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Determination of Fertilizer Doses of Sweet potato (*Ipomoea batatas* L.) “Rancing”

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Abstract

Nitrogen, phosphorus, and potasium availability are the most thresholding factors for maximum growth and yield. The tuber yield of sweet potato varies depending on growing area therefore a fertilization program, especially in the type and the dose of the fertilizers, is required. This research was conducted at Pasir Muncang experimental farm at Gadog, Bogor, West Java, Indonesia. The study site is located ±500 meters above sea levels, 6°39’31.90” south latitude and 106°52’7.77” east longitude. The experiment started in May to September 2017. Multi nutrient response method was used for this study, and the interpretation of the results was used to develop fertilizer recommendations using single-nutrient quadratic model. The recommendation was determined using N, P_2O_5, K_2O fertilizer response curve, where the first recommendation was calculated from the maximum relative yield, and the second, third, and fourth recommendations were determined from N, P_2O_5, K_2O threshold. Each treatment for N, P and K was evaluated with different level of fertilizer dose using a randomized complete block design with three replications. The fertilizer doses were 50, 100, 150 and 200% from reference (100% N = 100 kg N ha^{-1}, 100% P = 75 kg P_2O_5 ha^{-1}, dan 100% K = 100 kg K_2O ha^{-1}). Relative yield of sweet potato (y), response to fertilizer (x) had improvement quadratically with equation $y = -0.0017x^2 + 0.538x + 40.035$ for N, $y = -0.0041x^2 + 0.8595x + 38.211$ for P_2O_5, and $y = -0.0025x^2 + 0.4318x + 73.377$ for K_2O. The optimized dose of fertilizer to get maximum yield of sweet potato tuber is 158.23 $kg.ha^{-1}$ of N, 78.60 $kg.ha^{-1}$ of P_2O_5, and 83.60 $kg.ha^{-1}$ K_2O, or 343.97 kg ha-1 of Urea, 218.53 kg ha-1 of SP36 139.33 kg ha-1 of KCl.

Keywords: multi nutrient response, nitrogen, relative yield, phosphorus, potasium

Introduction

Sweet potato (*Ipomoea batatas L.*) is an important crop grown for its starchy tuberous roots in the tropics, including in Indonesia. The sweet potato tubers are rich in carbohydrate and used as food and also an important source of raw materials for starch-derived industrial products. The sweet potato in Indonesia has a high diversity of genotypes. Information on characteristics of tuber genotypes, chemical content, potential yield are very important to manage the continuity of maximum production, and for maintaining quality of sweet potato tubers (Waluyo et al., 2013). Based on previous research, “Rancing” is the mostly grown cultivar because it had a high productivity and physico-chemical. Based on our previous studies (unpublished) “Rancing” is one of the local cultivars that produces 24.06 $t.ha^{-1}$ with carbohydrate content of 26.52%, starch content of 21.49%, sugar content of 4.19%, making it potentially a high profit business.

Production of sweet potato in Indonesia in 2015, ranged from 2.3 million tons per year (BPS, 2015a). West Java is the largest producer of sweet potato in Indonesia, contributing 456,000 tons in 2015 (BPS 2015b). The sweet potato productivity in West Java is still classified as low (19.4 $t.ha^{-1}$) compared to West Sumatra (31.3 $t.ha^{-1}$) and Jambi (31.6 $t.ha^{-1}$) (BPS, 2015b). One of the reasons of variable results of sweet potato cultivation is improper fertilization and the unavailability of dose recommendation for farmers in a particular region.

Correct dose and time of application of fertilizer can potentially increase sweet potato productivity (Paturrohman and Sumarno, 2015). Nutrient addition can increase the expected productivity so that the nutrient that is added by fertilization equivalent to the amount of nutrients removed during harvesting. The profits of farming will be increased if the farmers are capable of producing 18 to 23 $t.ha^{-1}$ of tubers (Paturrohman and Sumarno, 2015). However, different regions have different soil nutrient status and different soil properties which affects nutrient utilization. The dose of fertilizers applied has not been based on the soil test results so fertilization can increase the production levels in some regions but has no significant impact on the others.

The determination of fertilizer doses in sweet potato is required to obtain the maximum productivity. Multi nutrient response to fertilizer has been reported on water spinach (*Ipomoea reptans L.*) (Susila et al., 2012) and sorghum (*Sorghum bicolor* L.) (Suminar et al., 2017). Fertilization dosage recommendation was determined using general crop growth response curve to fertilization. According to Webb et al. (2011) the determination of maximum dose fertilization can use basic theory of quadratic function which represents the nutrient state in a deficient, sufficient, and excessive condition. Therefore, the objective of this study was to determine the optimum dose fertilization of N, P_2O_5, and K_2O to produce maximum crop growth and yield of the sweet potato.

Materials and Methods

Experimental Site

The experiment was conducted in May until September 2017 in the Pasir Muncang experimental farm at Gadog, Bogor, West Java, Indonesia. The altitude, latitude and longitude of the study location is ±500 meters above sea levels, 6°39'31.90" south latitude and 106°52'7.77" east longitude.

Treatments

The materials that were used in this study were sweet potato "Rancing", and fertilizer Urea, SP36, KCl. The study was conducted by setting up three separate experiments organized in a randomized complete block design. Five doses of fertilizer were tested, 0%, 50%, 100%, 150%, and 200% from the reference dose. The reference dose of fertilizer was based on Wahyuni (2011), i.e. 100 kg ha^{-1} of urea, 75 $kg.ha^{-1}$ of SP36, and 100 $kg.ha^{-1}$ of KCl. There were 15 combinations of treatments and every treatment was replicated three times, totalling 45 experimental units of 1 m x 5 m blocks.

Data was analyzed with ANOVA using SAS 9.4 software; significant differences between treatments were further tested by orthogonal polynomial contrasts. The determination of the optimum dose of N, P_2O_5, and K_2O was based on the following steps:

1. Measuring the relative value (relative = % R) which was (Yi/Ymax) x 100% given:
   Yi = value on dose treatment of N, P_2O_5, and K_2O n-i
   Ymax = maximum value on dose treatment N, P_2O_5, and K_2O
2. Relative value as dependent variable (Y) related to the dose value of N, P_2O_5, and K_2O as independent variable (X) to be analyzed using linier regression and quadratic model.
3. Determining the selected recommendation

The selected recommendation of maximum fertilization was based on the dry weight of the tuber at 14 weeks after planting (WAP) that was converted into relative result. The approach was to determine the recommendation of fertilization using quadratic model of several fertilization treatments. The data of relative result was turned into quadratic equation, and then was interpreted simultaneously to decide the selected recommendation. There were four recommendations which are maximum fertilization on usage threshold of fertilizer N, P_2O_5, and K_2O. The maximum fertilization dose was obtained by using regression quadratic model (Susila et al., 2010): $R = a + bX + cX^2$ with given R = plant relative value, X = fertilizer dose, and a, b, c = constant. The optimum fertilizer dose was determined using a derived formula from regression equation: $dY/dX = b + 2cX = 0$; $X = -b/2c$.

Every experimental unit was planted with 25 shoot cuttings of 10 cm length at spacing of 20 to 25 cm within the rows. Chicken manure at 10 $t.ha^{-1}$ was applied at the earlier stage of land preparation. The plant beds were made into slopes of 45 to 60^0 to produce more tubers. Fertilization N and K_2O were applied at 30% of the full dose at planting and the rest of 70% when the plants were at 4 to 6 WAP. Fertilization P_2O_5 was applied once, which is 100% during the planting. The crop maintenance includes tidying the raised plant beds at 5 WAP and the stem reversals at 8 and 12 WAP. Sweet potato tubers were harvested at 16 WAP. The parameters measured were length of the tendrils, leaf wide index, green intensity of the leaf, and dry weight of leaf, stem, and tuber. Leaf color intensity was measured by Konica Minolta Chlorophyll Meter SPAD-502plus. The measurement was conducted on 10 leaves of each sample from each treatment. The leaf color intensity was measured in three part of leaves, base, middle, and tip, then averaged.

Results and Disscussion

General Condition of the Location

This study was conducted in dry season with the rainfall intensity < 100 mm per month according to the classification of Oldeman (BMKG Citeko, 2017). The average temperature during the study was 21.02 to 22.61C with the relative humidity of 70 to 90%. The soil in the experimental site is sandy clay soil and was categorized as acidic soil with pH of H_2O around 4.31. The component of organic materials that consisted of C-organic was classified as low (1.15%), total of N (0.15%) was classified as low, available P (22.17 ppm) was classified as high, available K was classified as low (0.09 cmol.kg^{-1}), and the reaction exchange capacity was classified as moderate.

Plant Growth

The tendrils length response to dose enhancement of N from 0 to 200% from reference was quadratic at 6 and 9 WAP. This response was likely due to the sweet potato's growth was still in the early and the middle phase that consisted of the growth of stem, leaf, and root. Sweet potato growth cycle consists of three phases, early phase is until 6 WAP, middle phase is between 7 to12 WAP and the final phase was when the tuber grows rapidly (Edmond, 1971; Hozyo et al., 1986). During the middle phase, the stem and leaf grow fast, but the tuber grew slowly.

The measurement of leaf green color intensity used Chlorophyll Meter (SPAD)-502 plus that correlates with the chlorophyll content. Chlorophyll was one of the factors that determine the N status in leaf. The increased dose of fertilizer N linearly increased the chlorophyll content of sweet potato "Rancing" (Table 1). Nitrogen levels are closely related to chlorophyll synthesis. The increased nitrogen content in plant influences the process of photosynthesis through chlorophyll content as well as the photosynthetic enzymes (Marschner, 2012). If the nitrogen content of the leaf increased, the result of photosynthesis would also increase for the growth of stem and leaf.

Response of leaf area index (LAI) towards the additional dose N of 0 to 200% was linear ($y = 0.0104x + 2.336$) at 14 WAP. The linear pattern showed that the additional dose of N from 0 to 200% from reference still improve the vegetative growth. The sweet potato leaf was the major source for the photosynthesis to

Table 1. Tendril's length, leaf area index and leaf color intensity of sweet potato "Rancing" in various dose of N, P_2O_5, K_2O

Treatment ^{t}	Tendril's length (cm)		Leaf area index (m^2 per m^2)		SPAD
	6 WAP	9 WAP	10 WAP	14 WAP	value
N0	43.33	41.00	2.28	2.16	43.6
N50	46.67	56.00	2.43	3.18	43.65
N100	67.67	62.00	3.17	3.40	46.10
N150	71.33	59.00	3.64	3.56	49.85
N200	57.33	64.00	3.57	4.56	50.50
Pr>F	0.0002	0.0095	0.1765	0.0048	<.0001
Regression	Q**	Q**	ns	L**	L**
P0	39.00	47.50	3.17	3.21	43.6
P50	41.50	52.00	4.46	3.06	48.4
P100	37.50	58.00	3.96	3.55	47.4
P150	49.00	78.00	3.91	3.83	52.1
P200	44.00	64.50	3.8	4.55	49.7
Pr>F	0.4725	0.0138	0.2553	0.0103	0.0542
Regression	ns	Q*	ns	L*	Q*
K0	50.00	61.00	3.29	2.83	46.25
K50	37.50	85.00	3.29	3.78	46.00
K100	36.25	64.00	3.63	3.44	45.80
K150	42.50	62.00	3.02	3.08	46.50
K200	50.50	55.00	3.06	3.23	44.40
Pr>F	0.1184	<.0001	0.6176	0.0465	0.7806
Regression	ns	Q**	ns	L*	ns

Note: t : orthogonal polynomial test on fertilizer dose; significance according to orthogonal polynomial test is given; Q: quadratic; L: linear; ns: not significantly different; significance according to anova test is given; *P<0.05, **P<0.01* take place because the LAI was related to the ability to absorb light energy. The optimum LAI of sweet potato was 3.5 m^2 per m^2 (Wargiono and Tuherkih, 1986). LAI enhancement to 4.4 m^2 per m^2 could cause net assimilation rate to decrease by 17% resulting in tuber yield of 21 $t.ha^{-1}$(Wargiono and Tuherkih, 1986). Referring to this study the enhancement of N fertilizer up to 200% from the reference led to the higher LAI from the optimum which was 4.56 m^2 per m^2. The photosynthates were directed to the shoots and the proportion for the tubers decreased, resulting in the dry weight of the tuber to decrease to 140.48 g per plant (Table 2).

Response of tendril's length towards the increased dose P_2O_5 from 0 to 200% of the reference did not show significant difference at 6 WAP after it reached 9 WAP quadratic ($y = -0.0006x^2 + 0.2457x + 44.857$). This response was predicted because of the nature of fertilizer SP36 which has slow solubility in the early stage of the plant's growth, therefore utilization of nutrient by the plant had not been maximized. The greater the phosphorus availability for the plant, the more phosphorus could be absorbed so the LAI at 14 WAP had exceeded the optimum LAI (Table 1). Phosphorus was one of the major nutrients that support the process of photosynthesis; phosphorus affects root growth and improve nutrient absorption for the growth and development of the plant (Fahmi et al., 2010, Mapegau, 2000).

The application of P_2O_5 fertilizer was significantly quadratic ($y = -0.0002x^2 + 0.0815x + 43.817$) improved the leaf green color intensity (Table 1). The highest leaf color intensity was obtained by the enhancement dose of fertilizer P_2O_5 at 150% from the reference. Increased absorption of N, P and K and leaf chlorophyll content could improve the photosynthesis rate that eventually increased crop yield.

The response of LAI towards the enhancement dose of fertilizer P_2O_5 from 0 to 200% of the reference was linear ($y = 0.0069x + 2.95$) at 14 WAP. Hermanuddin et al. (2012) reported that corn showed more efficient uses of fertilizer P_2O_5 and had better the vegetative growth with P_2O_5 fertilization. P_2O_5 could improve nitrogen absorption indicated by the increased height, leaf size as well as dry weight. Application of P_2O_5 would increase the availability of P_2O_5 in the soil that could improve N absorption.

The response of tendril's length towards the enhancement dose of K_2O_5 from 0 to 200% of the reference was linear ($y = -0.0012x^2 + 0.1757x + 66.257$) at 9 WAP. Research by Putra and Permadi (2011) revealed that the enhancement of potassium fertilizer to 180 $kg.ha^{-1}$ could improve the tendril's length of sweet potato "Narutokintoki". The tendril's length of the stem was expected to correlate with the function of potassium to improve translocation of the result of assimilation from source to sink, as well as to keep the tendril upright to enhance the flow of nutrient and water. The response of LAI towards the enhancement dose of K_2O_5 was linear at 14 WAP. The response of LAI was still optimum despite the enhancement of K_2O_5 200% of the reference.

Tuber Production

The enhancement of dose N from 0 to 200% from the reference increased the tuber's dry biomass and total dry biomass of the plant quadratically at 6, 10, and 14 WAP (Table 2). Nitrogen plays an important role in the metabolism process of the plant. Research by Bustami and Sufardi (2012) demonstrated that dry weight of the plant reflected the nutrient status and the amount of nutrient absorbed by the plant, as well as the photosynthesis rates.

The increasing dose of P_2O_5 from 0 to 200% from the reference increased the tuber's dry biomass and total dry biomass of the plant quadratically at 6, 10, and 14 WAP (Table 2). The administration of 100% dose from the reference improved the total dry biomass up to 88.86% compared to 0% dose from the reference at 14 WAP. N and P fertilization increased the availability of nutrient N and P to support the optimum growth of the plant. N and P increased sprout dry weight, root dry weight, and total dry weight of corn crops (Fahmi et al., 2010). Therefore, in regosol and latosol soil, the administration of both nutrients simultaneously would significantly improve the growth and increase biomass of the plant. Cruz et al. (2011) stated that increasing phosphorus dose from 120 to 180 $kg.ha^{-1}$ P_2O_5, significantly increased the aerial part dry matter and tuberous root dry matter of the sweet potato. The positive response of sweet potato to fertilization was likely possibly due to the improved availability of nutrients in the soil and their absorption by the plant.

The additional dose of K_2O from 0 to 200% from the reference also increased the tuber's dry biomass quadratically at 10 and 14 WAP (Table 2). Potassium improves the ability of plant to produce photosynthate (source), distribute net photosynthate to the storage organs (sink), and transform photosynthate that is essential for increasing yield (Fisher et al., 2012). Translocation of the result of assimilation to sink organ was determined by the relative position and power of the sink. Accumulation of assimilates in the tuber will increase tuber yield, which is the primary sink in sweet potato (Wargiono and Manshuri, 2011). High-yielding sustainable agriculture comprised of efficient and sufficient nutrient management with the

Table 2. Tuber dry weight and total shoot dry weight of sweet potato in various dose of fertilization of N, P_2O_5, K_2O

Treatment [t]	Tuber dry weight			Total dry weight (leaf, stem, tuber)		
	6WAP	10WAP	14WAP	6WAP	10WAP	14WAP
			g per plant			
N0	1.40	24.09	89.62	24.45	48.81	143.80
N50	3.34	44.33	104.08	24.98	85.77	147.01
N100	2.47	38.73	138.50	17.02	81.80	202.86
N150	3.31	57.97	195.71	38.61	98.23	254.43
N200	8.74	35.81	140.48	35.22	81.26	227.97
Pr>F	<.0001	0.0001	<.0001	<0.0001	0.0001	0.0003
Regression	Q**	Q**	Q**	Q**	Q**	Q**
P0	4.26	73.01	60.37	27.53	176.53	116.26
P50	3.22	62.27	96.67	14.17	133.38	158.04
P100	10.16	60.59	153.11	53.62	126.07	219.58
P150	3.26	73.03	94.74	20.15	150.995	133.51
P200	3.44	45.86	79.73	28.02	120.71	118.27
Pr>F	<.0001	0.0354	0.011	<.0001	0.0126	0.0019
Regression	Q**	Q*	Q*	Q**	Q*	Q*
K0	3.05	54.23	118.21	25.3	115.93	160.37
K50	5.64	67.1	126.93	38.69	127.31	183.34
K100	2.27	41.37	156.16	20.08	88.33	233.37
K150	3.13	66.21	122.14	33.14	111.60	156.77
K200	5.22	63.06	94.26	30.39	131.24	149.1
Pr>F	0.0004	0.0432	0.0072	<.0001	0.0158	0.1139
Regression	L**	Q*	Q**	Q**	L*	ns

Note: t: orthogonal polynomial test on fertilizer dose; significance according to orthogonal polynomial test is given; Q: quadratic; L: linear; ns: not significantly different; significance according to anova test is given; *P<0.05, **P<0.01*

appropriate type at the correct dosage. Preparation of fertilizer is based on the general response curve of the crop growth to the applied fertilization. Webb et al. (2011) stated the determination of maximum fertilization dose can be based on the basic quadratic function theory; the function represents the nutrient in deficiency, sufficient, and excessive condition.

Recommendation of Sweet Potato Fertilization

The approach of multi nutrient response was a method that was developed to determine the recommended fertilization using quadratic model from several experiments. The result of dry weight at 14 WAP was converted into relative result so that the three experiments could be compared. The relative result was the result from the treatment divided by the highest result obtained in each experiment. There were four recommended fertilization which were based on threshold of fertilizer N, P_2O_5, K_2O, and in maximum condition. Multi nutrient response interpretation is a method to develop fertilizer recommendation using single-nutrient quadratic model. The recommendation choice was developed using N, P_2O_5, K_2O fertilizer response curve, where the first recommendation was calculated from the maximum relative yield, whereas the second, third, and fourth recommendations determined from N, P, K threshold (without fertilizer) (Susila et al., 2012).

According to the relative result of the tuber's dry weight at 14 WAP, quadratic equation obtained for N is $y = -0.0017x^2 + 0.538x + 40.035$ with $R^2 = 0.6993$ showed by Figure 1. The point in the equation could be determined to reach the maximum result from the N fertilization by specifying the first differential equal to zero. The maximum score of N fertilization was 158.23 kg ha^{-1} or 343.97 kg ha^{-1} of urea.

The quadratic formula for P_2O_5 was $y = -0.0041x^2 + 0.8595x + 38.211$ with $R^2 = 0.7327$ as shown in Figure 2. The maximum fertilizer P_2O_5 is 104.81 kg ha^{-1} or

218.35 kg ha^{-1} for SP36. The quadratic formula for K_2O was $y = -0.0025x^2 + 0.4318x + 73.377$ with $R^2 = 0.8188$ shown in Figure 3. Therefore K_2O fertilization of 83.6 kg ha^{-1} or 139.33 kg ha^{-1} KCl is required.

Figure 1, 2 and 3 were interpreted simultaneously to determine the thresholds of N, P_2O_5, K_2O. Four recommended doses of fertilization for sweet potato are shown in Table 3.

The four fertilizer recommendations were based on the threshold of N (without N) which was 0.0, 1.6, 0.0 $kg.ha^{-1}$ N, P_2O_5, K_2O relative value up to 40.04% and threshold of P_2O_5 (without P_2O_5) which 0.0, 0.0, 0.0 $kg.ha^{-1}$ N, P_2O_5, K_2O with relative value up to 38.21%, whereas the threshold of K_2O (without K_2O) which was 84.6, 41.8, 0.0 $kg.ha^{-1}$ N, P_2O_5, K_2O with relative value up to 73.45%.

Based on Table 3 the relative result of fertilizer threshold was in the order of P_2O_5 < N < K_2O in which the order of relative result became the basis of fertilizer recommendation starting from the first to the third recommendation.

The fourth recommended fertilization was based on the maximum relative result. Fertilizer required in maximum condition was obtained from the first differential of each experimental equation on N, P_2O_5, and K_2O so that the dose was determined according

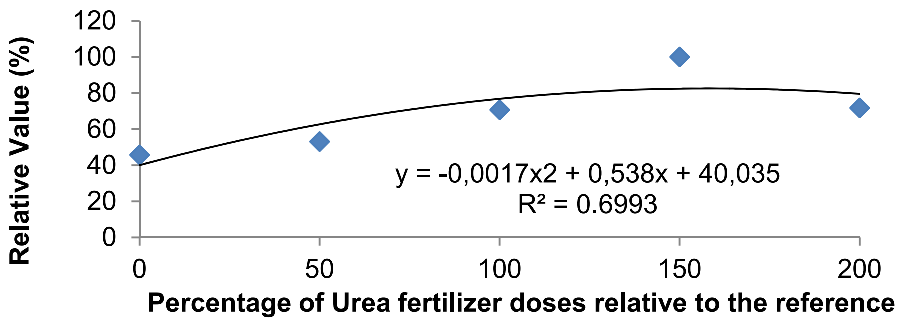

Figure 1. Result of tuber's relative dry weight at 14 WAP in various dose of N fertilization

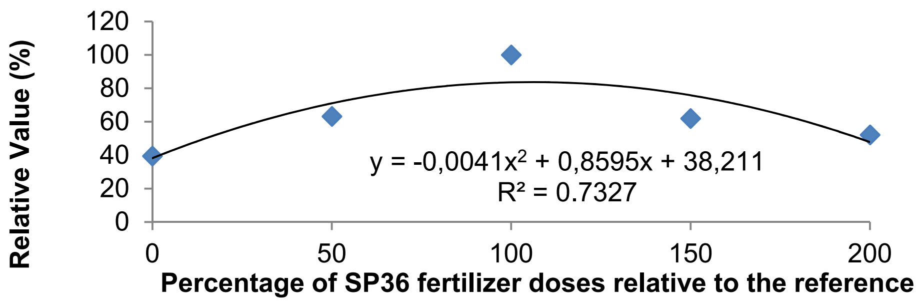

Figure 2. Result of tuber's relative dry weight at 14 WAP in various dose of P_2O_5 fertilization

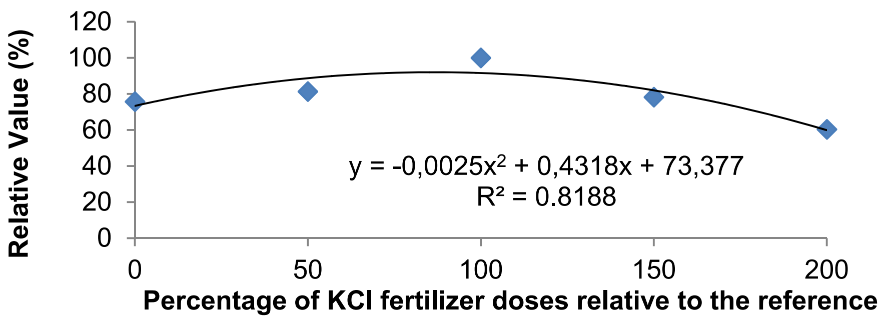

Figure 3. Result of tuber's relative dry weight at 14 WAP in various dose of K_2O fertilization

Table 3. Recommended fertilization dosages and fertilizer requirement based on multi nutrient response method

Selected recommendation	Unit	N threshold	P_2O_5 threshold	K_2O threshold	Maximum
N		0.0	0.0	84.6	158.2
P_2O_5	(%)	2.1	0.0	55.7	104.8
K_2O		0.0	0.0	0.0	83.6
N		0.0	0.0	84.6	158.2
P_2O_5	kg.ha^{-1}	1.6	0.0	41.8	78.6
K_2O		0.0	0.0	0.0	83.6
Urea (46%)		0.0	0.0	183.8	343.9
SP6 (36%)	kg.ha^{-1}	4.46	0.0	116.1	218.4
KCl (60%)		0.0	0.0	0.0	139.3

to the maximum fertilization equal to 158.2 kg ha^{-1} of N, 104.8 kg ha^{-1} of P_2O_5, 83.6 kg ha^{-1} of K_2O, or 343.9, kg ha^{-1} Urea, 218.4, 139.3 kg ha^{-1} of SP36, and 139.3 kg ha^{-1} of KCl with relative value up to 83.25 %.

Result of the smallest order showed that the nutrient became the prominent limiting factor or the law of the minimum. In this experiment, the P_2O_5 nutrient was the major limiting factor followed by N, and the least limiting factor was nutrient K_2O. Without the nutrient P_2O_5, the yield would be significantly low with a relative value equal to 38.21%. One or two factors that became the limit in the process of plant's growth, the increased factor would determine the response of the plant's growth. According to Tisdale et al. (2005) phosphorus in the soil can form compounds that are relatively difficult to dissolve. As a result, it had become a limitation for the plant and this is one of the main issues in the management of soil fertility.

The availability of N and P_2O_5 at sufficient amount could support the optimum growth of the crop. Therefore, the administration of fertilizer N and P_2O_5 simultaneously could increase the yield of sweet potato. Research by Fahmi et al. (2010) demonstrated that N fertilization during the early growth could elevate the phosphorus concentration in the soil resulting on the improved growth of the roots and improve the absorption rate of P_2O_5.

Economic Analysis

The estimation of the production expense for an area of one hectare in sweet potato cultivation was equal to IDR 28,325,000 according to the analysis of farming. Every one kg of fertilizer that was used based on the price floors as regulated on PERMENTAN number 69/ Permentan/SR.310/12/2016 for urea (46% N) costed IDR 2,000 and SP36 (36% P_2O_5) costed IDR 1,800. KCl (60% K_2O) on the market costed IDR 12,000. The economic analysis for each of recommended fertilization was presented in Table 4.

The first recommended fertilization selection based on the lowest relative result was recommendation selection on the threshold of fertilizer P. The result of economic analysis according to this fertilization threshold had production expense equal to IDR 28,325,000; It is the highest cost component among other recommendation selections. The second recommended fertilization selection on the threshold of fertilizer N costed production expense equal to IDR 28,333,920 with the percentage of increased expense equal to IDR 8,920 or 0.03 for fertilizer expense with increased relative result equal to 1.82% from the first recommendation selection. The relative expense for each unit result was IDR 707,782. The third recommendation selection based on the threshold of fertilizer K with production expense was equal to IDR 28,888,000 and the relative expense for each unit result equal to IDR 393,730.

The fourth recommendation selection was based on the maximum expense incurred for the fertilization expense of urea, SP36, and KCl to obtain maximum yield, or equal to IDR 2,727,800 with relative result value up to 83.25% resulting on the increased relative result up to 9.89% from the third recommended fertilization selection. The relative expense for each unit result was IDR 372,980. The relative expense is the lowest expense that was incurred to gain relative result up to 83.25%. The result became the selected calculation of fertilization dose that was best utilized to get high production yield by incurring the lowest expense.

Table 4. The economic analysis on recommendation of sweet potato fertilization

Recommendation Selection (Urea, SP36,KCl) kg.h^{a}-1	Relative result (%)	Changes from previous recommendation		Fertilizer expense (IDR)	Total of production expense per ha (IDR)	Changes from previous recommendation		Relative expense in each relative unit result (IDR)
		Increased relative result (%)	Percentage of increased relative result (%)			Increased expense (IDR)	Percentage of increased expense (%)	
0, 0, 0	38.21	0.00	0.00	0	28,325,000	-	-	741,298
0, 4.46, 0	40.03	1.82	4.77	8,920	28,333,920	8,920	0.03	707,782
183.8, 116.1, 0	73.37	33.34	83.28	563,000	28,888,000	554,080	1.96	393,730
343.9, 218.4, 139.3 (maximum)	83.25	9.89	13.47	2,727,800	31,052,806	2,164,806	7.49	372,980

Conclusion

Recommended fertilization for sweet potato was determined based on the maximum yield which was the maximum recommendation selection that was in accordance with the economic analysis at the experimental site, which was 158.23 kg.ha^{-1} of N, 78.60 kg.ha^{-1} of P_2O_5, and 83.60 kg.ha^{-1} of K_2O, or 343.97 of kg.ha^{-1} Urea, 218.53 kg.ha^{-1} of SP36, 139.33 kg.ha^{-1} of KCl. Further research needed to be conducted to determine the fertilizer requirements based on the soil types for various cultivars of sweet potato.

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