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Monitoring of maize root growth on N, P, and K fertilization using rhizotron

Pemantauan pertumbuhan akar jagung pada pemupukan N, P, dan K dengan menggunakan rhizotron

Fajrin Pramana Putra*, Roni Ismoyojati

Departement of Plantation Production Technology, Politeknik Lamandau, Lamandau, Indonesia

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ABSTRACT

Maize roots will show varying growth responses to the type of fertilizer given. The objective of this study was to determine the effect of N, P, and K fertilizers on the growth of maize roots and the function of the relationship between root dry weight and shoot dry weight of maize under rizhotron. The research was conducted in April - June 2019 at the screen house and Plant Laboratory, Politeknik Lamandau in Lamandau Regency. The research was conducted in rizhotron's growth medium which was arranged in a completely randomized design (CRD) with a fertilizer treatment consisting of urea (N = 200 kg ha^{-1}), SP36 (P = 100 kg ha^{-1}), KCl (K = 100 kg ha^{-1}), and control (without fertilizer) with three replications. The results showed that N fertilizer was able to provide better root dry weight growth compared to P and K fertilizer, namely 2.59 g. Root dry weight has a significant effect on plant dry weight gain based on the function of y = 4.10x + 0.06 (R^2 = 0.96 **).

INTRODUCTION

Fertilization is an activity that is closely related to plant growth and yield. This activity gives optimal results depending on several factors, one of which is the type of fertilizer used. Types of fertilizer N, P, and K are widely used to assess crop growth and yield responsiveness because they are included in macronutrients (Ismoyojati et al., 2020). Crop growth occurs at the above-ground (shoot) of the plant and occurs at the below-ground (root) of the plant. Roots are the main organs in crops to absorb and transport nutrients to the leaves (Mohd-Radzman et al., 2013).

N deficiency is more likely to promote N accumulation at the same root surface area level (Xiaoli et al., 2020). Nitrogen plays a vital role in root growth. Root growth is significantly affected by N fertilization, such as enhanced root length and root biomass (Fan et al., 2010; Gaudin et al., 2011). The optimal application rate of N fertilizer can increase the distribution of roots in the soil layer (Zhang et al., 2017). The effects of P on root growth present conflicting results among the studies on container crops. According to (Kim & Li, 2016), P fertilizations primarily stimulate root growth, while other studies reported that no effect on root growth (Ristvey et al., 2007). K-deficiency inhibited the root growth, such as the total length, root surface area, root diameter, and root volume of the root system (Du et al., 2017).

Roots are an essential part of crop growth, and root growth will affect canopy growth and yield (Ota et al., 2020; C. Wang et al., 2014). Root growth is determined by the amount of dry matter that is transferred from the source to the root (sink) (Kumar et al., 2015). When the dry matter is limited, the existing dry matter will be used by crop tissues that are closest to the location of photosynthesis. Therefore roots receive dry matter only when there is excess dry matter produced through photosynthesis which is not used for shoot growth (Kumar et al., 2015).

*Corresponding Author
E-mail: fajrin.pramana.p@gmail.com

The limited amount of dry matter formed is influenced by many factors, and one of the factors is nutrient deficiency. Roots show varying variations in morphological responses to nutrient deficiency (Aguirrezabal et al., 1994; Artacho & Bonomelli, 2016; Trachsel et al., 2013).

Visually viewing root growth is challenging to obtain in the field. It takes a special tool that can be used to see root growth, namely rhizotron, visually. Rhizotrons are soil-filled plant growing areas with transparent glass sides, allowing for analysis of root growth (Huck & Taylor, 1982; Klepper & Kaspar, 1994). It can be used to visualize the root system (root system architecture and root growth dynamics) of various plant species grown in rhizotrons based on the treatments tested (Agustina et al., 2010; Huck & Taylor, 1982).

For this reason, it is necessary to study root growth patterns at different fertilizers to be able to support better plant growth and development, so that objective of the study was to determine the effect of nutrients N, P, and K on the root growth of maize under rhizotron and function of the relationship between root dry weight and shoot dry weight of maize.

MATERIALS AND METHODS

The research was carried out in April - June 2019 at the screen house and Plant Laboratory, Politeknik Lamandau in Lamandau (2°09'57.8"S 111°25'55.2"E). The tool used is a ruler and rhizotron. Rhizotron made of transparent glass with a size of 10 cm x 25 cm x 3 cm as filled by Muljanto (1994). The research materials were a sweet boy variety of maize, inorganic fertilizers in the form of urea, SP-36, and KCl.

The research used was a completely randomized design (CRD) with fertilization treatment consisting of urea fertilizer (N = 200 kg ha^{-1}), SP36 (P = 100 kg ha^{-1}), KCl (K = 100 kg ha^{-1}), and control (without fertilizer) with 3 repetitions. Application of urea 200 kg ha^{-1} is given 1/3 part at planting and 2/3 parts at two weeks after planting, SP36 100 kg ha^{-1} is given at planting, KCl 100 kg ha^{-1} is given two times, namely 1/3 at planting and 2/3 at the generative phase (Anonymous, 2016; Krismawati & Firmansyah, 2005). After planting, the rhizotron is placed in an oblique position with an inclination of 45°.

The variables observed were root length (cm), the number of roots, root surface area (cm^2), root weight per soil depth (g), root dry weight (g), and crop dry weight (g). The measurement of root and crop was done at the age of 60 DAP.

The root data obtained were analyzed using analysis of variance (ANOVA) based on a completely randomized design using ms. Excel macro add-ins (DSAASTAT version 1.101) at an error rate of 5% and will be further tested with the Tukey test (HSD) if the analysis of variance shows a significant difference (Onofri & Pannacci, 2014). To determine the function of the relationship between root dry weight and shoot dry weight, regression analysis was performed (Onofri & Pannacci, 2014).

RESULTS AND DISCUSSIONS

The results of the variance showed that the type of fertilizer treatment had a significant number of primary roots and the surface area of maize roots (Table 1). In urea fertilization, it was seen that it was able to provide better maize root growth, such as growth in the number of primary roots and root surface area that was better than SP-36, KCl, or without fertilization. However, the type of fertilizer did not significantly affect root length growth (Table 1). The same root length growth in this study was thought to be due to the factor of root lengthening in maize being inhibited by rhizotron media which limited root elongation.

Table 1. Root length (cm), the number of the primary roots, and root surface area (cm^2) plant on N, P, and K fertilization.

Treatment	Root length (cm)	The number of primary roots	Root surface area (cm^2)
Without fertilizer	28.54 a	5.33 c	98.55 c
Urea	25.71 a	10.67 a	305.91 a
SP36	31.02 a	7.67 b	174.42 b
KCl	26.54 a	8.33 b	167.13 b
CV (%)	20.67	16.92	29.09

Note: The numbers followed by the same letter in the same column are not significantly different based on the Tukey HSD test α 0.05.

Urea in this research is a source of nitrogen in the form of nitrate. In the crop, nitrate is also involved in several more complex processes, namely: 1) proliferation of the root system (formation of new roots); 2) respiration regulation; 3) other crop physiological changes. Specifically related to the root system, the effect of nitrogen is emphasized on the process of root system proliferation (Saito et al., 2014). There is an essential role of nitrate from urea fertilization for the root system (Desnos, 2008; Lynch, 2013). In this research, it was proven that the urea fertilization treatment had good results on the growth of the number of primary roots and the surface area of the roots. The fresh weight of the roots describes the crop's ability to absorb the solution from the soil. The higher the fresh weight of the roots, the higher the solution contained therein. The results of the variance showed that the type of fertilizer treatment had a significant effect on the fresh weight of maize roots (Table 2). Fertilization using urea seems to give better root fresh weight results than SP36 and KCl fertilization at 5-35 cm depth soil level. The nitrogen contained in urea fertilizers directly has a significant effect on the growth and development of the root of maize (Y. Wang et al., 2019; Yang et al., 2019). Its shows that the role of nitrogen is vital in crop development. It can be seen that fertilization using urea provides better root growth and development compared to other treatments (Figure 1).

Table 2. The fresh weight of root based on soil depth (g)

Treatment	The fresh weight of root based on soil depth (g)						
	5 cm	10 cm	15 cm	20 cm	25 cm	30 cm	35 cm
Without Fertilizer	0.22 b	0.05 b	0.04 b	0.03 c	0.03 b	0.04 b	0.09 c
Urea	1.87 a	0.57 a	0.42 a	0.44 a	0.56 a	0.32 a	0.49 a
SP36	0.32 b	0.13 b	0.11 ab	0.09 c	0.07 b	0.08 b	0.10 c
KCl	0.53 b	0.13 b	0.24 ab	0.27 b	0.07 b	0.07 b	0.26 b
CV (%)	13.28	40.03	14.66*	10.23	27.51	32.90	8.07

Note: The numbers followed by the same letter in the same column are not significantly different based on the Tukey HSD test α 0.05 and (*) root transformation with $\sqrt{x + 0.5}$

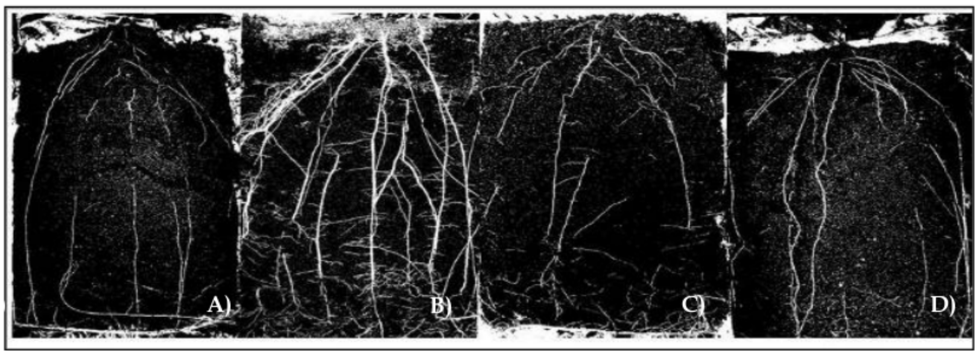

Figure 1. The appearance of maize root on fertilization treatment on 60 day after planting: A) Without fertilization, B) Urea, C) SP-36, D) KCl.

The results of variance show that the type of fertilizer treatment has a significant effect on root dry weight and crop dry weight (Table 3). Fertilization using urea fertilizer gives better results than SP36 and KCl fertilization; this shows that the solution containing water, and nutrients, especially nitrogen, is successfully absorbed by the crop roots, which are then synthesized and accumulated into plant dry weight. The increase in root dry weight can increase crop dry weight because the amount of nitrogen that can be used in the photosynthesis process to form crop dry matter will increase. The assimilates are produced by the photosynthesis process. The crop will use it for the growth and development of crop vegetative organs. Giving nitrogen at the optimum dose can increase crop growth, increase protein synthesis, chlorophyll formation, and increase the root-canopy ratio (Rasyid et al., 2010).

Table 3. Root Dry weight (g) and crop dry weight (g)

Treatment	Root dry weight (g)	Crop dry weight (g)
Without Fertilizer	0.34 c	1.57 c
Urea	2.59 a	11.05 a
SP36	0.58 bc	2.34 b
KCl	0.69 b	2.47 b
CV (%)	9.39	17.63

Note: The numbers followed by the same letter in the same column are not significantly different based on the Tukey HSD test α 0.05

There is a close relationship between the addition of root dry weight and crop dry weight (Figure 2). An increase followed the increase in the root dry weight value in the dry weight value of the crop. Shoot growth is identical to how the root growth process occurs. When the crop roots are able to grow optimally, it will be followed by optimal shoot growth. It can be shown in the function Y = 4.10x + 0.06 (R^2 = 0.96), where Y is the shoot dry weight and X is the root dry weight. Root growth is affected by many factors, namely environmental stress such as drought and flooding stress. The most important is the nutrient adequacy factor used for crop metabolic processes. The root dry weight data shows that crops given N fertilizer can increase dry matter accumulation. This dry matter accumulation can be thought to be due to the uptake of N by plant roots so that it is able to form dry matter through the photosynthesis.

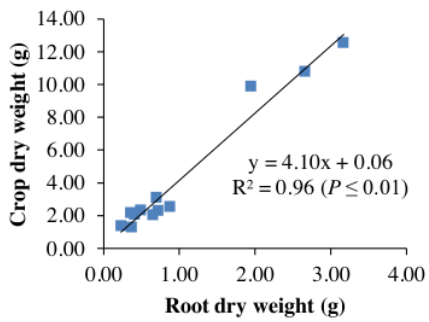

Figure 2. The relationship between root dry weight (g) and crop dry weight (g).

Direct application of urea fertilizer with the right dose can increase the nitrogen content in crop tissue (Ismoyojati et al., 2020; Putra et al., 2019; Putra et al., 2019). The development of crop tissue is mostly determined by the availability of nutrients, especially nitrogen. The availability of sufficient nitrogen means that crop will form fast vegetative parts because the meristem tissue that will carry out cell division, extension, and enlargement of cells needs nitrogen to create new cell walls and protoplasm (Bell et al., 1966; McGrath et al., 2014; Schöll & Nieuwenhuis, 2004).

CONCLUSIONS

Nitrogen (N) can provide growth in root length and root surface area of maize. The good growth of root dry weight on nitrogen (Urea) compared to phosphorus (SP-36) and potassium (KCl), namely 2.59 g. Root dry weight has a significant effect on crop dry weight gain based on the fu nction of y = 4.10x + 0.06 (R^2 = 0.96**). In this research used a small rhizotron dimension, so that it was not optimal in observing the root growth of maize because of limited space for root growth.

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