Original Research Article

EFFECT OF COMBINATION OF SOIL IMPROVERS AND FERTILIZER N, P, K ON C-ORGANIC, N-TOTAL, N-UPTAKE, AND YIELD OF FIELD RICE (*Oryza sativa* L.) IN INCEPTISOLS FROM JATINANGOR

ABSTRACT

Intensive inorganic fertilization in conventional agriculture can cause a decrease in soil quality. Modification through balanced fertilization with soil amendments is expected to improve soil quality and increase plant productivity. The experiment aims to determine the effect of a combination of soil improver and N, P, K fertilizer on lowland rice (*Oryza sativa* L.) with a focus on increasing organic C, total N, and N uptake, as well as finding the dose that provides the best lowland rice yields in Inceptisols from Jatinangor. Field experiments using plastic buckets as experimental units for 5 months were carried out and arranged based on a Completely Randomized Block Design (CRBD) with eight treatment groups, including control (A), recommended N, P, K fertilizer (B), soil improver (C), ½ soil improver and ¾ dose of N, P, K (D), ¾ soil improver and ¾ dose of N, P, K (E), soil improver and ¾ dose of N, P, K (F), 1½ soil improver and ¾ dose of N, P, K (G), as well as soil improver and doses of N, P, K (H). The results of the analysis show that there is an influence of the combination of soil improver and N, P, and K fertilizer in increasing organic C, total N, N uptake, and rice yield. This experiment concluded that the dose of 1 soil improver (8 Mg ha^{-1}) and ¾ dose of N, P, K fertilizer (262.5 kg ha^{-1} Urea, 37.5 kg ha^{-1} SP-36, and 37.5 kg ha^{-1} KCl) is the best treatment in increasing rice yields and it is necessary to carry out experiments on rice fields with a higher level of heterogeneity.

Keywords: Humic acid, Organic material, Straw biochar, Water hyacinth compost, Nitrogen

INTRODUCTION

Soil improvements in agriculture are often used because of their ability to improve soil health and increase plant productivity (Urra et al., 2019). In general, the use of soil amendments is a step to utilize natural resources efficiently and can reduce the use of inorganic fertilizers. Organic soil amendments such as compost, green manure, plant residues, humic acid, and biochar can improve the physical, chemical, and biological properties of soil to support plant growth and development (Shinde et al., 2019). One way to increase the effectiveness of soil improver can be achieved by making several modifications to the organic material which is the main ingredient in soil amendments (Subiksa, 2018). Modifications that can be made are by mixing soil amendment materials. The limited information in determining the optimal mixing ratio of soil improver materials is the basis for Mustikasari's (2023) preliminary research, namely researching the formula ratio of soil improver ingredients. This research states that the ratio of water hyacinth compost: straw biochar: humic acid 1:1:1 with a dose of 8 Mg ha^{-1} is a combination that can produce the highest increase in nutrient content in ex-sand mining soil.

These findings provide hope and great potential for application to Inceptisols media. Inceptisols are a soil order that generally has less fertile soil properties with several characteristics, such as soil pH that tends to be slightly acidic, moderate organic carbon content, and low N, P, and K nutrient content (Yuniarti et al., 2020). According to BBSDLP (2020), Inceptisols are the order with the widest distribution in Indonesia with an area reaching 52.89% or approximately 99 million ha, and the island of Java has an area of approximately 8 million hectares. Seeing the fairly wide distribution of Inceptisols, this land has the potential for expanding agricultural land and can be improved with appropriate handling and technology (Sudirja et al., 2017).

After the soil conditioner is applied to the soil, the water that enters the pores of the soil conditioner will dissolve the dissolved organic and mineral compounds on the outer and inner surfaces of the soil conditioner. These solutes increase dissolved organic carbon, cations, and anions in the soil solution, which increases electrical conductivity and pH (Joseph et al., 2021). Soil improver can provide cations such as K, Ca, and Mg, and have a large surface area, thereby increasing the adsorption of exchangeable cations. Improving the pH in the soil can increase the stimulation of the hormone auxin in the roots and leaves so that plant cells develop to encourage plant growth (Chen et al., 2022).

Commented [H1]: N, P, K Fertilizers
Commented [H2]: Organic C, Total N, Uptake N
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Commented [H26]: Soil PH

To support plant growth and production, it is necessary to include inorganic fertilizers N, P, K. Based on this, this experiment was carried out by mixing the soil improver material water hyacinth compost, straw biochar, humic acid, and inorganic fertilizer N, P, K in Inceptisols from Jatinangor with lowland rice (*Oryza sativa* L.) as an indicator plant to see the ability of soil improvers to provide nutrients for rice. Rice is a commodity that has a strategic role in Indonesia because the rice plant produces rice as the main source of food for the Indonesian people. Rice requires quite a lot of nutrients. According to Minister of Agriculture Regulation No. 13 of 2022, rice requires the nutrients N, P, and K respectively 350 kg ha^{-1} Urea, 50 kg ha^{-1} SP-36, and 50 kg ha^{-1} KCl in the Jatinangor area. However, with the combination of soil improver and inorganic fertilizer N, P, K in this experiment, it is hoped that it will be able to increase organic C, N-total, N uptake, and yield of lowland rice (*Oryza sativa* L.), as well as reducing N fertilizer doses, P, K.

Based on the previous description, to determine the effect of the soil conditioner, an experiment was carried out with several dose levels accompanied by the application of inorganic fertilizers N, P, and K, namely a combination of doses of soil improver (½, ¾, 1, 1 ½ recommended) and N, P, K (¾ and 1 recommendation). This experiment aims to determine the effect of the combination of soil improver and N, P, K fertilizer on increasing organic C, N-total, N uptake, and the yield of lowland rice on Inceptisols from Jatinangor and to obtain the dosage of soil improver and fertilizer N, P, and K which provide the best lowland rice results in Inceptisols from Jatinangor.

MATERIALS AND METHODS

This experiment was carried out in July – December 2023 at the Soil Chemistry and Plant Nutrition Laboratory Experiment Field, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor District, Sumedang Regency at an altitude of ±794 m above sea level with coordinates – 6.921˚ N, 107.773 ˚E. 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, Universitas Padjadjaran, Jatinangor District, Sumedang Regency, West Java.

The materials used in this experiment were planting media in the form of Inceptisols order soil from Jatinangor which is included in the Fluventic Eutrudepts subgroup, Inpari 32 HDB rice seeds from seed producer CV. Fiona Benih Mandiri, goat manure as a seeding soil medium, soil conditioner consisting of water hyacinth compost, straw biochar, and humic acid, urea fertilizer, SP-36 fertilizer, and KCl fertilizer in various doses according to the treatment.

The experimental method used was a quantitative field experiment method with the type of research being experimental research. The field experiment was arranged using a Completely Randomized Block Design (CRBD) and using plastic buckets as the experimental unit, with the treatments tested consisting of 1 control treatment, 1 treatment with recommended N, P, and K fertilizer doses, 1 treatment with soil improver doses, and 5 combination treatments between soil improver and N, P, K fertilizers. There are a total of 8 treatments (A, B, C, D, E, F, G, H) repeated in 4 groups so that in 1 plot there are 8 × 4 = 32 experimental units. There were 2 experimental plots so there were a total of 64 experimental units. Plot 1 is used for taking soil and plant samples in the maximum vegetative phase for analysis of C-organic, N-total, and N-uptake, and plot 2 is used to obtain data on lowland rice yields.

Observed variables included soil organic C using the Walkley and Black method, total soil N using the Kjeldahl method, N content of plants destroyed by wet ashing and determined using the Kjeldahl method, and yield components in the form of number of grains per panicle, percentage of filled grain per panicle. , weight of 100 dry grains, and weight of milled dry grain.

RESULTS AND DISCUSSION

1. Soil C-organic content

Based on the results of statistical tests on soil organic C content, it shows that the application of a combination of soil improver and N, P, K fertilizer gave significantly different results compared to the control treatment and the recommended N, P, K treatment (Table 1).

Table 1. Effect of Soil Improvement and N, P, K Fertilizer on C-organic Inceptisols from Jatinangor

Treatments	Soil C-organic (%)

Commented [H27]: of N

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Commented [H29R28]: NPK fertilizer

Commented [H30]: NPK fertilizer

Commented [H31]: Total N, uptake N

Commented [H32]: NPK fertilizers.

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Commented [H35]: total N, uptake N

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Commented [H37]: Organic C, total N, and uptake N

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A	control	2,05 a
B	N, P, K Dose Recommendations	2,41 b
C	Soil Improver	2,59 c
D	½ Soil Improver + ¾ dose N, P, K	2,69 c
E	¾ Soil Improver + ¾ dose N, P, K	2,94 d
F	Soil Improver + ¾ dose N, P, K	2,93 d
G	1 ½ Soil Improver + ¾ dose N, P, K	3,19 e
H	Soil Improver + dose N, P, K	2,95 d

Note: Numbers marked with the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

The lowest C-organic content results were found in the control treatment (A) and then the recommended N, P, and K treatment (B). This is due to the absence of organic material input which can increase the soil organic C content. In line with research by Anshori et al. (2020) which states that the application of organic material provides significantly higher results compared to the application of inorganic fertilizer on soil C-organic content. Treatment G, namely 1 ½ soil improver + ¾ dose of N, P, and K showed the highest average results with soil organic C levels of 3.19% compared to other treatments. Adding a ½ dose of soil improver can produce significantly different levels of soil organic C and can reduce the use of N, P, and K fertilizer by ¼ the recommended dose. This can be seen in treatment G which is significantly different from treatments F (soil improver + ¾ dose of N, P, K) and H (soil improver + dose of N, P, K). This is by the statement of Salehi et al. (2017) which states that the provision of organic material can stimulate optimal growth of soil microbes and increase the efficiency of using inorganic fertilizers, thereby reducing the amount of inorganic fertilizers used.

There is an increase in soil organic C content along with increasing doses of soil improver because soil amendment is a large source of C for the soil. This is by the statement of Aytenew & Bore (2020), that increasing the application dose of soil improver has a positive role in increasing soil organic C. Li et al. (2021) said that soil improvers contain abundant organic C which can increase soil fertility. According to research by Mahbub et al. (2023), there was an increase in organic C content in soil treated with organic material due to the addition of organic material to flooded rice fields causing the decomposition process to take place slowly so that the organic material residue in the soil increased.

2. Soil N-total content

The results of statistical test analysis of N-total soil showed that the soil improver and N, P, K fertilizer treatments were significantly different from the control treatment soil (Table 2).

Table 2. Effect of Soil Improvers and N, P, K Fertilizers on N-total Inceptisols from Jatinangor

	Treatments	Soil N-total (%)
A	control	0,12 a
B	N, P, K Dose Recommendations	0,22 b
C	Soil Improver	0,15 ab
D	½ Soil Improver + ¾ dose N, P, K	0,31 c
E	¾ Soil Improver + ¾ dose N, P, K	0,31 c
F	Soil Improver + ¾ dose N, P, K	0,40 d
G	1 ½ Soil Improver + ¾ dose N, P, K	0,51 e
H	Soil Improver + dose N, P, K	0,44 de

Commented [H46]: Control
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Note: Numbers marked with the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

Table 3 shows that the highest total soil N content was in treatment G (1 ½ soil improver + ¾ dose of N, P, K) at 0.51%. However, this treatment did not show any significant differences with treatment H (soil improver + doses of N, P, K). Providing soil improver has a real effect on total N in the soil which can significantly increase fertilizer efficiency because the addition of 1½ doses of soil improver can reduce ¼ of the dose of N, P, K fertilizer. There is an increase in the addition of N from the soil improver material, water hyacinth compost, and biochar. able to increase the total N content of the soil. The applied soil improver is also a source of nutrients, including nitrogen (Anshori et al., 2020), in line with the statement by Ahmed et al. (2020) which states that water hyacinth compost is a material that is a rich source of N. According to research by Begum et al. (2021) providing water hyacinth compost can increase the nitrate (NO_3^-) and ammonium (NH_4^+) content.

The research results of Abujabhah et al. (2018) showed that biochar can increase total N content in soil, with an increase of up to 58.9%. These results indicate that the use of biochar has a positive impact on increasing the total N content of soil because biochar has a porous structure, and a large surface area, which allows biochar to absorb and store N in the soil, reducing N loss due to leaching, and increasing nutrient content. N in the soil. In line with the statement of Mukherjee & Zimmerman (2013), which states that the positive influence of biochar on the soil ecosystem comes from the nutrients in biochar itself, or indirectly from its ability to absorb and retain nutrients.

3. N-uptake by rice plants

The results of the statistical analysis test for plant N-uptake are presented in Table 3 which shows that the combination of soil improver and N, P, and K fertilizers had a significant effect on N-uptake.

Table 3. Effect of Soil Improvers and N, P, K Fertilizers on N-Uptake of Rice

	Treatment	N-Uptake by Rice Plant (mg/plant)
A	control	61,04 a
B	N, P, K Dose Recommendations	428,98 b
C	Soil Improver	85,12 a
D	½ Soil Improver + ¾ dose N, P, K	419,71 b
E	¾ Soil Improver + ¾ dose N, P, K	403,18 b
F	Soil Improver + ¾ dose N, P, K	423,28 b
G	1 ½ Soil Improver + ¾ dose N, P, K	562,72 c
H	Soil Improver + dose N, P, K	455,00 b

Note: Numbers marked with the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

One indicator that a plant's nutrient needs are met is nutrient uptake. N levels in plants are influenced by ammonium (NH4+) and nitrate (NO3-) in the soil as forms of N that are absorbed by plants. Plant N uptake is obtained from the calculation of the product by multiplying plant N content by plant dry weight. Based on Table 3, it can be seen that treatment A (control) shows the lowest plant N uptake results and treatment G (1 ½ soil improver + ¾ dose of N, P, K) shows the treatment with the highest level of N nutrient absorption by plants. This shows that the application of soil improver and N, P, and K fertilizers can increase plant N uptake by providing N nutrients in the soil. In line with the research results of Supramudho et al. (2012) which state that the greater the amount of total N in the soil, the more N absorption by plants will increase.

The high N uptake by plants is caused by reduced N loss in the soil. According to Omar et al. (2011), soil improver mixtures encourage the formation of ammonium (NH_4^+) and nitrate (NO_3^-) rather than

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Commented [H65]: biochar

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Commented [H67R66]: N content

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Commented [H70R69]: Control

Commented [H71]: Recommended NPK

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Commented [H73]: Nitrogen

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Commented [H75R74]: NH_4^+

Commented [H76]: NO_3^-

Commented [H77]: Soil, i

Commented [H78]: Uptake N

ammonia (NH_3), thereby reducing N evaporation (volatilization). Furthermore, the N, NH_4^+, and NO_3^- that are adsorbed on the surface of the soil amendment are slowly released into the soil, so that they can meet the N needs of rice plants according to their growth phase. This is supported by the statement of Liu et al. (2019) which states that soil improvers can release nutrients slowly.

There was no significant effect between treatments D, E, F, and H because these treatments received fewer soil improver doses than treatment G, in line with research by Selvarajh et al. (2021) which states that a lower application level of soil improver will affect the ability of the soil improver to absorb nutrients. This occurs when treatment with a lower dose will have a lower adsorption capacity and cause greater N volatilization and denitrification.

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4. Rice Yield Components

Test results on the number of grains per panicle, the weight of 100 dry grains, and milled dry grains showed that there were significantly different effects between treatments, but the percentage of filled grains per panicle showed no significant influence between treatments (Table 4).

Table 4. Effect of Soil Improvers and N, P, K Fertilizers on Rice Yield Components

	Treatments	Number of Grains Per Panicle	Percentage of Grain Contents Per Panicle (%)	Weight of 100 Dry Grain Seeds (g)	Milled Dry Grain (g)
A	control	42 a	89,28	2,50 a	4,78 a
B	N, P, K Dose Recommendations	82 d	78,94	2,68 b	22,38 b
C	Soil Improver	56 b	85,04	2,66 b	5,49 a
D	½ Soil Improver + ¾ dose N, P, K	81 d	82,44	2,65 b	20,64 b
E	¾ Soil Improver + ¾ dose N, P, K	71 cd	84,95	2,64 b	22,27 b
F	Soil Improver + ¾ dose N, P, K	67 c	82,33	2,72 b	23,23 c
G	1 ½ Soil Improver + ¾ dose N, P, K	78 cd	88,49	2,70 b	25,93 c
H	Soil Improver + dose N, P, K	83 d	84,74	2,68 b	22,33 b

Note: Numbers marked with the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% significance level.

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Commented [H81]: Control

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The combination treatment of soil improver and N, P, K fertilizer on the number of grains per panicle was significantly different from the control and not significantly different from the recommended N, P, K treatment except for treatment F (soil improver + ¾ dose of N, P, K). Treatments both C (soil improver) and B (N, P, K recommendations) were significantly different and treatment B (N, P, K recommendations) was significantly different than the soil improver treatment in increasing the number of grains per panicle. Based on the results of these statistical tests, the effect of the combination of soil improver and N, P, K fertilizer will have the advantage that a dose of ½ of the soil improver has a good effect on reducing the dose of N, P, K to ¾ of the recommended dose.

This shows that the application of soil improver with N, P, and K fertilizers has not been able to increase the number of grains per panicle. According to Rachmawati et al. (2010), the amount of filled grain per panicle is strongly influenced by nutrient availability, especially N obtained from fertilization. In line with the statement of Nurhermawati et al. (2021) which states that the N content in the soil contributes to the photosynthesis process and plays a role in seed filling.

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In this experiment, the percentage of filled grain per panicle was not significantly influenced by increasing doses of soil conditioner and N, P, and K fertilizer. The percentage of filled grains was obtained by comparing the number of filled grains per panicle with the number of empty grains per panicle. There was no significant difference between the treatments in the percentage of filled grain per panicle. This is in line with the statement of Fahmi & Sunarya (2022), which states that the greater the amount of grain that is formed, the higher the load on the plant to form full grain so that if the availability of water and nutrients is less when producing grain, the grain produced will be grain. empty. Thus, this explains why the percentage of grain content in the control treatment was not significantly different from the other treatments.

Based on Table 5, there is no real difference between the soil improver and N, P, and K fertilizer treatments, which shows that the increasing dose of soil improver does not affect the weight of 100 dry grains. This could be because the varieties used in this experiment were the same, in line with the statement by Mufikha & Machfud (2016) which states that differences in the weight yield of 100 grains of grain will be visible when various varieties are used in an experiment. This is supported by the statement of Hamdani & Haryati (2021) which states that the weight of 100 grains of the Inpari 32 variety is 2.62 g.

The components of milled dry grain yield in treatments A (control) and C (soil improver) produced no significant effect. The best treatment was obtained by treatment F (soil improver + ¾ dose of N, P, K) and G (1½ soil improver + ¾ dose of N, P, K) which were not significantly different. The recommended N, P, K treatments and the combination of soil improver with N, P, K fertilizer were significantly higher compared to treatments A (control) and C (soil improver). This is because large amounts of nutrients are obtained from N, P, and K fertilizers and can be absorbed by soil improvers so that the nutrients are available to plants. In line with research by Yuniarti et al. (2020) which states that nutrients from fertilizer will dissolve in the soil and with the presence of organic material, excess nutrients from inorganic fertilizer can remain in the soil exchange complex. Thus, the nutrients in this exchange complex can be exchanged with other ions and are not easily leached. Apart from that, the GKG weight results are closely related to the number of productive tillers, the number of grains per panicle, the percentage of grain per panicle, and the weight of 100 grains of filled grain (Ofdiansyah et al., 2023).

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CONCLUSION

The application of a combination of soil improvers with N, P, and K fertilizers has an effect in increasing organic C, total N, N uptake, and lowland rice yields which include the number of grains per panicle, the weight of 100 dry grains, and milled dry grains. Soil improver treatment (8 Mg ha^{-1}) and N, P, K fertilizer (262.5 kg ha^{-1} Urea, 37.5 kg ha^{-1} SP-36, and 37.5 kg ha^{-1} KCl) are treatments the best in providing lowland rice (*Oryza sativa* L.) yields on Inceptisols from Jatinangor.

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