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by Wipsar Sunu Brams Dwandaru

The Effect of pH, Electrical Conductivity, and Nitrogen (N) in the Soil at Yogyakarta Special Region on Tomato Plant Growth

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Abstract **– The purpose of this study was to determine the effect of pH, electrical conductivity, and nitrogen content in the soil of five cities in Yogyakarta Special Region considering the growth of tomato plants. This study was conducted using quantitative methods and observations on the growth of tomato plants. The results showed that pH, electrical conductivity (EC), and soil nitrogen (N) elements originating from Yogyakarta were in accordance with the theory for tomato plant growth which were (5.380 $\pm$ 0.005), (284.0 $\pm$ 0.5) $\times$ 10^{-3} mS/cm, and (264.680 $\pm$ 0.005) ppm, respectively. Based on these results, the growth of tomatoes planted using the soil samples from Yogyakarta in terms of plant height, leaf length, and leaf width was more optimal. However, the tomato plant stem diameter growths from the five soil samples are relatively the same about 0.38-0.30 cm.**

Keywords **– pH, electrical conductivity, soil nitrogen element, tomato plant growth.**

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1. Introduction

Soil is a natural resource, which is used by humans in order to carry out activities in fulfilling their daily needs. Soil is composed of three main components, i.e. solids, liquids, and air. Solids consist of mineral and organic ingredients occupying half the volume. Mineral materials derived from the destruction of host rocks occupy 45% and organic matter from decomposition of dead micro bodies occupies 5% of the volume [1]. The remaining half is filled with dissolved liquids and electrolytes, and air with a volume that is structured according to the amount of liquid [2]. Rice fields are soil that is used to grow rice, either continuously or take turns with other crops. Rice fields are soil that has been used for 40-50 years and plow pan is formed. This layer is found at a depth of 10-15 cm from the surface of the soil and is 2-5 cm thick [3].

Fertile soil is the soil that can produce high yields. Definition of soil fertility is the ability of a soil to continuously provide nutrients at certain doses to support the growth of plants with other growth factors in favorable conditions [4]. The higher the availability of nutrients, the more fertile the soil will be. Nutrient content in the soil is always changing, depending on the season, tillage and plant species [5]. The value of the soil fertility cannot be measured or observed, but it can only be estimated. The value estimation can be carried out based on the physical, chemical, and biological properties of the soil associated with plant growth parameters, e.g.: stem length, number of leaves, width, and length of leaves. Evaluation of soil fertility needs to be done to determine the types and nutrients contained.

Evaluation of the soil fertility can be done by soil analysis, including i) availability analysis of primary macro nutrients [N, phosphor (P), and K] in the soil and ii) measuring the pH with good pH values for plants ranging from 6.0 to 6.5 [6]. Masfufah *et al.*

(2012) [7] states that vegetables such as tomatoes (*Solanum lycopersicum*) need suitable soil pH of 5.0 - 7.0 or somewhat acidic to neutral. If the soil pH is too acidic, the soil will lack potassium, so that tomato plants are susceptible to disease. Furthermore, Böhlenius (2016) obtained a good soil pH of 5.0 to 6.0 for tomato plant growth.

Soil fertility levels can also be measured from the soil water content. This is related to the ability of a soil to absorb water, i.e. the electrical conductivity (EC) of the soil or the conductivity of the soil electricity [9]. EC is the ability of the soil to conduct electric current. EC occurs because of the existence of free salt content found in soil water content and exchangeable ion content found on the surface of solid soil particles [10].

The EC value of the soil has a positive correlation with the content of N in the soil, which is due to the addition of the ratio of potential nutrient levels to increase the amount of ionized nutrients increasing the EC value of the soil [11]. The value of N can be increased using organic fertilizers [12]. The value of good EC for the growth of tomato plants is at intervals of 0.25 mS/cm to 0.5 mS/cm, and the optimal value of EC for tomato plant growth is 0.28 mS/cm [13]. In addition to the EC value of the soil that correlates with the N content contained in the soil, the EC value, soil pH, and N elements in the soil are interconnected.

Soils that have a pH less than 7 or acidic cause the H^+ ions to increase producing electrolyte [14]. Additionally, the more H^+ ions contained in the soil, the greater the EC. Meanwhile, the N element absorbed by plants for the growth process is in the form of nitrate (NO_3^-) which comes from the reaction of nitrite (NO_2^-) with water (H_2O). This is what is known by nitrification reaction where the chemical reaction is as follows [15]:

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-. \qquad (1)$$

It may be observed from (1) that if more H^+ ions contained in the soil, then NO_3^- increases as well. Moreover, NO_2^- come from organic materials such as manure or compost [15]. A soil that contains a lot of N affects the plants and they will experience dense growth in their leaves.

Based on the process of absorption of N elements by plants, a good amount of N for the growth of tomato plants is at intervals of 250 ppm to 500 ppm and the optimal value of N for the growth of tomato plants is 260 ppm [16]. Meanwhile, plants that grow on a soil lacking N will grow stunted, which indicate slow growth and yellow leaves [17]. Meanwhile, in this study we have added an organic fertilizer, i.e. compost [18]. Aziablé (2018) stated that the content of the compost has a minimum N element of 0.4%, phosphorus (P_2O_5) of 0.1%, and potassium (K_2O) of 0.2%. Macro nutrients are needed for plant growth including N, which functions to stimulate vegetative leaf (green color, length, width) and stem (height and size) growths [19].

P plays an important role in the transfer of energy in plant cells, encourages the development of roots and early fertilization, strengthens the stem so that it does not fall easily, and increases N uptake at the beginning of growth [20]. K element also plays an important role in plant growth for example to stimulate carbohydrate translocation from leaves to plant organs. Compost fertilizer functions to increase EC and cation exchange capacity, and also improve soil structure [21].

Furthermore, compost fertilizer is very helpful in photosynthesis [22]. The length and width of leaves are very influential on photosynthesis carried out by plants. N elements available to plants were sufficient to stimulate shoot and leaf formation, enhance protein content and increase the amount of chlorophyll [23]. This is in line with [6] that the N element affects the formation of leaves with wider strands and higher chlorophyll content, so that it can produce a lot of carbohydrates for vegetative growth of plants.

The Indonesian people favor tomato plants because tomatoes are a source of vitamins A, C, and a small amount of vitamin B. This can be seen from the increasing consumption of tomatoes from year to year. This is reflected in the number of tomato production according to data from Central Bureau of Statistics and Directorate General of Horticulture of Indonesia (2016) [24] during 2011 to 2015, i.e. (in tons): 954,046; 893,463; 992,780; 915,987; and 878,741; respectively. Tomato productions in the Special Province of Yogyakarta during 2011 to 2015 were (in tons) 747; 446; 1,067; 1,253; and 1,244, respectively. In this experiment, tomato plants become an indicator of soil fertility, which can be comprehended from the results of plant growth on the soil. The reason for choosing tomatoes is that the growth of tomatoes is fast and sensitive to nutrients in the soil [13] in which tomato plants grow faster than okra (*Abelmoschus esculentus Moench*) and spinach (*Amaranthus*) plants with N element treatment contained in compost.

This study uses soil samples from five cities in the Special Region of Yogyakarta, i.e.: Yogyakarta, Bantul, Sleman, Kulon Progo, and Gungungkidul (Wonosari), as it is related to the purpose of this study, i.e. to determine the effect of EC, soil pH, and N content in the soil on tomato plant growths (height, stem diameter, leaf length, and leaf width). This study also determines the ratio of tomato plant growths (height, stem diameter, leaf length, and leaf width).

2. Material and methods

This study is appropriate to the type of research conducted through observation and quantitative methods. After obtaining the results of measurements of several tomato plant growth parameters, the data are compared with the standard parameter values based on several references about pH, EC, and N elements, which are optimal for the growth of tomato plants. This research was conducted from September to December 2017, and it began with the preparation of planting media by taking soil samples from five cities in Yogyakarta Special Region, i.e.: Yogyakarta, Bantul, Sleman, Wonosari, and Kulonprogo as shown in Figure 1.

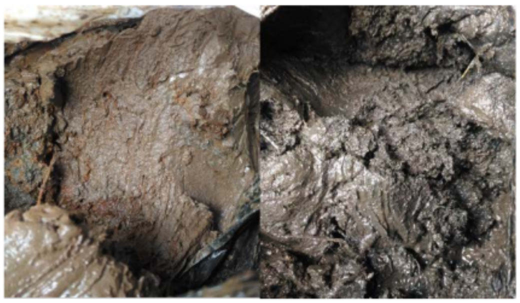

Figure 1. Soil samples from two cities in the Special Region of Yogyakarta

Meanwhile, the variables examined in this study were plant growths, i.e.: plant height, stem diameter, leaf length, leaf width, and number of leaves. The sample soils from each city was divided again into five samples in polybag of 1 kg in size. The soil pH, EC, and N element values are measured using a pH meter, an EC meter, and Deverda Aloy method, respectively, in the Soil Science Laboratory, Universitas Gadjah Mada. This may be observed in Fig. 2.

Each soil sample was mixed with 50 grams of manure and then put into a 1 kg plastic polybag, so that 25 samples are obtained. Afterward the 25 soil samples were put into plastic polybags. The next step was to incubate the planting media for 24 hours. After 24 hours of incubation, the tomato seeds were planted in the planting media with each polybag containing 1 tomato seed. The average daily temperature at the study site is 23 ^{o}C to 31 ^{o}C, and the average sunlight intensity is 665 lx. Maintenance of tomato plants is done by watering as much as 300 ml every three days.

Measurements of the tomato plant height, width and length of the leaf, and the diameter stem are carried out every day for four weeks. The measurement of the tomato plant height is done using a ruler. The height measurement is taken from the lowest point of the plant just above the soil to the tip of the plant. Similar measurements are conducted for the width and length of the tomato leaf using a ruler. Measuring the stem diameter of the tomato plant is conducted using calipers on the base of the stem, which is parallel to the surface of the planting medium.

Figure 2. pH measurement, electrical conductivity of soil samples.

3. Measurement of soil pH, EC, and N elements

Measurement of pH and EC on five soil samples was carried out using a pH meter and digital EC meter, each of which had a standard deviation of 0.005 and 0.0005 mS/cm, respectively. The results of the measurements can be shown in Table 1.Based on the data obtained in Table 1, the highest soil pH value originating from Wonosari, which is 6.630 $\pm$ 0.005 and the lowest soil pH value is from Yogyakarta, which is 5.380 $\pm$ 0.005. According to research conducted by Masfufah (2012) [7],[8] the growth of tomato plants is effective in the pH range about 5.0 to 6.0 and optimal growth of tomato plants is at pH of 5.5. Meanwhile, the highest EC value of soil originates from Yogyakarta, which is $(284 \pm 0.5) \times 10^{-3}$ mS/cm and the lowest EC value of soil originates from Wonosari, which is $(122 \pm 0.5) \times 10^{-3}$ mS/cm. In the opinion conveyed by Nelson (2003) it is explained that the effective growth of tomato plants is in the range of EC values between 0.25 mS/cm to 0.5 mS/cm and the optimal growth of tomato plants is at EC value of 0.28 mS/cm.

The highest element of N in the soil comes from Yogyakarta, which is 264.680 ± 0.005 ppm and the lowest element of N in the soil comes from Wonosari, which is 96.200 ± 0.005 ppm. According to Nelson (2003) the effective growth of tomato plants is in the range of N element values of 250 ppm to 500 ppm and the optimal growth of tomato plants is in the range of N element of 260 ppm in the soil.

Table 1. Results of pH, Electrical Conductivity, and Nitrogen Content Measurements

Soil	pH (± 0.005)	EC (mS/cm) (± 0.5) × 10^{-3}	N (ppm) (± 0.005)
Yogyakarta	5.380	284	264.680
Kulon Progo	5.700	256	228.100
Bantul	6.380	158	212.930
Sleman	6.590	124	198.750
Wonosari	6.630	122	96.200

Based on the above measurement results, the pH, EC, and N element of the soil samples affect the growth of the tomato plants studied. The growth of the tomato plants in the form of plant height, stem diameter, leaf length, and leaf width are the highest for tomato plants using soil samples from Yogyakarta with pH approaches the optimal pH value. In addition, the EC of the soil is (284.0 ± 0.5) × 10^{-3} mS/cm, which is close to the optimum value of soil EC for the growth of tomato plants. Finally, the N element is 264.680 ± 0.005 ppm which approaches the optimal N element for the growth of tomato plants.

According to Benton (2001) if the soil has a pH less than 7 or the soil is acidic, then the more H^+ ions are contained in the soil. Therefore, the soil's EC will be greater because the NO_3^- ions will be absorbed by the plant [15]. In line with the theory's view, the results of measurements of pH, EC, and N elements values in the soil are suitable for tomato plant growth in the form of plant height, stem diameter, leaf length, and leaf width of tomato plants.

4. Effect of pH, EC, and N content in the soil towards tomato plants height

According to the measurement results of pH, EC, and N elements in soil samples used as planting media in this study, the effect on height of tomatoes for one month or 4 weeks can be shown in Figure 3.

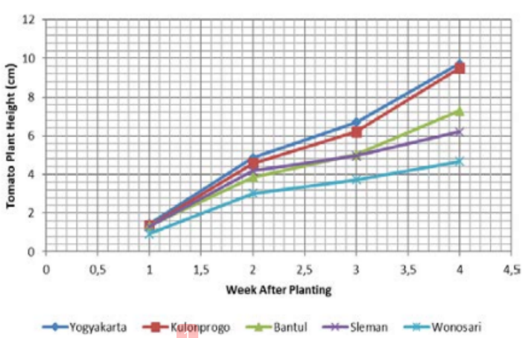

Figure 3. Graph of the effect of pH, EC, and N element in the soil on tomato plant height.

Measurements on the height of tomato plants planted using soil samples from cities in the Special Region of Yogyakarta were carried out every day for four weeks. It may be observed in Figure 3 that the highest height of tomato plants is grown from Yogyakarta 9.7 ± 0.4 cm and the lowest was from Wonosari 4.67 ± 0.35 cm.

Meanwhile, the growth of tomato plant height in the second and fourth weeks for tomato plants grown from Bantul and Sleman soil samples experienced a change in their profiles. During the second week tomato plants from Sleman are higher than Bantul, but for the fourth week the reverse is true. This is because the value of the N element of the two soils is almost the same, i.e.: 212.930 ± 0.00 ppm and 198.750 ± 0.005 ppm for Bantul and Sleman, respectively. This happens because tomato plants need NO_3^- and H^+ ions to accelerate growth.

5. Effect of pH, EC, and N content in the soils on tomato leaf length

The measurement results show that pH, EC, and N elements in soil samples used as planting media in this study affect the length of tomato plant leaves. This may be observed in Figure 4. Figure 4 shows that the highest growth of leaf length of tomato plants is planted from Kulon progo and Yogyakarta that is around 3.44 ± 0.01 cm, and the lowest is from Wonosari, which is 2.11 ± 0.01 cm.

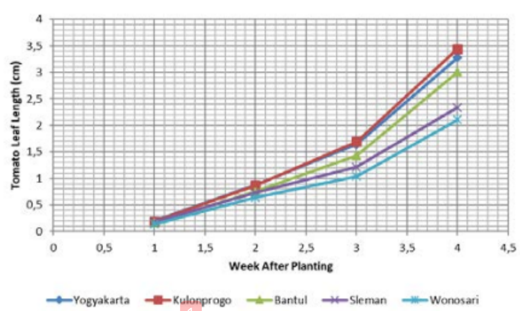

Figure 4. Graph of the effect of pH, EC, and N element in the soil on tomato leaf length.

6. Effect of pH, EC and N element in soils on tomato leaves width

The effect of pH, EC, and N elements of the soil on the width of leaves of tomato plants for one month or four weeks can be shown in Figure 5. Based on Figure 5, it can be seen that the highest growth of leaf width of tomato plants is planted from Yogyakarta, which is 1.40 ± 0.03 cm and the lowest is from Wonosari, which is 0.94 ± 0.02 cm.

Meanwhile, the growth of leaf width of tomato plants in the third and fourth weeks for tomato plants grown from Bantul and Kulon Progo soil samples experienced a change in their profiles. In the third week the leaves of tomato plants from Bantul are wider than Kulon Progo, but for the fourth week it is vice versa.

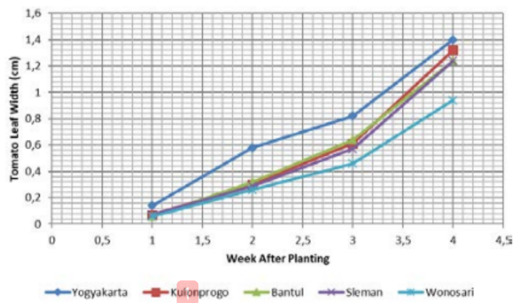

Figure 5. Graph of effect of pH, EC, and N element in the soil on tomato leaf width.

7. Effect of pH, EC, and N element in the soils on tomato stem diameters

Based on the measurement results, the pH, EC, and N element in the soil samples used as planting media in this study affect the stem diameter of tomatoes for one month or four weeks, which can be shown in Figure 6. It may be observed fro Figure 6 that the growth of the stem diameter is almost the same for all tomato plants grown in all cities, i.e. around the values of 0.3 cm up to 0.38 cm. However, at the end of the planting, i.e.: at the fourth week, it may be observed that the stem diameter of the tomato plants from Yogyakarta is the highest, whereas it is the lowest for the tomato plants from Wonosari.

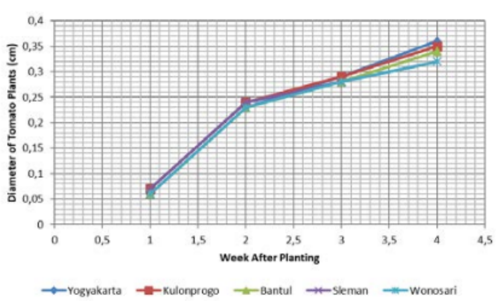

Figure 6. Graph of effect of pH, EC and N element in soil on tomato stem diameter.

8. Conclusions

This research shows that the growth of tomatoes planted using soil samples from the city of Yogyakarta in terms of plant height, leaf length, and leaf width resulted in a more optimal growth than the growth of tomatoes planted using soil samples from the other four cities. This is because the soil from the city of Yogyakarta has the most suitable and optimal pH, EC and N elements for the growth of tomato plants. In addition, the pH, EC, and N element values do not significantly affect the growth of stem diameter of tomato plants in all cities.

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