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Research Paper

Determination of in situ NPK fertilization for rice growth in intensive farming system

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Abstract
Rice fields that were intensively cultivated by the application of chemical fertilizers for a long time aging will experience declining rice production. For this reason, it is necessary to know the fertility of the paddy soil for rice cultivation. Site-specific balanced fertilization is calculated from soil test results that represent the in situ soil chemical properties. This study aims to analyze the fertility level of paddy fields and determine N, P, K fertilizer for rice growth based on soil fertility status in Marga Cinta, Belitang Madang Raya District, Ogan Komering Ulu Timur of South Sumatra, Indonesia. This study used a random sampling method with 6 samplings where each sample was drilled at a depth of 0 - 30 cm and then composited. The result showed that fertility of paddy soil at the study site was relatively low, with an average yield of pH was 5.32, C-Organic 0.67%, CEC 9.85 cmol kg^{-1}, Base Saturation 21.05%, N-total 0.10%, P-available 1.87 mg kg^{-1}, K-exchangeability 0.10 cmol kg^{-1}. The fertilization recommendations obtained are urea amounting to 199.89 kg ha^{-1}, SP-36 147.91 kg ha^{-1} and KCl 28.45 kg ha^{-1}.

Keywords
Fertilizer, Intensive rice fields, Soil fertility

1. INTRODUCTION

Marga Cinta is one of the villages located in Bendungan Komering 11 (BK 11), Belitang Madang Raya District, Ogan Komering Ulu Timur, South Sumatra, Indonesia covered 96 hectares of paddy fields that is intensively used for rice cultivation. Based on data from the Agricultural Extension Agency of Belitang Madang Raya (2022), rice production in 2017 was 5.85 tons ha^{-1}, in 2018 was 6.70 tons ha^{-1}, 2019 was 6.88 tons ha^{-1}, and decreased in 2020 and 2021 to 5.58 tons ha^{-1} and 6.22 tons ha^{-1}, respectively (Agustian and Simanjuntak, 2018).

Intensive cultivation and continuous inundation of rice fields followed by large-scale chemical fertilizers for a long time cultivation showed decreasing rice production due to changes in soil chemical properties in the form of decrease in organic matter, decrease in the speed of providing N, P, K nutrients in the soil, organic acids and nutrient imbalances. Thus increase in addition of input units is not followed by increasing rice production economically (Mahbub et al., 2018).

The excessive use of conventional fertilizers can reduce fertilization efficiency and life quality. In this regard, it is necessary to carry out the site-specific dosage fertilization. Site-specific balanced fertilization is obtained from calculation of soil test results that represent the chemical properties of the soil. Soil test is a soil chemical analysis activity to evaluate the status of soil fertility (Suarjana et al., 2015). Soil chemical properties play a major role in determining the status of soil fertility and the description of fertilization activities, namely in the form of Cation Exchange Capacity (CEC), Base Saturation, C-Organic, and soil pH as well as nutrient content in the soil (Batu et al., 2019).

From the description above, this research needs to be carried out to analyze the fertility of paddy fields that are intensively cultivated. The data obtained can be used to determine the in situ N, P, K fertilizer dosage for rice growth.

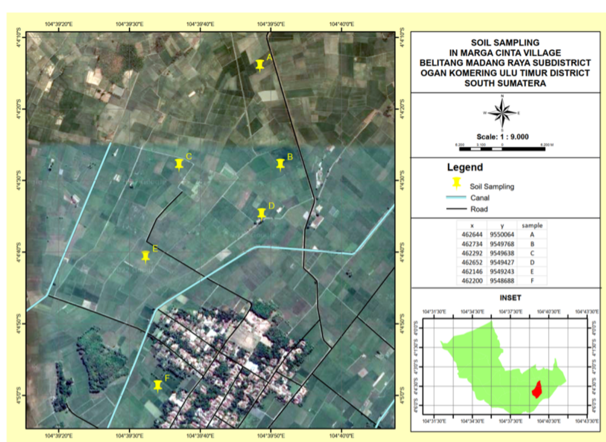

Figure 1. Soil sampling point map

2. EXPERIMENTAL SECTION

2.1 Materials

The research was conducted on rice fields owned by farmers in Marga Cinta, BK 11, Madang Raya District, Ogan Komering Ulu Timur of South Sumatra. Analysis of soil chemical properties was carried out at the Laboratory of Soil Chemistry, Biology, and Fertility, Department of Soil science, Faculty of Agriculture, Sriwijaya University. This field experiment was conducted from January 2022 to October 2022.

This detail collecting soil sample used a map with a scale of 1:9,000 (Figure 1). The area study covered 96 hectares. Soil sampling was carried out at 6 samples using the random sampling method where each sample was performed 5 times soil drilling at a depth of 0-30 cm and then composited. Soil samples were taken when the rice plant was 60 days after transplanting. The rice variety used was Inpari 32 variety.

2.2 Variable Observed

The variables observed were soil pH, C-Organic, CEC, Base Saturation, N-total, P-available, and soil K-exchangeability (Table 1). The soil N, P and K observed can be used to calculate the rate of fertilizers should be applied in the paddy soil.

Table 1. Soil analysis methods

Chemical properties	Analysis Methods
Soil pH	Electrometry
C-Organic	Walkley and Black
CEC	Sodium Saturation
Base Saturation	Extraction NH_4OAc 1 N pH 7
N-Total	Kjeldahl
P-Available	Bray I
K-exch	Extraction NH4OAc 1 N pH 7

Source: Soil Fertility Evaluation Technical Manual from LPT (1984)

3. RESULTS AND DISCUSSION

3.1 Site description of soil sampling location

The study site has a tropical climate with an average temperature of $22 - 31°C$ per day at an altitude of 55-70 meters above sea level. Rainfall data for the last 5 years (2017-2021), obtained from the Meteorology, Climatology and Geophysics Agency of the Class I Climatology Station of South Sumatra, showed a monthly rainfall amount of 2,809.4 mm year^{-1}. According to the classification criteria of Oldeman (1975), the number of wet months (> 200 mm month^{-1}) was 7 months, humid months (100-200 mm month^{-1}) was 4 months, and dry months (<100 mm month^{-1}) was 1 month. Based on these conditions, the research site is considered suitable for the growth of rice cultivation.

The paddy field was cleared in 1969 and plowed using a tractor. The planting pattern followed the Jajar Legowo system with seedlings. The commonly used rice variety was Inpari 32. Farmers harvested 2 to 3 times a year. Currently, farmers use urea and phonska fertilizers at a rate of 277.77 kg ha^{-1}.

3.2 Characteristics of Some Soil Chemical Properties of Paddy Field

3.2.1 Soil pH

Based on soil analysis presented in Table 2, it is known that the pH of paddy soil at the study site ranged from 4.98–5.60 or with an average of 5.32 ± 0.21, which is classified as acidic to slightly acidic. These results are lower than the research of Firdaus et al. (2022) in Banyumas Regency, Central Java, which is around 6.23–6.92 (close to neutral). Meanwhile, the pH of Syachroni's research rice fields (2020) in Palembang, South Sumatra ranges from 3.19–4.61 (very acidic) (Syachroni, 2020).

Soil acidification at the study site can be caused by the high annual rainfall, which ranges from 1,936–3,493 mm year^{-1}. This is in line with Syofiani et al. (2020) – if rainfall is high, H^+ ions will increase in the soil causing a decrease in pH, so that the soil will react sourly.

3.2.2 C-Organic

In Table 2, the results of the analysis of C-Organic content at the study site ranged from 0.33–1.06% or with an average of $0.67\% \pm 0.30$, which was classified as very low. C-organic content in paddy fields was found to be higher in Banyumas Regency, Central Java, which was more than 1% (Firdaus et al., 2022), and found to be less than 1% in Serdang Bedagai Regency, North Sumatra (Ompusunggu et al., 2015).

Based on the interviews conducted, many farmers dispose of or process hay as fodder, fuel for the manufacture of bricks, and burn the remaining hay after the harvest period. According to Ansari et al. (2014), straw is a source of carbon (C) and energy for organisms in the soil. In addition, the low C-Organic content is caused by paddy fields that are always flooded. According to Bahagia et al. (2022), organic matter will be difficult to decompose or undergo preservation due to flooded soil, while in paddy fields that are rarely inundated, the decomposition process will run quickly.

3.2.3 Cation Exchange Capacity (CEC)

Based on Table 2, it is known that the value of CEC at the study site ranged from 7.5–10 cmol kg^{-1} or with an average of 9.58 ± 1.02, which is relatively low. The lower CEC value is found in Tebing Kaning Village, Bengkulu, which ranges from 6.47–8.42 cmol kg^{-1} (Wahyuni et al., 2020), while the high CEC value is found in Boyolali Regency, Central Java,

Table 2. Analysis Results of pH, C-Organic, CEC, BS, N-total, P-available, and K-exchangeability

Sample	pH H_2O	C-Organic (%)	CEC (cmol kg^{-1})	BS (%)	N-total (%)	P-available (mg kg^{-1})	K-exch (cmol kg^{-1})
A	5.6^{sl}	0.48^{VL}	10^{L}	21.78^{L}	0.2^{M}	1.25^{VL}	0.19^{L}
B	5.3^{M}	0.33^{VL}	10L	20.87^{L}	0.05^{VL}	0.31^{VL}	0.19^{L}
C	5.25^{M}	1.06^{L}	10^{L}	20.38^{L}	0.06^{VL}	4.84^{VL}	0.19^{L}
D	5.35^{M}	0.70^{VL}	10^{L}	20.78^{L}	0.08^{L}	3.12^{VL}	0.19^{L}
E	5.45^{M}	0.45^{VL}	7.5^{L}	21.09^{L}	0.05^{VL}	0.78^{VL}	0.26^{L}
F	4.98^{M}	0.97^{VL}	10^{L}	21.38^{L}	0.15^{VL}	0.94^{VL}	0.19^{L}
Average (±SD)	5.32 ± 0.21	0.67 ± 0.30	9.58 ± 1.02	21.05 ± 0.49	0.10 ± 0.07	1.87 ± 1.75	0.20 ± 0.03

sl (slighly acidic); a (acidic); VL (very low); L (low), M (medium); Assessment Criteria for Soil Chemical Properties Based on LPT (1983)

Table 3. Soil Fertility Assessment at paddy field in intensive farming system

Sample	CEC (%)	BS (%)	C-Organic (%)	P-available (cmol kg^{-1})	K-exch (cmol kg^{-1})	Soil Fertility Status*
A	L	L	VL	VL	L	Low
B	L	L	VL	VL	L	Low
C	L	L	L	VL	L	Low
D	L	L	VL	VL	L	Low
E	L	L	VL	VL	L	Low
F	L	L	VL	VL	L	Low

VL (Very Low); L (Low)
*) Assessment of Soil Fertility Status According to PPT (1995)

which is 75.41 cmol kg^{-1} (Agustian and Simanjuntak, 2018). The high and low CEC values depend on the texture of the soil, the type of clay minerals, and organic matter. The secondary clay mineral content of 1:1 (kaolinite) has a low amount of CEC, while the primary clay mineral content of 2:1 (montmorillonite) has a high amount of CEC (Suryani, 2014).

The low soil CEC at the study site was caused by soil C-Organic levels, where the study site had a very low C-Organic level of 0.67%. C-Organic affects soil CEC because with the increase in humus by a high amount of organic matter, the amount of soil colloids will increase due to the presence of bonds in high soil particles (Peku, 2021).

3.2.4 Base Saturation (BS)

BS) value at the study site ranged from 20.38–21.78% or with an average of 21.05% ± 0.49, which was relatively low. Low results were also found in Deli Serdang Regency, North Sumatra, which ranged from 19.39–28.94% (Hutapea et al., 2018). While the high soil BS value can be found in Boyolali Regency, Central Java, with the highest value up to 78.58% (Agustian and Simanjuntak, 2018).

Low BS values are due to high soil acidification. Base Saturation has a close relationship with the soil pH, where if the soil pH is high, the base saturation level is also high; on the other hand, if the soil pH is low, the soil base saturation becomes low (Suarjana et al., 2015). The pH at the study site ranged from 4.98–5.60, which is classified as sour, so the base saturation becomes relatively low.

3.2.5 N-Total

From the results shown in Table 2, it is known that the N-total at the study site ranged from 0.05–0.21% or with an average of 0.10% ± 0.07, which is classified as very low to moderate. N in the soil is generally easily lost because it is washed off by water or evaporates and is absorbed by plants; therefore, the average N in the soil is low (Benauli, 2021). The results ofAgustina et al. (2020) also showed very low N content in irrigated paddy fields in Malang Regency, East Java, ranging from 0.08–0.18%. The low content of N is thought to be due to the application of a land use system that is always flooded throughout the planting, making it difficult for N-tethering bacteria to develop.

Based on the results of the interview, farmers fertilize by spreading fertilizer, and after that, there is no immersion treatment. According to Sakti et al. (2011), this method is inefficient because the fertilizer will not enter the soil reduction layer where NH_4^+ will be dissolved in the puddle (oxidation) because urea is hygroscopic, then it will turn into NH_3^+ which will eventually evaporate into the air.

Table 4. Site Specific Fertilizer Recommendation compared to the Ministry of Agriculture

Sample	Calculation result*			Suggestion**		
	Urea (kg ha^{-1})	SP-36 (kg ha^{-1})	KCl (kg ha^{-1})	Urea (kg ha^{-1})	SP-36 (kg ha^{-1})	KCl (kg ha^{-1})
A	151.70	155.88	30.12	350	75	100
B	220.88	167.80	30.12	350	75	100
C	218.44	110.14	30.12	350	75	100
D	208.62	132.02	30.12	350	75	100
E	220.89	161.83	20.08	350	75	100
F	178.83	159.79	30.12	350	75	100
Average	199.89	147.91	28.45	350	75	100

*) The results of the calculation of fertilizer needs based on the results of soil chemical analysis
**) Fertilization recommendations from the Ministry of Agriculture (2022)

Therefore, the fertilizer should be immersed in the soil 15 to 20 cm deep.

3.2.6 P-Available

Based on the results of soil analysis presented in Table 2, it was found that the P-available soil at the study site ranged from 0.31–4.84 mg kg^{-1} or with an average of 1.87, mg $kg^{-1} \pm$ 1.75, which was classified as very low. This also occurred in Nisam District, North Aceh Regency Sari et al. (2022). Fertilization practices can affect the availability of P in the soil. Based on interviews, farmers only use Phonska compound fertilizer (NPK), while in Lombok, the use of single fertilizers TSP and SP-36 is still often used to produce high P-available paddy soils, ranging from 11.1–40.5 mg kg^{-1} (Habiburrahman et al., 2018).

Soil pH is closely related to the availability of P in the soil. According to Firnia (2018), the maximum P availability in the soil is found in the pH range of 5.5–7. If the soil pH is lower than 5.5 or higher than 7, then the available P will decrease. In addition, the low P-available can also be caused by farmers throwing hay away after harvest. Straw is an organic matter that is one of the sources of P elements. This is in line with Sari et al. (2017), where organic acids resulting from the decomposition of organic matter will form chelation bonds with Al and Fe ions, which causes a decrease in the solubility of these ions, thereby increasing the availability of P. Furthermore, organic acids resulting from the decomposition of organic matter can also release absorbed P, increasing the available P.

3.2.7 K-exchangeability

The results of the analysis in Table 2 found that the soil K-exch content at the study site ranged from 0.19–0.26 cmol kg^{-1} or with an average of 0.20, cmol $kg^{-1} \pm 0.03$, which was relatively low. Low levels of K in the soil are caused by the soil's potassium input capacity, insufficient application of potash fertilizers, small contribution of irrigation water, and low efficiency of fertilizer absorption (Agustina et al., 2020). Very high potassium is found in Manggis District, Bali Province (Suarjana et al., 2015).

The low K-dd is caused by the low CEC, resulting in K being easily washed off. This is in line with Suarjana et al. (2015), as high CEC can influence soil solutions to slow release K and lower the leaching rate of K in the soil. The transportation of harvested hay from the field without any return also causes the soil K nutrient content to be low because straw contains a relatively high amount of K. Asmin and Karimuna (2014) mention that the amount of K transported in grain is more than 20% of the total K absorbed, and about 80% of K is in hay.

Based on the results of the soil chemical properties analysis, combined with fertility status, it was found that the soil fertility at the study site was low in all soil samples. The low fertility of this soil is thought to be due to the age of the soil and intensive planting. Additionally, the continuous use of irrigation water flowing through the field can cause leaching of soil cations and loss of nutrients. This is in line with Khairunnisa et al. (2017), which states that cations such as K^+, Ca^{2+}, Mg^{2+}, and Na^+ are easily washed off by percolation water and released into the soil horizon.

Disposing of or processing hay as fodder, fuel for making bricks, and burning straw residue in the field also contributes to low soil organic matter, which plays an important role in maintaining and improving soil fertility. According to Kamsurya and Botanri (2022), organic matter can increase soil fertility by slowly releasing nitrogen and other nutrients through the mineralization process. Additionally, organic matter serves as a source of energy for soil microorganisms, which emit enzymes that promote an increase in the amount of available nutrients in the soil.

3.3 Recommendations for in situ N, P, and K fertilizers for rice growth in Marga Cinta

Rice production in Marga Cinta Village has reached 5 tons ha^{-1}, supported by the irrigation system and the Inpari 32 rice variety. Based on the specifications, the Inpari 32 variety has a potential yield of up to 8 tons ha^{-1}. According to the Ministry of Agriculture (2021), to produce 8 tons ha^{-1} of rice, plants require N nutrients of 111.78 kg ha^{-1}, P of 27 kg ha^{-1}, and K of 30 kg ha^{-1}. Site-specific fertilization recommendations were obtained from the analysis of in situ N-total, P-available, and K-exch soils, which were then used to calculate the doses of urea, SP-36, and KCl fertilizers. The fertilizer recommendations for urea, SP-36, and KCl at the study site were obtained and compared with the recommendations from the Ministry of Agriculture, as presented in Table 4.

The N, P, and K levels in the paddy fields in Marga Cinta, based on the results of the analysis, fall within the very low to low category (Table 4). To fulfill these nutrient requirements, the recommendations for urea fertilizer range from 151.70–220.89 kg ha^{-1}, with an average of 199.89 kg ha^{-1}. The recommendations for SP-36 fertilizer range from 110.14–167.80 kg ha^{-1}, with an average of 147.91 kg ha^{-1}. The recommendations for KCl fertilizer range from 20.08–30.12 kg ha^{-1}, with an average of 28.45 kg ha^{-1}. When compared to the recommendations of the Ministry of Agriculture (Table 4), the study site has higher fertilization recommendations, except for SP-36 fertilizer.

4. CONCLUSIONS

The conclusions of the research that has been carried out are paddy fields in Marga Cinta, BK 11, Belitang Madang Raya District have soil pH of slightly acidic to acidic, very low C-Organic, low CEC, low BS, medium to very low N-total, very low P-available, and low K-exchangeability. Thus, the soil fertility status was obtained low or in fertility status. Nutrient deficiencies of N, P, and K at the study site could be corrected by the addition of urea with an average of 199.89 kg ha^{-1}, SP-36 with an average of 147.91 kg ha^{-1}, and KCl with an average of 28.45 kg ha^{-1}.

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