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Response of Corn (*Zea mays*) Growth and Yield to Urea Fertilization Techniques on Vertisol in Playen, Gunungkidul

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ABSTRACT

Corn production can be increased by proper urea fertilizers. Fertilization techniquescommonly used by farmers are broadcast and deep placement. However, both techniques can lead to faster urea loss because urea is easily changed to ammonium (NH_4^+) then changed to ammonia (NH_3), which leads to volatilization or leaching. This study aimed to compare urea fertilization techniques commonly used by farmers and to determine their effects on the growth and yield of corn on Vertisol during rainy season. The research was arranged in randomized complete block design (RCBD) with fertilization techniques as treatments and four blocks as replications. The treatments were without urea application (N1), deep placement technique (N2), and broadcast (N3). The urea dose was 348 $kg.ha^{-1}$, obtained from soil sampling analysis. The variables observed include (1) climatic condition, (2) physical and chemical properties of soil, (3) plant height, (4) effect of N fertilization on root and shoot, (5) chlorophyll content and nitrate reductase activity, and (6) yield. The data were analyzed using Analysis of Variance (ANOVA) at α= 5% levels and continued to be analyzed using Duncan Multiple Range Test (DMRT) at 5%. The results showed that the fertilization techniques significantly affected all variables. Deep placement (N2) and broadcast (N3) technique gave different effect only on N content in the leaf, which was 3.31% (N2) and 2.16% (N3), and also on the plant height. Based on this research, farmers still use broadcast technique since it is more efficient in terms of time and energy.

Keywords: fertilization method, nitrogen, broadcast, buried into soil, agronomical efficiency.

INTRODUCTION

National corn needs is reaching 8.6 million tons per year or around 665 thousand tons per month. Corn production in Indonesia in 2011–2015 is equal 48.88 $ton.ha^{-1}$ (Hanifah *et al*., 2018). The production of corn can be improved by some practices, among them, through fertilization and extensification. According to Diana *et al*. (2013), corn farmers usually fertilize their crops using urea because the content of Nitrogen (N) in urea is quite high, reaching 46%. Corn can be grown on a variety of soils, including Vertisol with appropriate N fertilization techniques.

According to Prasetyo (2007), Vertisol is a type of soil that is dark gray to black and dominated by montmorillonite clay spreading evenly on each of its horizon. Vertisol is one of ordo in soil taxonomy, which expands when swelling due to wet condition and becomes cracked when dry (Utomo, 2016). Vertisol surface is inundated during rain, causing anaerobic conditions. Urea fertilizer given under anaerobic conditions is not easily changed into ammonia (NH_4^+), due to the less urease activity. Zakaria *et al*. (2008) state that Vertisol has high nutrient content although the nutrient is unavailable yet for crops.

Therefore, the management of soil fertility through fertilization must be considered so that the soil can support the growth and yield of crops. The fertilization technique is one of the factors controlling the availability of elements from the fertilizer to the crops. This study aimed to compare urea fertilization techniques commonly used by farmers and to determine their effects on the growth and yield of corn on Vertisol during rainy season.

MATERIALS AND METHODS

The study was conducted in Gading VII, Playen District, Gunung Kidul Regency, from October 2016 to January 2017 (rainy season). Materials used were corn seeds and urea. The field experiment was arranged in a Randomized Complete Block Design (RCBD) with single factor and four blocks as replications. The factor was urea fertilization technique. There were three techniques of urea fertilization, namely without urea fertilization (N0), deep placement technique (N1), and broadcast of urea (N2). Deep placement technique is fertilization technique by burying the fertilizer in the soil. Meanwhile, broadcast is fertilization technique by spreading the fertilizer to the soil surface. The total plots were twelve, and each plot had an area of 12 m^2. The urea dose was determined from soil analysis, which was 348 $kg.ha^{-1}$, applied two times at 2 and 4 weeks after planting. The observation were made on several variables, including (1) climatic condition, (2) physical and chemical properties of soil conducted at before and after observation, (3) plant height, which was observed for 8 weeks, (4) effect N fertilization on root and shoot at 8 weeks after planting, (5) chlorophyll content and nitrate reductase activity on day 75 or in generative phase of seed filling, and (6) yield.

The chlorophyll content was measured based on Hendry and Grime (1993) method (Lestari *et al*., 2008). The observation of nitrate reductase activity was made based on Hartiko (1991) method. The agronomical efficiency was calculated based on the formula from Fageria *et al*. (2005).

The data were analyzed using Analysis of Variance (ANOVA) with α = 5 %. If there was a significant difference between treatments, the data were continued to be analyzed using Duncan Multiple Range Test (DMRT) at α = 5%.

RESULTS AND DISCUSSION

Climatic condition

High rainfall can be a factor causing the loses urea due to leaching to be higher than the loses of urea due to evaporation (Figure 1).

Physical and chemical properties of soil

Physical and chemical properties of the soil layers at 0–20 cm depth at the study sites are presented in Table 1. Vertisol of Playen Gunung Kidul has a

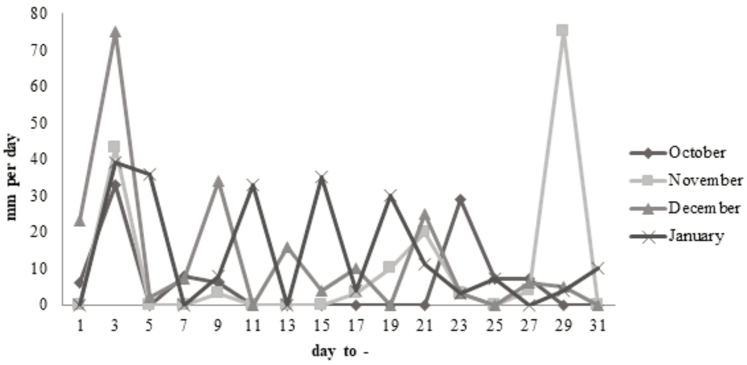

Figure 1. Rainfall (mm/day) during the study period (October 2016–January 2017) in Playen, Gunung Kidul. (Data source: BPP Playen)

Table 1. Physical and chemical properties of vertisol Soil Gunung Kidul before treatment

No.	Test paramter	Vertisol soil	Method
1	Texture		Hydrometer
	Sand (%)	14	
	Dust (%)	31	
	Clay (%)	55	
2	Soil pH (H_2O)	5.67	pH meter 1 : 5
3	C-Organic (%)	0.98	Walkly and black
4	N-total (%)	0.04	Kjeldahl
5	CEC (cmol (+). kg^{-1})	19.86	Distillate

Source: Soil analysis by BPTP Yogyakarta, (2016)

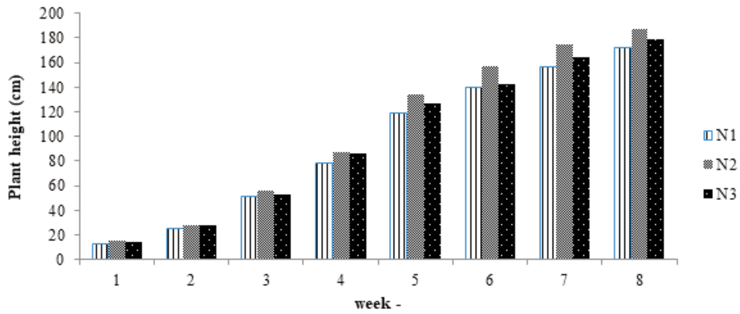

Figure 1. Rainfall (mm per day) during the study period (October 2016–January 2017) in Playen, Gunung Kidul. (Data source: BPP Playen)

Table 2. The effects of N fertilization method to the N total (%)

Treatment	N total
N1	0.01 b
N2	0.10 a
N3	0.10 a

Remarks: Means followed by the same letters in the same column are not significantly different based on F test and DMRT at α= 5%.

slightly silty clay texture with an acid pH and has low total N contents. Thus, it is expected that urea application at the optimum dose can increase the productivity of corn in that area.

The result of total N of soil after research is presented in Table 2. The total N content of the soil increased by 0.6. The N element in the soil can't be stored because it is mostly utilized or lost.

Nitrogen is exploited by the crops and sometimes lost due to leaching. A lot of total N is accumulated on the soil surface, hence with this dispersion processes, soil erosion and total N lost due to the erosion are increased (Tando, 2018).

Figure 2 shows that deep placement technique (N2) gave better results when compared with broadcast technique (N3) and without urea fertilization (N1). Yanti *et al*., (2014) suggested that nitrogen is the most captivating element in relation to plant growth.

Effects of N fertilization on root and shoot

Biomass is the accumulation of photosynthetic products and nutrient uptake in the form of organic compounds that make up the entire tissues in vegetative and generative plants (Bidwell, 1979) in the form of fresh and dry weight. Fresh weight measurement was made when the crops were just harvested to minimize water loss.

Fresh root weight is used to determine the ability of plants to absorb water (Torey *et al*., 2013). Based on Table 3, the corn plants in N1 treatment had the lowest root fresh weight, while there was no significant difference between the plants in N2 and N3 treatment. The addition of N through fertilization will stimulate root growth and increase plant root weight (Fahmi *et al*., 2010). Dry root weight indicates the ability of plant to absorb water. The objectives of drying are

Table 3. The effects of N fertilization method to the root fresh and dry weight, root volume, shoot fresh and dry weight

Treatment	Fresh root weight (g)	Dry root weight (g)	Root volume (cm^3)	Fresh shoot weight (g)	Dry shoot weight (g)
N1	208.25 b	51.77 b	45.00 b	550.25 b	63.16 b
N2	278.25 a	74.17 a	55.00 a	804.50 a	297.66 a
N3	261.25 a	59.8 ab	53.75 a	711.25 ab	189.73 ab

Remark: Means followed by the same letters in the same column are not significantly different based on F test and DMRT at α= 5%.

Table 4. Chlorophyll, nitrate reductase activity

Treatment	Chlorophyll content* ($mg.g^{-1}$)	Nitrat reductase activity* (μ mol $NO^{2-}.g^{-1}.h^{-1}$)
N1	0.12 b	6.54 b
N2	3.91 a	15.77 a
N3	2.86 a	13.26 a

Remark: Means followed by the same letters in the same column are not significantly different based on F test and DMRT at α= 5%. *Transformation of Chlorophyll content and Nitrate Reductase Activity was performed with formula of √+1.

Table 5. Nitrogen content in stems, roots and leaves of plants (%) weight

Treatment	N Stems	N Roots	N Leaf
N1	0.12 b	0.46 b	0.52 c
N2	1.75 a	1.58 a	3.31 a
N3	1.34 a	1.65 a	2.16 b

Remark: Means followed by the same letters in the same column are not significantly different based on F test and DMRT at α= 5%.

Table 6. Seeds weight per cob, weight of 100 seeds and agronomical efficiency

Treatment	Weight of seeds per cob (g)	Weight of 100 seeds (g)	Agronomical efficiency ($kg.kg^{-1}$)
N1	421.30 b	0.53 b	0 b
N2	1678.40 a	38.14 a	0.58 a
N3	1163.12 a	20.32 a	0.37 a

Remark: Means followed by the same letters in the same column are not significantly different based on F test and DMRT at α= 5%.

to remove all water content and stop the activity of plant metabolism (Sitompul and Guritno, 1995). The data showed that N1 treatment produced the lowest dry root compared to N2 and N3.

Crops that have high root volume are able to absorb more water, therefore, they are able to survive under water shortage. N1 treatment resulted in the smallest root volume, compared to N2 and N3. The higher root volume leads to higher capacity to absorb water and nutrients.

The fresh and dry shoot weight of plants without fertilizer is lower compared to with urea application. Sufficiently available N elements result in optimum vegetative growth, resulting in an increase in fresh weight (Salisbury and Ross, 1995).

Chlorophyll content and nitrate reductase activity

Mengel and Kirkby (1987) suggested that increased N and Mg content may increase chlorophyll formation. Magnesium is the core of the chlorophyll arrangement, and N plays role as the connector with the pyrrole ring. Nitrogen uptake and chlorophyll content can increase the rate of photosynthesis, which will then increase the yield of the plant.

Nitrate reductase is a nitrogen assimilation regulating enzyme in plants, which is controlled by light/dark changes. Although the response of nitric reductase activity to light/darkness may vary with each species, it is generally higher in light than dark condition. Light increases the activity of nitrate reductase by speeding up the nitrate uptake (Puranic and Srivastava, 1985).

Based on Table 4, the application of N fertilizer on plants had an effect on the chlorophyll content in leaves. Total chlorophyll content of plants treated with N2 and N3 was not significantly different. However, N1 significantly gave produced lower chlorophyll content compared to N2 and N3. Deep placement technique (N2) provided opportunity for the root to absorb nutrients N more quickly and maximally so that it can soon be utilized by plants.

Nitrate reductase is a nitrogen assimilation regulating enzyme in plants, which is controlled by light/dark changes. According to Table 4, the activity of nitrate reductase in N2 was not significantly different from that in N3. However, N1 significantly showed lower nitrate reductase activity compared to N2 and N3. The application of urea or N fertilizer can increase the activity of nitrate reductase in plants. Deep placement technique (N2) in the Vertisol soil will facilitate the roots in absorbing nutrients because they are in the vicinity of the root zone. Engelstad (1997) suggested that if NH_4^+ is added to the soil, it will initially react with cation exchange complexes to become absorbed on the surface of the clay particles. Their mobility is reduced, and the crop taking is limited to the NH_4^+ absorption of the solution, which is in equilibrium with NH_4^+ at exchange complex. The environmental conditions supporting the aerobic biological activity of most of the available NH_4^+ soils will be converted to a more mobile form of NO_3^-.

Yield

Nitrogen content analysis was carried out to determine nitrogen uptake in plant parts. Based on Table 5, total N content in the stems and roots of corn treated with N2 and N3 was not significantly different. However, N3 treatment produced higher N content in the leaf (3.31%).

The higher the plant dry weight the higher the assimilation. The application of urea fertilizer (N2 and N3) significantly produced better yield compared to without urea application (N1). However, there was no significant difference between the fertilization techniques. According to Nurcahya (2017), N fertilization increases the weight of the cob with husks, the weight of the cob without husks, and the weight of the seeds per plant. Corn, as a carbohydrate grain crop, needs a lot of nitrogen, thus, the application of N fertilization is very influential on the quantity of seeds. The N fertilization is always associated with an increase in photosynthetic rate (Dwyer *et al.*,1995).

The observation of agronomical efficiency was performed to identify and measure the difference in absorption and to determine the efficiency of the loss of N fertilizer (Fageria *et al*., 2005). There was no agronomic efficiency observed in N1 treatment because no fertilizer was given. Meanwhile, there was no significant difference between N2 and N3 in the agronomical efficiency. To improve the agronomical efficiency, it is necessary to improve the crop management, one of which is by adjusting the fertilizer doses to the recommended table on the targeted yield.

CONCLUSIONS

Fertilization gave a better effect on the crops compared to without fertilization. Deep placement (N2) and broadcast (N3) technique significantly gave different effect on the N content in the leaf, which was 3.31% (N2) and 2.16% (N3) and on the plant height. Based on this research, farmers still use broadcast technique due to its efficiency in time and energy.

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