Effectivenes of NPK compound (10-30-20) to improve growth and yield of hybrid maize on vertisol soil

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Abstract. To determine the effectiveness of NPK compound (10-30-20) fertilizer to maize growth and yield, a study was conducted on vertisol soil of the rainfed rice field in Gambir Kuning village, Kraton District Pasuruan Regency, from September 2020 until February 2021. The study was arranged in randomized block design with four replications. As the treatment i.e., A. control (without inorganic fertilizer), B. standard/local recommendation (NPK 15-15-15) 300 kg, C. NPK (10-30-20) 100 kg, D. NPK (10-30-20) 200 kg, E. NPK (10-30-20) 300 kg, F. NPK (10-30-20) 400 kg, G. NPK (10-30-20) 500 kg ha-1. Except for control, all treatments were fertilized with 200 kg Urea and 100 kg ZA. P27 hybrid maize variety was used as an indicator plant. The results showed that the applications of NPK compound ((10-30-20) were increasing plant growth and yield effectively. The optimum dosage of NPK (10-30-20) was 499.55 kg ha-1. Treatment F produced the highest yield (6.83 tons ha-1) and was significantly different from the control (4.13 tons ha-1) and higher than the standard (6.24 tons ha-1). This treatment also gave the highest RAE value (127,55).

1 Introduction

Maize is one of most important food crops and second main staple food after rice in Indonesia. Maize also has an important value in the development of the food and animal feed industry, especially as a raw material in the chicken feed industry. The demand is increasing along with the growth of the food and feed industry. However, maize productivity in Indonesia is still relatively low, even though the data showed an increase in the last five years. According to statistical data of Indonesia, maize productivity in 2020 about 5.47 tons ha^{-1} [1]. This productivity was still lower than the potential yield of hybrid varieties.

Besides the cultivation techniques, this condition is affected surely by the type and dosage of fertilizer. Fertilizer is one of the main production factors, in addition to land, labor, and capital. Balanced fertilization has a role in increasing maize yield. Therefore, fertilization recommendations should be made more rational and balanced, based on the

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ability of the soil to provide the nutrients and crop needs for nutrients. This action can improve the effectiveness and efficiency of fertilizer use without damaging the environment due to excessive fertilization.

Vertisol soil is usually used as agricultural land in Indonesia. This soil was dominated by clay textures, with organic matter relatively high and lime various. Cause cracks in the dry season and inflates in the rainy season. Therefore, to ensure that plants can grow and produce optimally, irrigation water must be available during the dry season [2].

N, P, and K are essential nutrients for plants, and at the same time become a limiting factor for plant growth. Application of N fertilizer affects phosphorus concentration, parameters of growth and dry matter of yield. P fertilization was very influential on nitrogen concentration, dry matter of shoot, and parameters of growth except for area and width of leaf. The increase in potassium dosage was equivalent to the concentration and uptake of N and K [3]. Plants fertilized with P and K alone without N can only increase lower production [4].

Generally, NPK compound fertilizer is used by farmers. Various brands with different contents are available on the market. Although the price of these fertilizers is more expensive, farmers have chosen compound fertilizers. Considering the nutrients contain more complete than single fertilizers. Labor efficiency in compound fertilizer application is also higher than single fertilizer, which must be applied by mixing [5]. As apart from an agronomic perspective, the farmers also get a benefit. Transportation costs are cheaper, take up less space in storage, save labor, and are faster in-field delivery [6].

One type of compound fertilizer is NPK (10-30-20). Supposedly, this fertilizer was able to increase the growth and productivity of corn plants, but its effectiveness needs to test in the field condition. The study was aimed to determine the effectiveness of NPK (10-30-20) fertilizer to improve plant growth and maize yields on vertisol soils.

2 Materials and method

The study was done at a farmer's rice field at Gambir Kuning village, Kraton district, Pasuruan regency (25 m asl), from September 2020 to February 2021. The experiment was designed in randomized block design with four replications (Table 1).

Table 1. Treatment's arrangement of effectiveness NPK (10-30-20) to maize growth and yield

Code	Treatments	Fertilizer dosage (kg ha^{-1})				Nutrient total (kg ha^{-1})		
		NPK Ponska	Urea	ZA	NPK (10-30-20)	N	P	K
A	Control	0	0	0	0	0	0	0
B	Standard*	300	200	100	0	158	45	45
C	NPK (10-30-20)	0	200	100	100	124	30	20
D	NPK (10-30-20)	0	200	100	200	135	60	40
E	NPK (10-30-20)	0	200	100	300	146	90	60
F	NPK (10-30-20)	0	200	100	400	157	120	80
G	NPK (10-30-20)	0	200	100	500	168	150	100

* Based on Integrated Planting Calendar 2020 by Indonesian Agency for Agriculture Research and Development-Agriculture Ministry

Before planting, the land was cleaning from the previous maize crop's waste and weeds. The treatments plots were arranged with a size of 10 m x 5 m (50 m2). The planting distance was arranged in 70 x 20 cm. Inorganic fertilizer as the treatment was applied twice. First, at 15 days after planting (DAP) as much as 1/3 dosage of urea, ZA, and NPK. Second, at the 30 DAP all remaining fertilizer. Plant maintenance was conducted according

to the standard cultivation procedure of maize in a rainfed rice field. The crops were harvested when the kernels have dried.

The variables observed in the vegetative phase were plant height, stem diameter, and leaf area from 2 to 8 weeks after planting (wap). Variables observed in the generative phase were wet and dry cob weight per plot, wet and dry weight of sample cob, diameter and length of sample cob, wet and dry weight of kernel per cob, wet and dry weight of 100 kernels. Data were tabulated and to test the effect of treatment using ANOVA (Analysis of Variance), while for further test using Duncan's Multiple Range Test (DMRT) 5%.

The effectiveness of compound NPK fertilizers was determined by the relative agronomic effectiveness (RAE). RAE is the ratio of the yield increase due to the use of fertilizers tested than standard fertilizer [7].

$$RAE = \frac{yield\ of\ tested\ fertilzer - yield\ of\ control}{yield\ of\ standard\ fertilizer - yield\ of\ control}\ x\ 100 \qquad (1)$$

3 Results and discussion

3.1 Existing conditions

The research location was a rainfed rice field with a rice-maize-maize cropping pattern. Temperatures ranged from 30.2 to 36.1 0C, and humidity ranging from 47 to 69 %. From the beginning of planting until the end of the vegetative stage, the climatic conditions were still in the dry season. Therefore, the water need of the plant was gained from the pump wells.

The soil in the research site was classified as vertisol soil and had a clay texture. This soil also had a moderately acid (pH 6.2) with low organic matter content (1.61 %), low C/N ratio (7.32), medium total nitrogen (0.22 %), very high P (124 ppm), very high K (1.03 cmol (+) kg-1) and high KTK (39.03 cmol (+) kg-1).

3.2 Plant growth performance

The research location was a rainfed rice field with a rice-maize-maize cropping pattern. Temperatures ranged from 30.2 to 36.1 ^{o}C, and humidity ranging from 47 to 69 %. During the vegetative stage, the climatic conditions were dry season. Therefore, the water need of the plant growth performance was quite uniform in the first observations. There was not a significant difference between the treatments tested. It relates to the first fertilizer application that has done on the same day by the time the plant observations at the age of 2 weeks after planting (wap).

In 4 wap showed that plant growth on control (without fertilization) and NPK (10-30-20) at 100 kg and 200 kg ha-1 slower than the other treatments. Increasing the dosage of NPK (10-30-20) to 300, 400, and 500 kg/ha significantly affected plant height. The same results were found in the next observation at 6 and 8 wap (Table 2). Arafah and Sirappa [8] cited that the average optimum height of maize was obtained on the combined treatment of N, P, and K. Because maize crops were very responsive to inorganic fertilizer, especially N, P, and K nutrients. Kasno and Rostaman [9] reported that increasing NPK fertilizer dosage to 300 kg ha-1 + 250 kg Urea has significantly influenced plant height compared to the dosage of 50 kg ha-1. However, increasing the dosage of NPK to 400 kg + urea 250 kg ha-1 was not significantly affected the plant height.

Table 2. Effect of NPK (10-30-20) fertilizer treatment on plant heigh of P-27 variety at 2, 4, 6 and 8 wap

Code	Treatments	Plant height (cm)			
		2 wap	4 wap	6 wap	8 wap
A	Control	19.08 a	68.14 c	116.60 d	150.56 c
B	Standard*	20.43 a	76.85 ab	140.78 a	177.58 a
C	NPK (10-30-20)	17.33 a	72.65 bc	120.08 cd	162.95 b
D	NPK (10-30-20)	18.35 a	73.54 bc	125.50 bc	165.88 b
E	NPK (10-30-20)	18.71 a	79.93 a	136.05 ab	177.72 a
F	NPK (10-30-20)	17.90 a	81.28 a	143.00 a	188.13 a
G	NPK (10-30-20)	19.13 a	81.35 a	146.38 a	186.38 a
	CV	10.51	4.41	10.07	3.86
	SE	0.98	1.68	6.68	3.33

Table 3. Effect of NPK (10-30-20) fertilizer treatment on stem diameter of P-27 variety at 2, 4, 6 and 8 wap

Code	Treatment	Stem diameter (mm)		
		4 wap	6 wap	8 wap
A	Control	14.05 b	16.91 c	19.13 d
B	Standard	20.09 a	21.94 ab	24.60 ab
C	NPK (10-30-20) 100 kg	18.17 a	18.73 bc	21.99 c
D	NPK (10-30-20) 200 kg	20.23 a	21.26 ab	23.48 b
E	NPK (10-30-20) 300 kg	20.95 a	21.37 ab	26.29 a
F	NPK (10-30-20) 400 kg	21.16 a	23.20 a	27.11 a
G	NPK (10-30-20) 500 kg	20.95 a	23.98 a	26.43 a
	CV	11,06	9,75	4,00
	SE	1,07	1,02	0,48

Table 4. Effect of NPK (10-30-20) fertilizer treatment on leaf area of P-27 variety at 2, 4, 6 and 8 wap

Code	Treatment	Leaf area (cm^2)			
		2 wap	4 wap	6 wap	8 wap
A	Control	38.70 a	263.73 c	370.21 c	465.96 c
B	Standard	43.52 a	402.31 ab	519.59 ab	595.13 ab
C	NPK (10-30-20) 100 kg	41.77 a	366.75 b	474.27 b	571.35 b
D	NPK (10-30-20) 200 kg	38.16 a	393.61 ab	469.17 b	572.69 b
E	NPK (10-30-20) 300 kg	41.89 a	443.62 a	533.35 a	625.43 ab
F	NPK (10-30-20) 400 kg	47.30 a	437.73 a	568.89 a	618.79 ab
G	NPK (10-30-20) 500 kg	44.50 a	445.60 a	559.61 a	641.65 a
	CV	10.27	9.18	7.46	6.80
	SE	2.18	17.98	17.89	19.88

Stem diameter was measured on the second observation. The first observations showed that the significant differences only showed by control or without inorganic fertilizers. The next observation showed that there was a significantly different effect between the dosage of NPK (10-30-20) fertilizer tested. The largest stem diameter was obtained at dosage treatment equal to and more than 300 kg ha-1. The last observation at eight wap also showed that the highest dosage of NPK (10-30-20) fertilizer had a significant effect than the control and dosage of 100 and 200 kg/ha NPK (10-30-20) (Table 3). Furtherly, the treatment above of 300 kg dosage resulted in the same effect as the standard treatment to the diameter of the stem.

3.3 Plant yield

The harvest yield components showed a significantly different effect between the treatments tested. The longest cob was obtained at the treatment of 500 kg/ha and was significantly different from the control and standard (Table 5).

Observation of the diameter of the cob showed that a significant difference between the treatments tested. The biggest cob was found at 400 kg/ha NPK treatment and was significantly different from other treatments (Table 5). Cob weight showed that the treatment of NPK (10-30-20) fertilizer above 200 kg shows a significant difference compared to the control and treatment of 100 kg NPK (10-30-20).

NPK treatment of more than 200 kg gave the highest dry kernel weight and was significantly different from the control. This table also showed that the NPK (10-30-20) fertilizer with a dosage of above 300 kg dosage could increase the kernel weight and be equivalent to standard (Table 5).

Table 5. Effect of NPK (10-30-20) fertilizer treatment on harvest yield component of P-27 variety

Code	Treatment	Cob length (cm)	Cob diameter (mm)	Cob weight (g)	Kernel weight/cob (g)	100 kernel weights (g)
A	Control	13.90 d	39.94 e	124.41 d	94.41 c	23.30 c
B	Standard	17.48 b	52.24 c	188.05 b	136.22 ab	30.22 a
C	NPK (10-30-20) 100 kg	15.45 c	41.16 e	175.50 c	130.92 b	24.00 c
D	NPK (10-30-20) 200 kg	17.35 b	48.04 d	206.74 ab	156.74 a	27.17 b
E	NPK (10-30-20) 300 kg	18.24 ab	53.49 bc	203.32 ab	147.49 a	28.66 ab
F	NPK (10-30-20) 400 kg	17.87 ab	57.68 a	210.88 a	157.30 a	31.67 a
G	NPK (10-30-20) 500 kg	18.60 a	53.84 b	200.58 ab	156.40 a	31.53 a
	CV	13.61	11.85	7.38	6.34	7.57
	SEM	10.30	10.46	6.90	4.83	1.06

The highest weight of 100 kernels has resulted from NPK fertilizer above 300 kg ha^{-1} treatment. And there was a significant difference between this treatment and the control and treatment of NPK fertilizer at 100 and 200 kg ha^{-1} dosage (Table 5). This fact indicates that the application of NPK fertilizer more than 300 kg can increase the weight of kernel, and it was equivalent to standard treatment. Pratikta et al. [10] cited that the production of maize correlated to cob diameter. The larger cob will produce a higher yield. The diameter of the cob is also affected by the size and weight of the kernel. The increase of kernel weight should be closely related to the amount of photosynthesis partitioned into the cob. The greater the photosynthetic allocated to the cobs, the accumulation of food reserves transplanted into the kernels will increase, thereby increasing the weight of the kernels. Therefore, the weight of the kernel may decrease.

The sampling yield data showed that the treatment of NPK fertilizer with a dosage of 400 kg gave the highest yield and it was significantly different from the others. The same fact also found that the treatment of NPK fertilizer dosage 400 kg gives the highest harvest yield, and it was significantly different from other treatments (Table 6). If studied further, it appears that NPK fertilizer with a dosage above 300 kg/ha has the same influence or equivalent to the standard. Allegedly, this fact is related to the increase in the availability of N and P elements due to the increase in the dosage of NPK (10-30-20) fertilizer. Sutoro et al. [11] cited that nitrogen fertilizer is the main effort to increase maize production. The absorption of N by maize plants along with their growth. Therefore, nitrogen nutrients in the soil should be sufficiently available during the plant growth phase.

Table 6. Effect of NPK (10-30-20) fertilizer treatment on sampling and harvest yield of P-27 variety

Code	Treatment	Sampling yield (kg/11.2 m^2)	Harvest yield (t/ha^{-1})	Percentage of treatment yield increasing (%)	
				Control	Standard
A	Control	5.05 d	4.10 d	-	-34.25
B	Standard	8.05 b	6.24 b	52.07	
C	NPK (10-30-20) 100 kg	6.65 c	5.13 c	25.00	-17.80
D	NPK (10-30-20) 200 kg	7.08 c	5.46 c	13.53	-21.69
E	NPK (10-30-20) 300 kg	7.69 b	5.94 b	32.99	-4.80
F	NPK (10-30-20) 400 kg	8.75 a	6.83 a	66.40	9.42
G	NPK (10-30-20) 500 kg	8.01 b	6.15 b	49.92	-1.40
	CV	7.38	8.02		
	SEM	0.27	1.22		

While Mapegau [12] stated that nutrients N and P are indispensable for root development. More developed rooting will increase for more nutrient absorption. Increased nutrient uptake of NPK and the amount of chlorophyll can increase the rate of photosynthesis so that the weight of the crop will increase. This finding in line with other reports that the application of compound NPK fertilizer significantly increases the dry weight of maize kernel or kernels. The highest dry weight of maize kernels was achieved at 300 kg/ha NPK + 250 kg of urea compared to lower dosages. Increasing the dosage of NPK fertilizer to 400 kg/ha + 250 kg urea does not increase the weight of dried kernel maize kernels compared to 300 kg/ha + 250 kg urea. The optimal dosage of NPK 15-15-15 for maize crops was 300 kg/ha + 250 kg urea/ha with a dry weight of maize yield harvest of 6.05 t ha^{-1} [9].

According to Tucker (1999) [13], the recommended model of fertilization can be demonstrated by quadratic regression method:

$$Y = b0 + b1x - b2x2 \quad (2)$$

Y = The total value of crop yields caused by NPK fertilization;
b0 = constant value;
b1, b2 = the value obtained from the regression equation;
x = variable obtained from the regression equation.

Based on the regression equation can be calculated the optimum dosage of NPK (10-30-20). The result of the analysis of the dosage of fertilization NPK (10-30-20) correlated positively with the increase in maize yield with R = 0.83 (Graph 1). The results of the quadratic regression analysis of the treatment of NPK (10-30-20) to the crop yield obtained the following equations:

$$Y = 41.179 + 0.0999x - 0.0001x2 \quad (3)$$

so that $\frac{dy}{dx} = 0{,}0002x - 0{,}0999.$ (4)

If maximum value = 0, then $x = \frac{0{,}0999}{0{,}0002} = 499{,}55$ (5)

Based on this result, it can be stated that the maximum usage dosage of NPK (10-20-30) in this location was 499.5 kg ha^{-1} with the addition of 200 kg ha^{-1} urea and 100 kg ha^{-1} ZA.

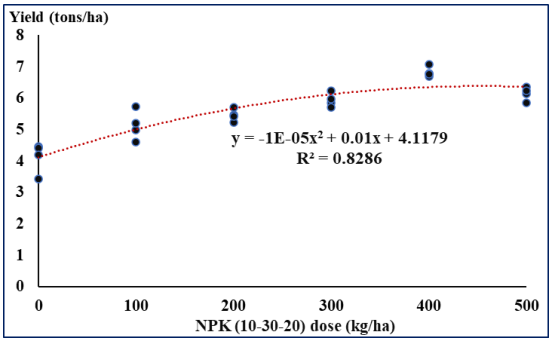

Fig 1. Relationship of NPK (10-30-20) dosage to the yield

3.4 Fertilizer effectiveness

To assess the effectiveness of a fertilization treatment, one of the methods used is the Relative Agronomic Effectiveness (RAE) formula. Relative Agronomic Effectiveness is the ratio between the increase of yield due to the use of treatment fertilizer and due to the use of standard fertilizers multiplied by 100. Based on the RAE value calculation that the application of NPK fertilizer increases the yield effectively. The highest RAE value was found in 400 kg ha^{-1} of NPK (10-30-20) which was 127.55 and higher than the standard (Table 7). This result was in line with Tuherkih and Sipahutar [14] that the optimal dosage was found at a dosage of 450 kg NPK + 100 kg urea which produced 9.0 tons ha^{-1} of dry kernel harvest with RAE 95.12% and equivalent to NPK compound standard fertilizer.

Table 7. RAE value of NPK (10-30-20) fertilizer treatments on P-27 variety

Kode	Treatment	Relative Agronomic Effectiveness (RAE)
A	Control	
B	Standard	
C	NPK (10-30-20) 100 kg	48.02
D	NPK (10-30-20) 200 kg	63.38
E	NPK (10-30-20) 300 kg	86.08
F	NPK (10-30-20) 400 kg	127.55
G	NPK (10-30-20) 500 kg	95.89

The use of NPK (10-30-20) fertilizer was increases the maize growth and yields effectively which were equivalent and higher than standard. The highest yield was 6.83 tons ha^{-1} and the highest RAE value of 127.55 was obtained in the NPK (10-30-20) fertilizer with a dosage of 400 kg + Urea 200 kg + ZA 100 kg ha^{-1}

4 Conclusions

The application of NPK (10-30-20) inorganic fertilizer was increase plant growth and yields of maize effectively. The highest yield of 6.83 tons ha-1 and the highest RAE value of 127.55 were obtained at (10-30-20) NPK 400 kg + Urea 200 kg + ZA 100 kg ha-1. The optimum dosage of NPK (10-20-30) in this location was 499.5 kg ha-1 with the addition of 200 kg ha-1 urea and 100 kg ha-1 ZA.

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