and weight of fruit in frequency Fe application along with increasing concentration. In one spraying, the highest number and weight of tomato were found in 0.5%, while in the twice spraying was on the 1% concentration. The $FeSO_4$ 5% application increased the number and weight of fruit. Both concentrations showed the significant increase compared to the control. There was a 50% increase in the number and weight of fruit in 0.5% $FeSO_4$ application and 160-170% in twice spraying with 1% concentration. This improvement was possible because Fe aids the synthesis of certain hormones to encourage flowering and fertilization. Fe is also required for plant metabolism functions such as chlorophyll synthesis, various enzymatic reactions, respiration and photosynthesis [6,18]. Therefore, the availability of optimum Fe can increase the photosynthesis activity and produce more photosynthate. Increased growth and yield after $FeSO_4$ spraying is also reported by several investigations, such as Roosta and Yaser [19] who reported that foliar Fe application increased growth of eggplant and the highest values of vegetative growth were treated with $FeSO_4$. Meena et al. [5] also showed that foliar application of 0.6% $FeSO_4$ and 0.3% borax produced maximum average fruit weight, fruit length, fruit width, pulp weight and fruit weight.

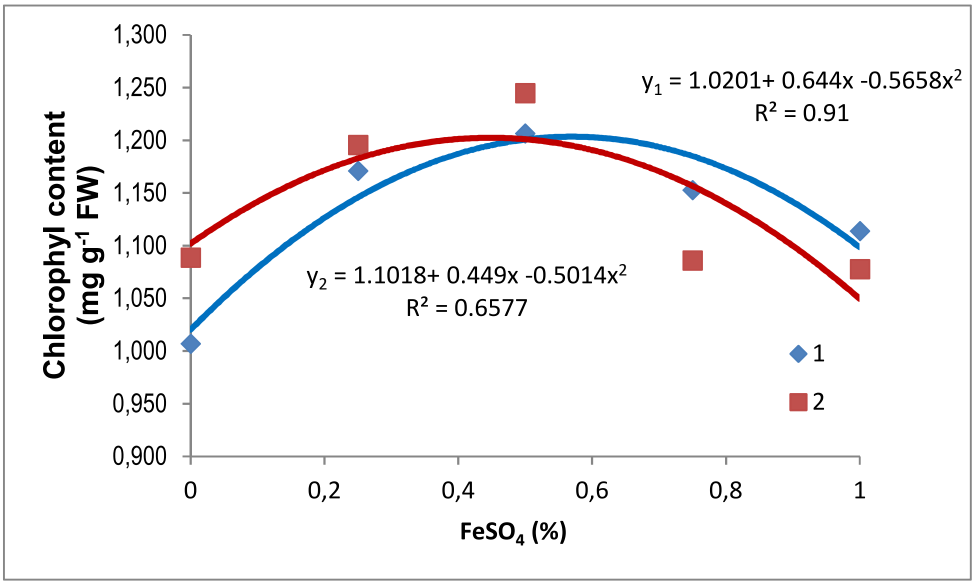

Figure 1. Polynomial relationship between $FeSO_4$ concentration and chlorophyll content

Table 4. Number and weight of tomato in foliar $FeSO_4$ application

$FeSO_4$	Concentration (ppm)					Mean
	0	0.25	0.5	0.75	1	
Number of fruit						
1	3.3^{ab}	0.7^{a}	5.0 ^{b}	1.7^{a}	2.7^{a}	2.7
2	3.3^{ab}	5.7^{b}	4.3^{b}	2.3^{a}	8.6^{c}	5.5
Mean	3	3	5	4	6	+
Weight of fruit						
1	90.95^{c}	18.72^{a}	136.56^{e}	57.76^{b}	107.43^{cd}	82
2	89.52^{bc}	156.18^{e}	145.61^{e}	92.39^{c}	241.76^{f}	145
Mean	90	87	141	75	175	+

Note: (+) : interaction.
^{a,b,c,d,e,f} Number followed by the same letter in one column or rows shows no significant difference in the Duncan test 5%.

4. Conclusion

The spraying frequency and concentrations of $FeSO_4$ up to 1 % does not affect plant growth. Spraying twice with 0.5% $FeSO_4$ produced the highest total chlorophyll content. Spraying twice with 1% $FeSO_4$ produced the highest number and weight of tomato fruit.

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