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Sources and Rates of Potassium for Drip Irrigation of Polyethylene-mulched Bean Production

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Abstract

Common bean is a type of vegetable that can be consumed in the form of young pods. Potassium is one of the macro nutrients needed to achieve maximum yield in common bean. Therefore this research is aimed at determining a suitable potassium source as well as an appropriate rate for drip irrigation in common bean using polyethylene mulch. The study was conducted from January to May 2018 at University Farm, IPB University. This experiment was set up as a nested randomized block design with two factors i.e. potassium sources as the main factor (KCl, ZK, and NPK), and potassium rates (0, 37.5, 75, 112.5, 150 kg of K_2O per ha). Fertilizer rates were nested in the main factor and fertilizers were applied Fetilization through a drip irrigation fertigation system with emitters placed close to the roots of plants. Fertilizer sources had significant effects on the variables of growth and bean yields. NPK resulted in a better growth and yield compared with KCl and ZK. Fertilizer sources that have very significant effect were likely related to the shape and solubility of the fertilizers, the ease of application, and also completeness of nutrient content in fertilizer. Based on the pod weight per plot, the productivity per hectare of bean pods produced in this study reached 7.52 $ton.ha^{-1}$. Potassium (K_2O) rate did not have significant effects on the variables of growth and yields of the bean.

Keywords: fertigation, fertilizer, *Phaseolus vulgaris*, pod weight, yield and yield components

Introduction

Common bean (*Phaseolus vulgaris* L.) is an introductory crop in Indonesia. Common bean originates from western Mexico-Guatemala (Kay, 1979). Common bean pods can be consumed in the form of young pods; young bean pods have a sweet taste which make them suitable for vegetable consumption. Common beans have a fairly high nutrient content, i.e. every 100 g of beans contains 35 g of calories, 2.4 g of protein, 0.2 g of fat, 7.7 g of carbohydrates, 65 g of calcium, 44 g of phosphorus, 1.1 g of iron, and water 88.9 g (IPGRI, 2003).

Community demands for beans continue to increase along with population growth. The average consumption per capita from 2013 to 2015 had been increasing from 0.782, 0.826, 1.143 kg/capita/year (Pusdatin, 2017). On the other hand, the statistical data from Direktorat Jenderal Hortikultura (2018) showed that the production of bean vegetables has been declining from 2013 to 2016, by 327.38, 318.21, 291.31, 275.51 tons, respectively.

The expansion of productive land has not keep up with the increasing population growth. It is important to carry out agricultural intensification to increase production using more efficient water and fertilizer uses. One of the methods to increase efficiency of watering and fertilizer is by using fertigation system.
Weeds can reduce fertilizer intake and increase competition with the main crops for sunlight. Weeds can also be the host of plant diseases. The use of land cover or mulch could potentially solve these problems. One of the types of mulch that can be used is polyethylene. Bosland and Votava (2012) stated that the use of polyethylene mulch has several advantages, which are to increase the yield and quality of crop yields, accelerate fruit maturity, maintain moisture and soil structure, increase soil temperature (stable), reduce evaporation or evaporation of soil, suppress weed growth, reduce nutrient loss, reduce soil compaction, and control pests and diseases. The disadvantage is the increase in cost of production at the beginning of planting, and fertigation through drip irrigation can compensate for this initial cost. Mulched plant beds do not get rainwater directly, except when heavy rain floods the beds.

To obtain high-quality beans, the ideal growing conditions and cultivation techniques need to be maintained by supplying nutrients. Nutrients available in the soil are often insufficient, so additional fertilizers are necessary. The soil nutrient content varies, therefore the fertilizer requirements of each soil type are also different, indicating more specific research was needed to determine the optimum fertilizer rate.

Potassium (K) is very important to crops as it affects metabolic, physiological processes, and K is required in large quantity. In bean potassium can stimulate the growth of new shoots, and maintain efficient use of water by crops. Sumpena and Hilman (2000) stated that beans are very sensitive to potassium deficiency, which can cause slow and dwarf plant growth, decrease yields or number of pods, decrease in the quality of pods, reduced taste and nutritional content, and plant stems can break easily.

Determining the correct application method and source of fertilizers can increase bean production. A study by Sousa et al. (2013) showed that the conventional potassium fertilization rate of 65.80 $kg.ha^{-1}$ K_2O would provide an estimate of maximum productivity of peanuts of 1,092.22 $kg.ha^{-1}$, whereas fertigation at 69.39 kg $ha^{-1}.K_2O$ could increase production to 1,530.68 $kg.ha^{-1}$.

Potassium chloride (KCl) and potassium sulfate (ZK) provides a single nutrient, while NPK supplies macro nutrients N, P and K. Two types of KCl fertilizer are available, KCl 80 which has K_2O content of 60% in a form of red powder, and KCl 90 which has K_2O content of 90% in a form of white powder. ZK fertilizers in the market can be found in two types, i.e. ZK 90 with K_2O content of 50% and ZK 96 which K_2O content of 53%. ZK is in a form of white powder or granules (PT Pupuk Kujang, 2017). NPK has different compositions of nutrients. NPK 16-16-16, NPK 15-15-15, or NPK 12-12-12 indicate the percentage of macro nutrient content.

Research on potassium (K) fertilization in bean plants through fertigation with drip irrigation in the field has not been widely done. This study investigated three types of K fertilizer to determine the best source of K fertilizer and rates for fertigation through a drip irrigation system in common bean which were grown with polyethylene mulch.

Materials and Methods

Experimental Site

This experiment was conducted from January to May 2018 at University Farm, IPB University at an altitude of ±230 meters above sea level. The soil analysis before the experiment was carried out at the Testing Laboratory; pod nutrient content analysis was conducted at Post Harvest Laboratory of Department of Agronomy and Horticulture, IPB University.

Treatments

This experiment used nested randomized block design with two factors. The first factors were potassium source, i.e., KCl, ZK, and NPK 16:16:16. The second factors were potassium rates that consisted of five levels, i.e. 0, ¼X, ½X, ¾X, dan X. The X rate level is the nutrient content of K_2O in each fertilizer used. In this experiment, the fertilizer rate was nested in the main factor (source of fertilizer). The general recommendation for fertilization in beans consisted of Urea (46% N) at 300 $kg.ha^{-1}$, or 138 kg $N.ha^{-1}$, SP-36 (36% P_2O_5) at 200 kg ha^{-1} or 72 kg $P_2O_5.ha^{-1}$, and KCl (60% K_2O) at 250 $kg.ha^{-1}$ or 150 kg $K_2O.ha^{-1}$ (Puslitbanghorti, 2016). In total there were 15 combination of treatments with three replications i.e. 45 experimental units. Each experimental unit consisted of 20 plants so that the total population was 900 plants.

The materials used in this study were cultivar of common bean "Ladju", Urea fertilizer, SP-36 fertilizer, KCl fertilizer, ZK fertilizer, NPK 16 fertilizer, manure, insecticide/fungicide, and polyethylene mulch. Installation of drip irrigation systems was carried out by assembling components consisting of head units and in-field unit. The components of the head unit are reservoir, engine pump, pressure regulator (PRV), disc filter, venturi injector, PVC ball valve, PVC fitting, and PVC pipe fitting. Head unit was connected to the in-field unit component, i.e. LDPE line, dripline 16 mm, neple tee, elbow, check valves, and joiners. The experimental beds were 45 plots of 1.5 m x 5 m (7.5 m^2) each bed. The height of beds is 0.3 m and space between beds is 0.6 m. Total land area is 400 m^2.

Basic fertilizers were applied preplant (1 week before planting) before the installation of polyethylene mulch, consisting of 100% SP-36, 40% Urea, and KCl, ZK, and NPK according to the treatment (Table 1). Fertigation was carried out weekly from 1 to 7 WAP (weeks after planting), so that the percentage of N and K at each treatment time was 8.6%.

The growth variables measured were stem diameter (measured every week from 1 WAP to 10 WAP), number of days to 50% anthesis i.e. when 50% plant population per plot had flowering, and stomatal density i.e. when 50% plant population had flowering was observed on a sample of leaves as high as 1 meter above the ground. The number of stomata was determined using a microscope.

Table 1. The rates of fertilizer before planting and through fertigation with drip irrigation

Rate (kg K_2O. ha^{-1})	Preplant (g)					Drip irrigation (g)			
	SP-36	Urea	KCl	ZK	NPK 16	Urea	KCl	ZK	NPK 16
0	150.0	90.0	-	-	-	135.0	-	-	-
37.5	150.0	90.0	18.8	22.5	70.3	135.0	28.1	33.8	105.5
75.0	150.0	90.0	37.5	45.0	140.6	135.0	56.3	67.5	210.9
112.5	150.0	90.0	56.3	67.5	210.9	135.0	84.4	101.3	316.4
150.0	150.0	90.0	75.0	90.0	281.3	135.0	112.5	135.0	421.9

Stomatal density was calculated using the formula:
SD = number of stomata / (π.r²)
where π = constant (3.14) and r^2 (radius of the field of view on 400x magnification)

The yield variables measured were pod number and pod length, pod weight per plant, and pod weight per plot (7.5 m^2) using the following formula:

$$= \frac{Total\ number\ of\ plants\ per\ plot \times pod\ weight\ of\ living\ plants\ per\ plot}{Number\ of\ living\ plants\ per\ plot}$$

Analysis of nutrient content of potassium in pods from the third harvest was measured using Atomic Absorbtion Spectrophotometer (AAS) using a method by Eviati and Sulaeman (2009). Measurements were made on two plants taken compositely from control (0 kg K_2O.ha^{-1}), medium rate of K_2O (75.0 kg.ha^{-1}), and highest rate of K_2O (150 kg.ha^{-1}).

During the course of the study weeds around the area of the crops were removed manually; insecticides to control caterpillar (*Plusia signata*/*Plusia chalcites*) and grasshoppers was sprayed when necessary.

Data Analysis

Data was analysed with ANOVA using the Statistical Analysis System (SAS) v 9.4 with a confidence interval of 95%. Separation between means were tested further with the Orthogonal Polynomial test to determine the pattern of the response. The interaction between treatments was tested using Combined Analysis using STAR (Statistical Tool for Agricultural Research) Nebula program. Correlation analysis to determine the relationship between observational parameters used Statistical Product and Service Solution (SPSS) v 23.

Results

General Condition

The result of soil analysis before the experiment showed a pH H_2O of 4.81 which is classified as acidic, and available K of 0.57 cmol kg^{-1}(high) (Table 2).

Based on BMKG data from the Darmaga Bogor Climatology Station the agroclimate zone from January to May the average temperature was 25.4-26.6°C with relative humidity (RH) was classified as high (81-86%) (Table 3). Rainfall was relatively high during the study. Based on Oldeman climate classification January and March are humid months, whereas February, April and May are wet months. The highest rainfall in April was 432.1 mm.

Stem Diameter

K fertilizer sources significantly increased stem diameter at 2 WAP, and the effects were highly significant at 4 and 6 WAP (Table 4). NPK produced crops with the largest stem diameter. K rates and their interaction with K sources did not significantly affect stem diameter (Table 4).

Table 2. The soil physical and chemical properties before experiment

Soil parameters	Extract	Value	Criteria
pH	H_2O	4.81	Acid
Organik carbon (%)	Walkley and Black	1.83	Low
Total N (%)	Kjeldahl	0.21	Medium
Available P (P_2O_5 ppm)	Bray I	103.92	Very high
Available K (cmol.kg^{-1})	NH_4OAc 1M pH 7.00	0.57	High
CEC (cmol.kg^{-1})	NH_4OAc 1M pH 7.00	19.00	Medium

Source: Analytical Laboratory of the Department of Agronomy and Horticulture of IPB

Table 3. The monthly agro-climate data *

Month	Average temperature (°C)	RH (%)	Rainfall (mm)	Rainfall criteria**	Light intensity (cal cm^{-2})
January	25.7	81	189.2	Humid month	311.5
February	25.4	86	358.9	Wet month	399.5
March	26.0	83	122.7	Humid month	597.4
April	26.3	85	432.1	Wet month	504.0
May	26.6	82	284.1	Wet month	519.0

Note: * BMKG-Climatology Station Darmaga Bogor; ** rainfall is based on Oldeman climate classification

Table 4. The average stem diameter at the various K sources and K rates fertilizer

Treatment	Stem diameter (mm) at weeks (WAP)				
	2	4	6	8	10
Source of K^x					
KCl	1.60 b	3.20 b	4.90 b	7.30 b	10.10 ab
ZK	1.70 ab	3.40 a	5.40 a	7.70 ab	9.40 b
NPK	1.90 a	3.70 a	5.80 a	8.60 a	10.90 a
F-test	*	**	**	*	*
Rate of K on the source of K (kg $K_2O.ha^{-1}$)					
0	1.70	3.40	5.30	8.10	10.50
37.5	2.00	3.50	5.50	8.20	10.30
75.0	1.70	3.40	5.40	7.80	10.00
112.5	1.60	3.40	5.10	7.30	9.70
150.0	1.50	3.40	5.50	8.30	10.20
Response^y	ns	ns	ns	ns	ns
K sources x rates	ns	ns	ns	ns	ns

^{x}The values followed by the same letter in the same column is not significant different at P<0.05 of DMRT; ^{y}Response regression by orthogonal polynomial test; ns : not significant, *: significant at P<0.05, **: significant at P<0.01.

Number of Days to 50% Anthesis

Days to anthesis was determined from the days required for 50% of the total population of plants to flower. Table 5 shows that K source and rates did not significantly affect the number of days of plants to flower. Flowering age of beans in this study ranged from 36.75 to 40.44 days after planting (DAP). Virisya (2014) research also showed that the number of days to 50% anthesis of beans was between 35-53 DAP.

Stomatal Density

Stomatal density is the number of stomata per unit area of view on a microscope. Almost all of the stomata at the bottom surface of the leaves was open at 50% anthesis. Table 5 shows that the source and rate of K fertilizer did not have a significant effect on the stomatal density with values between 336.31 to 397.45 mm^{-2}.

Yield Components

Table 6 shows that the sources of K fertilizer had very significant effects on crop yields, i.e. pod number per plant, pod length per plant, pod weight per plant, and pods weight per plot (Table 7), while the rate of K fertilizer and their interaction with K sources did not affect all yield variables.

NPK application resulted in the highest value for all yield variables (Table 6). The pod number of the plants treated with NPK was 33.73 per plant (Table 6) whereas the pod weight was 5,640 g per plot (Table 7), which was two times higher than pods from plants treated with KCl and ZK. The use of NPK increased the pod weight very significantly by 504 g per plant, which was almost five times more than the pods yield from the plants treated with other fertilizers.

Table 5. The number of days to 50% anthesis and stomatal density at the various K sources and K rates fertilizer

Treatment	The number of days to 50% anthesis (DAP)	Stomatal density (per mm^2)
Source of K[x]		
KCl	36.75	378.43
ZK	39.20	372.99
NPK	39.00	347.86
F-test	Ns	ns
Rate of K ($kg\ K_2O.ha^{-1}$)		
0	37.63	336.31
37.5	40.44	377.07
75.0	37.33	344.80
112.5	39.00	397.45
150.0	37.63	376.50
Response[y]	Ns	ns
K sources x rates	Ns	ns

[x]The values followed by the same letter in the same column are not significantly different at P<0.05 of DMRT;
[y]Response regression by orthogonal polynomial test; ns: not significant, *: significant at P<0.05, **: significant at P<0.01.

Table 6. Effect of different K sources and K rates on yield components of beans

Treatment	Pod number per plant	Pod length per plant (cm)	Pod weight per plant (g)
Source of K[x]			
KCl	13.16 b	12.18 b	123.02 b
ZK	16.20 b	12.25 b	185.60 b
NPK	33.73 a	13.44 a	504.00 a
F-test	**	**	**
Rate of K ($kg\ K_2O.ha^{-1}$)			
0	21.40	12.95	350.80
37.5	26.33	12.54	232.50
75.0	20.78	12.89	272.10
112.5	16.04	12.36	190.60
150.0	21.40	12.36	380.00
Response[y]	ns	ns	ns
K sources x rates	ns	ns	ns

[x]The values ber followed by the same letter in the same column is not significantly different at P<0.05 of DMRT;
[y]Response regression by orthogonal polynomial test; ns : not significant, *: significant at P<0.05, **: significant at P<0.01.

Table 7. The pods weight per plot (7.5 m^2) at different sources and rates of K

Treatment	Pods weight per plot (g)
Source of K[x]	
KCl	2,525 b
ZK	2,411 b
NPK	5,640 a
F-test	**
Rate of K (kg $K_2O.ha^{-1}$)	
0	4,248
37.5	3,234
75.0	3,568
112.5	2,874
150.0	4,339
Response[y]	ns
K sources x rates	ns

[x]The values followed by the same letter in the same column is not significant different at P<0.05 of DMRT;
[y]Response regression by orthogonal polynomial test; ns : not significant, *: significant at P<0.05, **: significant at P<0.01.

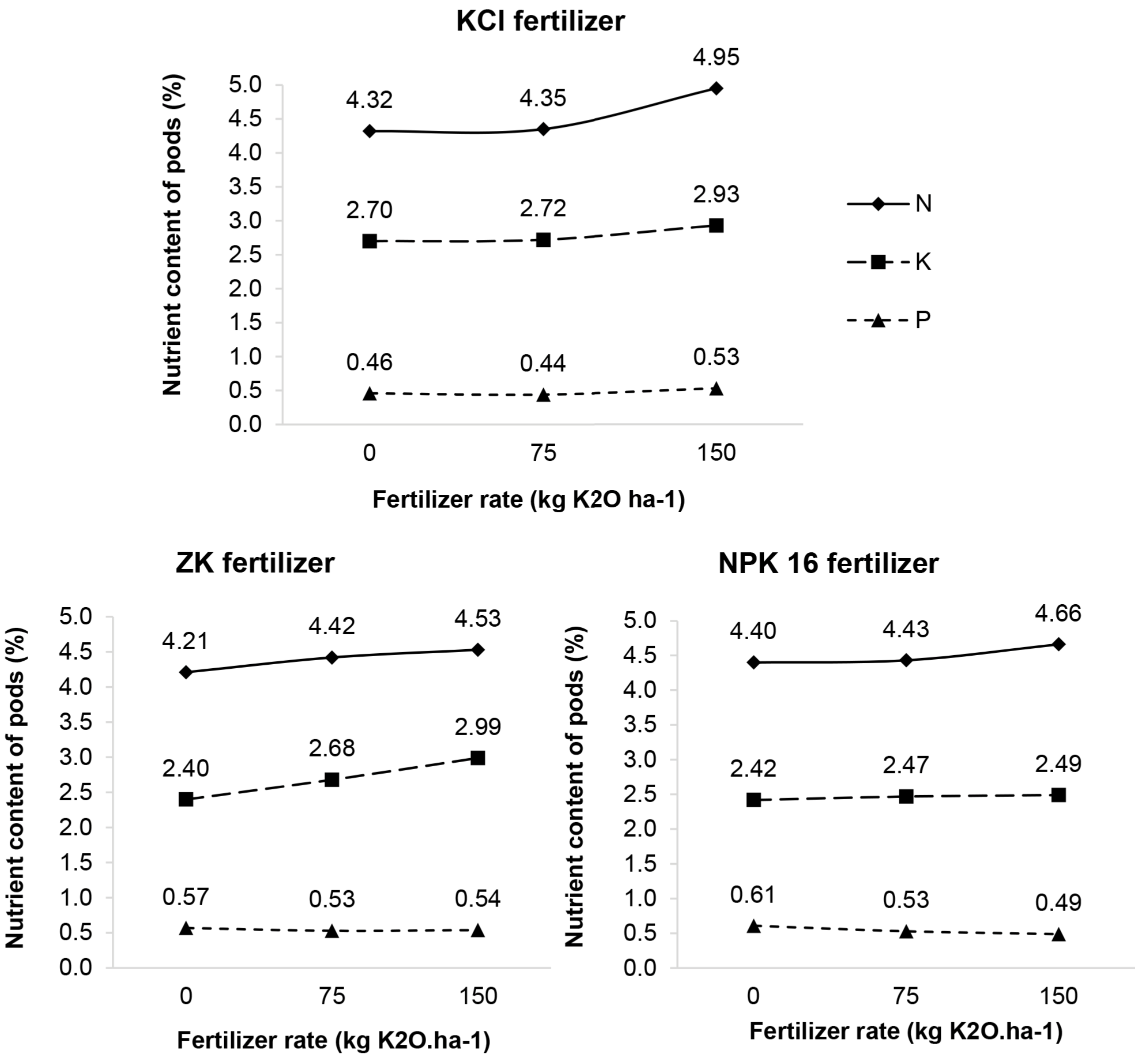

Figure 1. N, P, and K of the bean pods from different sources of fertilizer

Nutrient Content of Pods

Sampling for testing nutrient contents of pods was carried out from the third harvest from plants treated with three rates of potassium, i.e. control (0 kg $K_2O.ha^{-1}$), medium (75 kg $K_2O.ha^{-1}$), and highest (150 kg $K_2O.ha^{-1}$). Due to the limitation of the sample number, the data collection was carried out in a composite.

The average value difference of nutrient contents in plant pods with different sources of fertilizer (Figure 1) showed that an increase in K rate for each source of fertilizer tend to increase bean N and K, but not P. Bean N, P and K were 95%, 0.61%, and 2.99%, respectively.

Correlation Analysis of Plant Growth and Yield

Results of the correlation analysis showed that there was a relationship between plant growth variables and yields. Stem diameter at 6 WAP indicates the final phase of vegetative growth in plants, characterized by the emergence of flowers. Stem diameter 6 WAP had a positive correlation with pod number per plant, pod length per plant, pod weight per plant, and pod weight per plot (Table 8). Variables that was not significantly correlated with other variables was the number of days to 50% anthesis.

Farming Economic Analysis

In this study beans were harvested three times. The yield of this study was calculated from the average pod weight per plot in each fertilizer source treatment multiplied by 45 plots (in area of 400 m^2). KCl at 37.5 kg $K_2O.ha^{-1}$ resulted in pod weight of 3.92 kg per plot, whereas NPK at 150 kg $K_2O.\ ha^{-1}$ resulted in yield of 6.99 kg per plot (Table 7).

The results of the analysis showed that the highest R/C ratio was obtained from NPK, which was 1.69. The value of R/C ratio is the value of the comparison of revenues and costs incurred, and an agricultural business is considered feasible if the R/C ratio > 1.

Discussion

The different sources of K fertilizer have similar levels of K_2O. The total N and P_2O_5 from KCl and ZK treatment was 104 g N and 54 g P_2O_5 per plot, respectively, which are different from those from NPK treatment. However, there was no significant differences in the total N and P_2O_5 of the pods with each source of fertilizer. This could be caused by the high content of N and P_2O_5 in the soil.

Table 8. The result of Pearson correlation test for growth and yield variables

Variables	SD 6 WAP	NDA	PN	PL	PW
NDA	0.11				
PN	0.41**	0.13			
PL	0.38*	0.23	0.61*		
PW	0.56**	0.10	0.83**	0.65**	
PW per plot (7.5 m^2)	0.53**	0.15	0.70**	0.65**	0.72**

Note: Significant by correlation Pearson test; **: significant at P<0.01; *: significant at P<0.05
SD: stem diameter; NDA: number of days to 50% anthesis; PN: pod number per plant; PL: pod length per plant; PW: pod weight per plant.

Tabel 9. Farming economic analysis of bean production with drip irrigation

Source fertilizer	Pods weight per plot (kg)*	Price per kg (IDR)	Yield	Cost	Benefit	R/C ratio
KCl	3.92	12,000	2,116,800	2,190,997	(-) 74,197	0.97
ZK	3.48	12,000	1,877,040	2,219,677	(-) 342,627	0.85
NPK	6.99	12,000	3,769,800	2,232,717	(+) 1,537,083	1.69

Note: *obtained from the pod weight valueper plot multiplied by the number of plots (45 plots or 400 m^2).
The price of beans is assumed to be normal in the market, which is IDR 12,000 kg^{-1}. Investment in drip irrigation of IDR 328,567 is the result of the calculation of IDR 4,928,500 divided by 15. The drip irrigation is assumed to last for 5 years of use, or 15 growing seasons.

The high level of acidity of the soil in this research area might be the cause of the non-significant growth response in beans fertilized with KCl or ZK fertilizers. Legumes are very sensitive to soil acidity. ZK and KCl fertilizers contain 17% S and 2.5% Cl. Mikkelsen and Bruulsema (2005) reported that KCl and ZK fertilizers tends to reduce soil pH. Similarly, Starast et al. (2003) stated that fertilization using fertilizers containing sulfur and ammonium can reduce soil pH. Hydrolyzed sulfur and ammonium produce H^+ ions which caused soil pH to decrease.

NPK application resulted in better vegetative growth and yields compared to KCl and ZK. Research by Hamdani et al. (2019) regarding the sources and rates of K fertilizer applied through drip irrigation on chili also showed that NPK was a better choice compared to KCl and ZK. Futhermore, the same research also showed that NPK was the best source of nitrogen compared to Urea and ZA (Deli et al., 2019). The use of NPK resulted in the largest stem diameter. Balanced nutrient content of N, P_2O_5 and K_2O played a role in growth and increase in plant stem diameter. Gardner et al. (1991) stated that sufficient availability of macronutrients N, P, K, and water affected the growth of stem. Common bean that reached the age of 6 WAP have begun to flower, and at this stage the growth rate of the stem slowed down. This was due to photosynthate allocation to the generative organs,resulting in limited photosynthate distribution for leaves, stems, and roots. In generative stage the role of K elements was greater for fruit formation process (Du et al., 2006, Amisnaipa et al., 2009).

Hamdani et al. (2019) showed that in chilli higher rates of K reduced the number of days to 50% anthesis. Increasing the rates of K fertilizer can affect the acceleration of the growth rate which in turn affects the acceleration of the plant to enter the generative phase or flowering time. The sources and rates of K fertilizer, which did not affect number of days 50% anthesis in this study, was possibly due to the high soil K content. Karapanos et al. (2008) stated that time to flower is determined by many factors, including enviroment, cultivation management, and pests and disease infestation.

The sources and rates of K fertilizer did not influence leaf stomatal density, which was possibly related to high nutrient content of K in the soil. One of the function of stomata is to reduce water loss due to evaporation. State of the stomata which almost all opened at the time of observation showed that the availability of water and K+ ions for plants were sufficient (not experincing excessive evaporation). K plays a role in regulating stomata for CO_2 fixation in photosynthesis. Marschner (2012) states that the accumulation of K in guard cells increases cell osmotic pressure so that it can be absorb water from the surrouding cells. This causes turgor in the guard cell. K absorption can increase the pressure of the guard cell turgor so that it causes opening of the stomata which CO_2 fixation during photosyntesis. The research of Bhuvaneswari et al. (2013) showed that K fertilization can increase the durability of chili plants against water shortages and diseases and improve the quality of crop yields. The stomatal density in this study which ranged from 336.31 to 397.45 mm^{-2} was not much different from stomatal density in the lower surface of the leaves of cowpea were 301.81-387.18 mm^{-2} (Purnamawati et al., 2018). Futhermore, Liana (2019) also obtained stomatal density in cowpea ranging from 257.32 to 341.40 mm^{-2}.

In this study the pod harvests was carried out three times. Crops treated with NPK had the highest yield for all yield components. The result of research by Yusdian and Mulyadi (2017) showed that application of NPK 16 with a rate of 450 $kg.ha^{-1}$ in common bean produced the highest bean pods weight of 264.90 g per plant. NPK application in this study resulted in the pods weight reaching 504 g per plant, or 7.52 tons. ha^{-1}.The productivity of beans in this study is far below the national bean productivity which is 11.75 tons ha^{-1} (Direktorat Jenderal Hortikultura, 2018).

At the time of this research the amount of rainfall during the early flowering period during April was relatively high (432.1 mm), which might be the cause of the low yield in this study. High rainfall during flowering caused the flowers to fall, thus reduced pod formation. High rainfall also caused high humidity, a condition that is favourable for growth of *Fusarium oxysporum* that causes *Fusarium* wilt. *Fusarium* wilt infestation had been recorded since 3 WAP, and the percentage of infection reached 75% by the end of the experiment. The mycelium of *Fusarium* is in the form of white threads; it is soil-borne and infected the roots. This fungus attack was later demonstrated by yellowing of plants, wilting, and dwarfing (Srivastava et al., 2018). According to Souza et al. (2012) some bean crops can survive the attack, but will likely produce small number of fruits. It is important to check the soil condition prior to bean planting. In addition, the use of PGPR (Plant Growth Promoting Rhizobacter) biofertilizer could be tested as it was proven effective for inhibiting *Fusarium* growth, particularly in beans (Stanzin et al., 2018).

This research also tested the nutrient contents of plant pods, which were collected at the third pod yield. The bean pods had 4.95% N, 0.61% P, and 2.99% K. Islam et al. (2016) reported that N pods in the beans without fertilizer was 3.06%, whereas Beshir et al.

(2016) reportedthat the bean pods contained 0.48% P and 3.57% K. The increase in fertilizer rates from the three different sources of K fertilizers increased N and K in bean pods. Similar results were reported by Michalojc and Buczkowska (2009) in eggplant.

Potassium in plant tissues doen not bind in a compound, but are free as K^+ ions (Marschner, 2012). Therefore, if the absorption of K elements was excessive, there can be a condition of luxurious consumption in the plant tissue. Jones et al. (1991) stated that red onion plants absorb more amounts of K than needed and the excess K can cause plants to be lacking on Mg and Ca.

Correlation test results between plant growth and components of crop beans showed that the variable stem diameter growth of 6 WAP was the most significant and positively correlated with crop yield variables. The high level of correlation between variables also showed that the increase in stem diameter was always followed by increase in the pod number, pod length, and pod weight.

Based on the results of this research fertilizer rates did not significantly affect the growth variables, whereas fertilizer sources had significant effects. This can be caused by the high content of K nutrients in the soil so that the effects of K fertilizer rates was not significant. General rate of fertilizer recommendations cannot be used as a rigid guideline as soil condition vary with locations. Determination of the recommended rate of fertilizer should be based on the site-specific soil analysis results, therefore it is important to conduct soil analysis, the soil nutrient conditions, the availability of nutrients, and soil pH prior to planting.

Source of fertilizer that had significant effect was likely related to the form and solubility of the type of fertilizer used and nutrient content of each fertilizer. In a fertigation system, before channeled through an irrigation line, fertilizer must be first dissolved. The disadvantage of using KCl fertilizer was that pink crystals require longer time to dissolve and must be filtered, otherwise they leave insoluble deposits. ZK fertilizer in the form of white powder also requires a considerable amount of time in the dissolution process even though it does not leave deposits, while NPK in the form of granules are easily dissolved even though they still need filtering. Research by Subhan et al. (2009) reported that fertilizing with NPK resulted in the best tomato growth, N, P, and K uptake, fresh and dry weight, and fruit yield.

NPK fertilizer has macro-secondary nutrients MgO and CaO which are not present in the other fertilizer sources. MgO and CaO can correct the acidity of the soil to suit the pH needed by plants by neutralizing organic acids and can increase the effectiveness and efficiency of absorption of nutrients that already exist in the soil both from organic matter and inorganic fertilizer (Gardner et al., 1991). In addition, according to Hardjowigeno (2007) Mg and Ca are very important for the formation of chlorophyll which plays a role in the process of photosyntesis, formation of cell walls, and plant cell division.

The use of fertigation through drip irrigation in polyethylene-mulched crop provides convenience in the cultivation of beans. Fertigation can increase the efficiency of nutrient use because fertilizer is applied in a small but continuous amount. Fertigation through drip irrigation can potentially reduce the use of fertilizer by 25%-50% (Kumar et al., 2016). Fertilization problems that often occur, i.e. loss of nutrients due to leaching, can be minimized by applying mulch. The use of conventional irrigation in mulched crop could reduce the water received by the crops, and watering through drip irrigation could eliminate this problem. Drip irrigation can also prevent excessive watering and nutrient leaching. Based on the research of Shedeed et al. (2009) the use of fertigation through drip irrigation caused the absorption of N and K nutrients by tomato plants more efficiently compared to the fertigation method through furrow irrigation. Tomato yields were 28% higher in the use of drip irrigation methods compared to furrow irrigation.

The use of polyethylene mulch also reduce costs for weeding. The area around the main crop is free of weeds which can reduce compete for light and nutrient with the main crops. Berke et al. (2005) stated that the use of polyethylene mulch significantly suppressed weed growth in the chili planting area, therefore reducing labour costs for weeding.

The disadvantages in drip irrigation is in initial capital costs for setting up the system, but once set up the system can last for 5 years. Farming economic analysis carried out in this study can be used as a reference comparison between the production costs incurred and the production results obtained.The results of the farming economic analysis in this study demonstrated that the use of NPK the most feasible option and gave the best yield with the R/C ratio > 1.

Conclusion

Application of potassium nutrient from NPK fertilizer by fertigation in a drip irrigation system gave significantly better plant growth and yield compared to KCl and ZK fertilizer. The different rates of K fertilizer in this study did not significanlty affect the growth and yield of beans.

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