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The Effect of a Combination of Soil Improvers and N, P, K Fertilizers on P-Potential, P-Available, P Uptake, and Rice (Oryza Sativa L.) Yield in Inceptisols Soil from Jatinangor

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Abstract

Inceptisols are an order of soil that has great potential to be used as productive land for rice cultivation because of its wide distribution in Indonesia. However, this land order has low soil fertility so it is necessary to fertilize to increase soil fertility. Balanced fertilization with soil improvers and N, P, and K fertilizers can be applied to increase fertilization efficiency. This experiment aims to obtain the dose of soil improver and N, P, K fertilizer that has the best effect on P-potential, P-available, P-uptake, and rice yield. The experiment was carried out from July to December 2023 at the Soil Chemistry and Plant Nutrition Laboratory Experimental Garden, Faculty of Agriculture, University of Padjadjaran, Jatinangor, Sumedang. The experimental design used was a Completely Randomized Block Design (CRBD) with seven treatments and four replications consisting of control; N, P, K recommendations; soil improver; ½ soil + ¾ dose of N, P, K; ¾ soil improver + ¾ dose of N, P, K; 1 soil improver + ¾ dose of N, P, K; 1 ½ soil improver + ¾ dose of N, P, K; 1 soil improver + 1 dose of N, P, K. One dose of soil improver is 8000 kg ha^{-1}, while one dose of N, P, K fertilizer is 350 kg ha^{-1} Urea, 50 kg ha^{-1} SP-36, and 50 kg ha^{-1} KCl. The experimental results showed that the treatment of 1 ½ soil improver + ¾ dose of N, P, K was the best treatment for increasing the weight of 100 grains.

Keywords

Soil improver, organic matter, phosphorus, N, P, K fertilizer.

INTRODUCTION

Rice (*Oryza sativa* L.) is the main food crop in Indonesia because the majority of the population consumes rice as a staple food. The increasing population in Indonesia will require an increase in rice production needs. However, increasing rice productivity will be hampered because population growth causes agricultural land to be converted (Akhirul et al. 2020). One effort that can be made to increase rice productivity amidst the problem of land conversion is by optimizing land empowerment.

Inceptisols are one of the soil orders that have the potential to be planted with rice because they have a wide distribution in Indonesia, namely around 70.52 million hectares (Puslittanak, 2006). However, inceptisols have poor soil chemical properties, namely low N, P, K, and C-organic nutrient content (Yuniarti et al., 2019). Meanwhile, the growth and development of rice plants require sufficient nutrient requirements in large quantities, one of which is P, namely 50-100 kg ha^{-1} (Saidi, 2022). One effort that can be made to improve the chemical properties of the soil for the growth of rice plants is fertilizing.

Fertilization is an activity that provides additional macronutrients and micronutrients that must be given when the soil cannot provide these nutrients in sufficient quantities (Hasmi et al., 2020). Providing N, P, and K fertilizer is the right way to improve soil quality because it provides the elements N, P, and K which can increase plant production (Setiawati et al., 2018). However, continuous use of inorganic fertilizers at high doses can cause soil degradation, thereby reducing soil quality (Putra et al., 2022). What can be done to overcome this problem is balanced fertilization in the form of a combination of inorganic fertilizer and organic fertilizer.

Soil improvers derived from organic materials are known to increase the availability of P in Inceptisols soil. Organic matter releases organic acids to form organo-complexes which can reduce Al solubility and P fixation, thereby increasing the availability of P in soil solutions and increasing soil pH (Habi et al., 2018). Some organic materials that can be used as soil improvers are water hyacinth compost, straw biochar, and humic acid. Providing biochar at a dose of 10 tons ha^{-1} and NPK fertilizer at a dose of 135 kg ha^{-1} can increase rice production by 6.07 tons ha^{-1} on Ultisols soil (Mawardiana et al., 2013). Providing water hyacinth compost can increase the growth and yield of upland rice plants (Yusnaweti, 2018). The combination of 3 kg ha^{-1} of humic acid and 240 kg ha^{-1} of Phonska NPK fertilizer can increase plant height, number of tillers, organic C, and soil pH (Nuraini & Zahro, 2020).

This experiment was carried out to determine the combined dosage of soil improver and N,P,K fertilizer which gave the highest results in increasing P-potential, P-available, P-uptake, and rice yield in Jatinangor Inceptisols soil.

RESEARCH METHODS

This experiment was carried out from July to December 2023 at the Soil Chemistry and Plant Nutrition Laboratory Experiment Field, Department of Soil Science and Land Resources, Faculty of Agriculture, University of Padjadjaran, Jatinangor, Sumedang Regency, West Java, at an altitude of 794 m. Soil and plant analysis was carried out at the Soil Chemistry and Plant Nutrition Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, University of Padjadjaran, Jatinangor, Sumedang Regency, West Java.

The soil used as a planting medium is Inceptisols from Cileles, Jatinangor District. The rice variety used is Inpari 32. The soil improvers used come from a mixture of water hyacinth, straw biochar, and humic acid. The N, P, and K fertilizers used are Urea, SP-36, and KCl fertilizers. One dose used is 8000 kg ha^{-1} soil conditioner, 350 kg ha^{-1} Urea, 50 kg ha^{-1} SP-36, and 50 kg ha^{-1} KCl.

The experiment used a Completely Randomized Block Design consisting of eight treatments, namely: control; N, P, K recommendations; soil improver; ½ soil improver + ¾ dose of N, P, K; ¾ soil improver + ¾ dose of N, P, K; 1 soil improver + ¾ dose of N, P, K; 1 ½ soil improver + ¾ dose of N, P, K; and 1 soil improver + 1 dose of N, P, K. All treatments were repeated four times so that there were 32 experimental units.

Soil improvers are applied once, namely during the preparation of the planting medium. Urea fertilizer was applied three times, namely 20% when transplanting, 40% when the rice was 21 days after planting, and 40% when the rice was 35 days after planting. SP-36 and KCl fertilizer are applied once when transplanting.

Observations made included P-potential, P-available, and P-uptake carried out during the maximum vegetative phase, as well as rice yield which included the number of grains per panicle, percentage of filled grain per panicle, weight of 100 grains, and harvested dry grain yield.

RESULTS AND DISCUSSION

1. P-Potential

The results of statistical analysis show that the combination of soil improver and N, P, K fertilizer has a significant effect on soil P-potential (Table 1).

Table 1. Effect of Combination of Soil Improver and N, P, K Fertilizer on P-Potential in Inceptisols Soil from Jatinangor

Treatments		P-Potensial (mg 100 g^{-1})
A	Control	15,65 a
B	N, P, K dose rekomendasi	19,61 a
C	Soil improver	25,16 b
D	½ Soil Improver + ¾ dose N, P, K	23,80 b
E	¾ Soil Improver + ¾ dose N, P, K	24,52 b
F	1 Soil Improver + ¾ dose N, P, K	24,77 b
G	1 ½ Soil Improver + ¾ dose N, P, K	26,75 b
H	1 Soil Improver + 1 dose N, P, K	27,78 b

Note: Numbers followed by different letters indicate mean values that are significantly different based on the Duncan test at the 5% significance level.

The observation results in Table 1 show that the P-potential increases with increasing doses of soil improver and N, P, K fertilizer. Treatment A (control) is the treatment that produces the lowest P-potential, namely 15.65 mg 100 g^{-1}. Meanwhile, the highest P-potential was obtained from treatment H (soil improver + 1 dose of N, P, K) namely 27.78 mg 100 g-1. The difference in P-potential values is caused by differences in doses of soil improver and N, P, K fertilizer.

P-potential is defined as the accumulation of dissolved P and insoluble P but has the potential to become P in available form (Sofyan & Fauzan, 2014). The P-potential value in the soil used before treatment was 34.78 mg 100 g^{-1}. After being given treatment, the P-potential of the soil decreased. This is thought to be because P in the soil has changed form to available P. Organic material added to the soil can release P which is bound by metal ions so that the P is in a readily available form (Rosalina & Maipauw, 2019). In addition, the P-potential can be reduced due to leaching by rainwater. High rainfall can increase surface flow in transporting soil particles (Sucipto, 2007).

2. P-Available

Based on statistical tests, the combination treatment of soil improver and N, P, K fertilizer had a significant effect on available P (Table 2).

Table 2 Effect of Combination of Soil Improver and N, P, K Fertilizer on P-Available in Inceptisols Soil from Jatinangor

Treatments		P-Available (mg kg^{-1})
A	Control	4,63 a
B	N, P, K dose recommendation	5,90 a
C	Soil improver	4,25 a
D	½ Soil Improver + ¾ dose N, P, K	5,85 a
E	¾ Soil Improver + ¾ dose N, P, K	5,79 a
F	1 Soil Improver + ¾ dose N, P, K	20,06 c
G	1 ½ Soil Improver + ¾ dose N, P, K	21,94 c
H	1 Soil Improver + 1 dose N, P, K	10,48 b

Note: Numbers followed by different letters indicate mean values that are significantly different based on the Duncan test at the 5% significance level.

Table 2 shows that the combination treatment of soil improver with N, P, K fertilizer tends to increase available P. Treatments F (soil improver + ¾ dose of N, P, K) and G (1 ½ soil improver + ¾ dose of N, P, K) were the treatments that gave the best results for P-available with a value of 20.06 mg kg^{-1} and 21.94 mg kg^{-1}. Treatment B (N, P, K recommendations) increased P-available but was not significantly different from the control.

The increase in available P obtained from treatment B was caused by the addition of P fertilizer to the soil. Prasetyo et al. (2022) reported that applying P2O5 fertilizer can increase the availability of P in the soil. However, the increase in P-available in treatment B was not significantly different from treatment A (control). This shows that the addition of inorganic fertilizer alone cannot increase available P significantly. Habi et al. (2018) in their research reported that the increase in P availability from the addition of inorganic P fertilizer was only around 10-30%.

Treatment G gave the best results for available P, presumably because the N, P, and K fertilizer given was accompanied by soil improvers at the highest dose among the other treatments. The soil improver used in this experiment is an organic soil improver consisting of a mixture of water hyacinth compost, straw biochar, and humic acid. Adding these three ingredients to the soil is known to increase the organic matter content in the soil (Vignesh et al., 2022; Putri et al., 2017; Lisdiyanti et al., 2018).

Organic matter can increase the availability of P in the soil. The results of this study showed that the treatment that had the highest amount of organic material had the highest P-available value. This is in line with research by Kusumastuti (2014) which reported that giving the highest dose of organic material had the highest P-available value. Walida et al. (2020) also reported that increasing the dose of organic matter can increase P-available soil. Organic matter can increase soil-available P due to the release of organic acids which can bind metal ions such as Al and Fe, so that P can be available in the soil (Sari et al., 2017). The application of organic materials accompanied by the application of P fertilizer can increase the efficiency of P fertilization by up to 70% so that P availability can increase significantly (Siwanto et al., 2015).

3. P-uptake

The combination of soil improver with N, P, and K fertilizer has a significant effect in increasing plant P uptake (Table 3).

Table 3. Effect of the combination of soil improver and N, P, K fertilizer on P-uptake in Inceptisols Soil from Jatinangor

	Treatments	P-Uptake (mg $plant^{-1}$)
A	Control	18,36 a
B	N, P, K dose recommendation	34,73 b
C	Soil improver	23,82 ab
D	½ Soil Improver + ¾ dose N, P, K	47,37 c
E	¾ Soil Improver + ¾ dose N, P, K	50,57 cd
F	1 Soil Improver + ¾ dose N, P, K	53,45 cd
G	1 ½ Soil Improver + ¾ dose N, P, K	61,20 d
H	1 Soil Improver + 1 dose N, P, K	52,00 cd

Note: Numbers followed by different letters indicate mean values that are significantly different based on the Duncan test at the 5% significance level.

Based on Table 3, treatment G (1 ½ soil improver + ¾ dose of N, P, K) is the treatment that gives the best results for plant P-uptake, namely 61.20%. Meanwhile, treatment with recommended N, P, K fertilizer or soil improver alone provided lower P-uptake results than the combination treatment of soil improver and dose recommended N, P, K fertilizer. This shows that the combination treatment of soil improver and N, P, K fertilizer gave better results on P-uptake than the recommended N, P, K fertilizer treatment or soil improver alone.

Plant P-uptake can be influenced by the availability of P in the soil. Soepardi (1983) stated that the level of plant P-uptake is influenced by the availability of P in the soil. The availability of P in the soil can be influenced by the addition of organic material (Sandrawati et al., 2018). The highest P-uptake was found in treatment G which was thought to be because it had a higher organic material content than the other treatments. This is in line with the research results of Minardi et al. (2011) which state that increasing the dose of organic material can increase plant P-uptake.

P-uptake is positively correlated with rice crop yield components (Zheng et al., 2019). The higher the P absorbed, the higher the yield component of the rice plant. Yuniarti et al. (2020) reported that the amount of harvested dry grain and milled dry grain increased along with the increase in P uptake. Rosalina & Nirwanto (2021) in their research reported that the higher the P uptake, the higher the harvested dry grain per hill. The research results of Setiawati et al. (2016) stated that the number of panicles, number of filled grains per panicle, and percentage of filled grains were highest in the treatment with the highest P-uptake.

4. Rice Yield Components

The plant yield components observed included the number of grains per panicle, the percentage of filled grains per panicle, the yield of dry grain harvested, and the weight of 100 grains. The results of statistical analysis of the components of the observed results can be seen in Table 4.

Table 4. Effect of the combination of soil improver and N, P, K fertilizer on rice yield components

	Treatments	Number of grains per panicle (grain)	Percentage of filled grain per panicle (%)	Weight of harvested dry grain (g)	Weight of 100 grains (g)
A	Control	42,50 a	89,28	12,21 a	2,50 a
B	N, P, K dose recommendation	82,50 d	78,94	57,20 b	2,68 b
C	Soil improver	56,25 b	85,05	14,03 a	2,66 b
D	½ Soil Improver + ¾ dose N, P, K	81,00 d	82,44	52,74 b	2,65 b
E	¾ Soil Improver + ¾ dose N, P, K	71,00 cd	84,95	56,91 b	2,64 b
F	1 Soil Improver + ¾ dose N, P, K	67,50 c	82,33	59,36 bc	2,72 b
G	1 ½ Soil Improver + ¾ dose N, P, K	77,50 cd	88,49	66,26 c	2,70 b
H	1 Soil Improver + 1 dose N, P, K	82,50 d	84,74	57,06 b	2,68 b

Note: Numbers followed by different letters indicate mean values that are significantly different based on the Duncan test at the 5% significance level.

Table 4 shows that the combination of soil improver and N, P, K fertilizer has a significant effect on the yield components of rice plants, namely the number of grains per panicle, the yield of dry grain harvested, and the weight of 100 grains. Treatment D (½ soil improver + ¾ dose of N, P, K) and treatment H (1 soil improver + 1 dose of N, P, K) gave the best results for the number of grains per panicle. No treatment had a significant effect on the percentage of filled grain per panicle. Treatment G (1 ½ soil improver + ¾ dose of N, P, K) is the treatment that gives the best results for dry grain harvest. The application of N, P, K fertilizer, soil improver, and a combination of soil improver and N, P, K fertilizer were significantly different from the control in the weight parameter of 100 grains.

Treatment H is a combination treatment of soil improver and N, P, K fertilizer which produces a higher number of grains per panicle than treatment A. This is thought to be because the combination of organic material and inorganic fertilizer can maintain the N, P, and K content in the leaves and leaf sheaths. thereby increasing the number of grains per panicle. The number of grains per panicle is largely determined by the availability of nutrients, especially N (Moe et al., 2019). Treatment A produced the lowest number of grains per panicle because in this treatment no additional nutrients were added through fertilization.

The best results regarding harvested dry grain weight parameters were obtained from treatment G, namely 66.26 g. Meanwhile, treatment A (control) produced the lowest harvested dry grain weight, namely 12.21 g. This happens because soil improvers made from organic materials can store water and nutrients that plants need (Nugroho et al., 2021). The combination of organic materials and inorganic fertilizers is also known to increase the dry grain weight of rice harvests (Anisuzzaman et al., 2021). Treatment G showed the best results on harvested dry grain weight because the soil amendment dose given was the highest among the other treatments.

All treatments did not show significant differences in the parameters for observing the percentage of filled grain per panicle. This is thought to be caused by the translocation of distributed photosynthate to fill other grains. According to Pranata & Kurniasih (2019), the low amount of filled grain is caused by the low amount of assimilated translocated during grain filling. The number of grains in the treatment given was greater than the control so the grain content per panicle produced was lower.

The treated rice plants gave significantly different results from the control with a weight of 100 grains. This is because the availability of nutrients in treated plants is higher than in controls. Tajudin & Sungkawa (2020) stated that one of the factors that influences the weight of 1000 grains is the availability of nutrients. The treatment given organic material and inorganic fertilizer gave a higher weight of 100 grains than the control. This is in line with the research results of Murnita & Taher (2021) which reported that adding a combination of organic material and inorganic fertilizer had a significant effect on the weight of 1000 grains.

CONCLUSION

A treatment dose of 8 t ha-1 soil improver combined with ¾ dose of N, P, K fertilizer (262.5 kg Urea, 37.5 kg SP-36, and 37.5 kg KCl) only gave the highest results in increasing yield components rice is a weight of 100 grains.

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