

Integrated Nutrient Management of an Acid Paddy Soil in Karang Tanjung Village, Padang Ratu, Central Lampung

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ABSTRACT

Balanced fertilization is the key factor to improve the efficiency and effectiveness of fertilization. The dosage of inorganic fertilizers applied can be determined based on the nutrient status of P, K and rice productivity. The research aims to improve balance fertilization that combines inorganic fertilizers, which is set up based on soil nutrient status, and organic fertilizers. The research was conducted in Karang Tanjung Village, Padang Ratu District, Central Lampung, in the dry season of 2009 until 2012. An experimental plot of one hectare was set up in the farmer's paddy fields. Generally, the plot for every treatment was owned by two or more farmers. The treatments consisted of the dose of fertilizer applications for lowland rice, namely (1) dose of fertilizers based on farmer practice, (2) dose of fertilizers proposed by Petrokimia, (3) 75% of fertilizer dose that was set up based on soil analysis plus straw compost, and (4) 75% of inorganic fertilizer combined with manure and biofertilizer. At the fourth growing season, each plot was applied with 100% inorganic fertilizer (NPK fertilizer). The results showed that the limiting factor of the soil used in the current study is the content of organic-C, N, K, and CEC. The compost of rice straw used as organic matter in the current study contains higher organic-C and total-N in comparison to manure. Organic matter application in the form of straw compost or manure can reduce 25% of NPK application, while the production of rice remains high. Fertilization on paddy soils based on soil nutrient status can improve fertilization efficiency. Rice production in the treatment of 100% NPK is similar to that in the fertilization treatments based on farmer practice and Petrokima rate.

Keywords: Nutrient management, acid soil, fertilization efficiency

ABSTRAK

Pemupukan berimbang merupakan kunci peningkatan efisiensi dan efektivitas pupuk. Dosis pupuk anorganik didasarkan pada status hara P, K dan produktivitas padi. Penelitian ini bertujuan untuk memperbaiki pemupukan berimbang yang menggabungkan pemupukan anorganik berdasarkan status hara tanah dan bahan organik. Penelitian dilakukan di Desa Karang Tanjung, Kecamatan Padang Ratu, Lampung Tengah, pada musim kemarau tahun 2009 sampai 2012. Petak percobaan seluas satu hektar dengan menggunakan plot asli milik petani. Umumnya, setiap perlakuan terdiri dari lahan sawah milik tiga atau lebih petani. Perlakuan diset untuk menyusun dosis pupuk berimbang untuk padi sawah. Perlakuan terdiri dari (1) praktik petani, (2) dosis pupuk Petrokimia, (3) 75% dosis pupuk yang dibuat berdasarkan analisis tanah yang dikombinasikan dengan kompos jerami, dan (4) 75% pupuk anorganik dikombinasikan dengan pupuk kandang dan biofertilizer. Pada musim keempat ditambahkan perlakuan pupuk anorganik 100% (pupuk NPK). Hasil penelitian menunjukkan bahwa faktor pembatas tanah yang digunakan adalah C-organik, N, K, dan KTK. Kompos jerami padi yang digunakan sebagai bahan organik mengandung C-organik dan total N lebih tinggi dari pada pupuk kandang. Aplikasi bahan organik berupa kompos jerami atau pupuk kandang dapat mengurangi 25% NPK dengan produksi beras tetap tinggi. Produksi padi berdasarkan status hara tanah dapat meningkatkan efisiensi pemupukan. Produksi tidak berbeda antara perlakuan pemupukan 100% NPK dengan praktik petani dan dosis pupuk Petrokima.

Kata kunci: Pengelolaan hara, tanah masam, efisiensi pemupukan

INTRODUCTION

Fertilizer is an essential agricultural input needed by farmers to increase their crop yields. Fertilizer containing macro nutrients like N, P, and K are needed by plants. Soil nutrient balance is an important aspect in enhancing crop productivity. Balanced fertilization on rice plants grown on specific location can be determined based on soil nutrient status through soil analysis in a laboratory or by using a soil test instrument such as Rice Soil Test Kit (*PUTS*).

The farmers have not applied a balanced fertilization in paddy fields during the last decade because of many reasons, such as the price of fertilizers is expensive or the scarcity of fertilizers, such as KCl and SP-36. Most rice farmers only apply urea as a source of N because the price of urea is relatively cheap and its effects can be directly seen in the vegetative growth of the plants. Meanwhile, the application of P and K fertilizers in general does not follow the soil nutrient status and crop requirements due to an expensive price and the scarcity of P and K fertilizers.

A previous study showed that the application of urea (250 kg ha⁻¹), SP-36 (100 kg ha⁻¹), and KCl (100 kg ha⁻¹), respectively on paddy fields in Taman Bogo with low levels of N, P, K, and organic-C content in the soil could increase rice yields significantly (Soelaeman *et al.* 2010). The combination of the organic fertilizer with NPK fertilizers increased soil pH, the availability and uptake of potassium (K) in paddy soil, and the number of tiller of rice plants (Kaya 2014). Further, fertilization of 200 kg urea ha⁻¹ and a dose of P and K based on soil test in some areas of paddy fields in Pantura, Java could increase the dry weight of grains and nutrient uptake of N and K (Hartatik and Adiningsih 2003). Nitrogen fertilization increased rice production at rainfed areas in Boyolali, Jakenan, and Cianjur, K fertilization could increase rice production in Jakenan, but P fertilization hardly increased rice production (Kasno *et al.* 2016). NPK fertilization increased rice yield in the first and second seasons by 53.7% and 39.6%, respectively. Further, second NPK fertilization still increased rice yield by 18% and 15% in the first and second growing seasons, respectively (Bi *et al.* 2014). NPK fertilizer affected significantly rice growth and yield in Aceh Besar District (Samira *et al.* 2012). The study of Hermawan (2005) showed that the yield of IR64 rice plants increased significantly after application of 75 kg SP-36 ha⁻¹, but decreased at higher P doses. The recommendation of P fertilizer in Rejang Lebong and Kapahiang Regency, Bengkulu with high soil P status was 50 kg SP-36 ha⁻¹, 200 kg urea ha⁻¹, and

100 kg KCl ha⁻¹. Meanwhile, fertilization with 300 kg NPK Phonska ha⁻¹ and 333 kg ZA ha⁻¹ produced the highest IR64 rice yield in Sumedang, *i.e.* 7.5 Mg ha⁻¹ (Kurniadie 2002). However, it is worth to consider the results of study by Feng *et al.* (2003) that about 56% of P fertilizer was absorbed by paddy field soil, and the loss of N by denitrification was large during the irrigation period, accounting for about 20% of the applied chemical fertilizer.

Due to the lack of proper nutrient management and organic matter input, there has been a decline of soil organic matter content in the paddy field. The study of Kasno *et al.* (2003) showed that the soil organic-C content in approximately 65% of the rice fields in Indonesia is already below the critical limit (<2%). Soil organic matter content is correlated with the productivity of rice in which the lower the organic matter content, the lower the productivity of rice is (Karama *et al.* 1990). Management of rice straw is important for rice cultivation. Returning of straw in paddy field increased rice yields of 2.18 and 1.7 Mg ha⁻¹ in the 3rd and 4th year of cultivation, respectively, which is similar to the effect of application of 66 kg ha⁻¹ K fertilizer (Saha *et al.* 2009). Rice straw incorporation into the soil resulted in better yield, better physical and chemical properties after six rice growing seasons (Tuyen and Tan 2001). The cumulative effect of straw incorporation resulted in greater net N mineralization, microbial biomass N, and recovery of N in soil one year after application (Bird *et al.* 2001). Further, the content of organic-C and soil cation exchange capacity are influenced by planting system, NPK fertilizer and organic fertilizer made from chopped straw and manure. In contrast, the soil base saturation is only influenced by organic fertilizer application (Hanum *et al.* 2016).

Indonesian Soil Research Institute (ISRI) has produced fertilization technology and management of organic matter that have been proven to increase the productivity of the soil on a plot scale. The technology needs to be introduced to farmers and agricultural extension workers, among others, in the form of on-farm balanced fertilization on rice farming. This paper presents the results of the study that was conducted during 2009-2012 growing seasons in Karang Tanjung Village, Padang Ratu District, Central Lampung Regency, Lampung Province.

MATERIALS AND METHODS

Study Site

The experiment was conducted in Karang Tanjung Village, Padang Ratu District, Central Lampung Regency, Lampung, Indonesia (105° 01'

Table 1. Description of soil profile in the study site in Karang Tanjung Village, Padang Ratu District, Central Lampung.

| Location | : | KarangTanjung Village, Central Lampung Regency | | |
|---------------------|-----------------|--|--|--|
| Soil Classification | : | FluventicEpiaquepts | | |
| Landform | : | Peneplain | | |
| Physiography | : | Nearly flat | | |
| Slope | : | 1-3 % | | |
| Elevation | : | 45 m | | |
| Parent Material | : | Acid Tuff | | |
| Drainage | : | Poor | | |
| Permeability | : | Low | | |
| Land Use | : | Rice Field | | |
| Initial of Profile | : | KT | | |
| Altitude | : | 05°04'72" S | | |
| Longitude | : | 105°01'54" E | | |
| Date | : | August, 24, 2010 | | |
| No | Horizon | Dept(cm) | Morphological Characteristics | |
| I | Ap | 0 - 19 | Gray (2,5 Y 5/1) and light olive gray (2,5 Y5/4); silty clay texture; sticky and plastic (wet); massive structure; many fine root; strong brown (7,5 YR 5/6) mottles; clear smooth boundary. | |
| II | Bwg1 | 19 - 38 | Gray (2,5 Y 6/1) and light olive gray (2,5 Y 5/3); clay texture; sticky and plastic (wet); massive structure; abrupt smooth boundary. | |
| III | Bwg2 | 38 - 63 | Light olive gray (5 Y 6/1); clay texture; sticky and plastic (wet); massive structure; abrupt smooth boundary. | |
| IV | BC | 63 – 100 | Gray (5 Y 6/1) and brown (7,5 YR 4/4); clay texture; massive structure. | |
| | Notes | | Mangan Concretions (layer IV) | |
| | Epipedon | : | Ochric | |
| | Sub horizon | : | Cambic | |
| | Moisture Regime | : | Aquic | |

18" E, 05° 04' 56" S), with an elevation about 45 m above sea level. The soil parent material in the study site is acid tuff from Palembang. The soil in the study site is classified as Fluventic Epiaquepts. Rice could be planting three times every year. The experiment was conducted during six growing seasons, started in dry season of 2009 until dry season of 2012.

The characteristics of the soil in the study site are sandy loam, pH 5.39, low organic-C and total-N contents, high P₂O₅ content and medium K₂O content (both P and K are extracted using HCl 25%). In addition, the content of base cations and CEC of the soil are low, and the soil base saturation is high. Generally, after rice harvesting, rice straw is burned, and no application of organic matter (cow manure) on the fields. The application of N fertilizer in the experimental site is high, *i.e.* 145 kg N ha⁻¹.

Experimental Design and Treatments

The plots used for the experiment were the plots belong the farmers, which was around 1 ha for every

treatment. Generally, the plot for every treatment was owned by two or more farmers. The treatments consisted of (1) dose of fertilizers according to farmer practice, (2) dose of fertilizers proposed by Petrokimia, (3) 75% of fertilizer dose set up based on soil analysis combined with straw compost, and (4) 75% of inorganic fertilizer combined with manure and biofertilizer. At the fourth growing season, the plots were applied with 100% inorganic fertilizer (NPK fertilizer).

The dose of fertilizers used for farmer practice was set up based on the results of focus group discussion involving the farmers, farmer's group leaders, village officers and agricultural extension officers. The fertilizer doses used for farmer practice were 200 kg urea ha⁻¹, 325 kg NPK ha⁻¹ (ratio N:P:K in % was 15-15-15) and 450 kg ha⁻¹ cow manure. The doses of fertilizers proposed by Petrokimia were 200 kg urea ha⁻¹, 300 kg ha⁻¹ NPK compound fertilizer (ratio N:P:K in % was 15-15-15), and 500

kg ha⁻¹ organic granular fertilizer. The dose of 100% inorganic fertilizer treatment was 187 kg urea ha⁻¹ and 200 kg ha⁻¹ NPK compound fertilizer. The recommendation of 100% inorganic fertilizer treatment was set up based on the soil analysis in laboratory. The dose of organic matter that was added in the form of straw compost and cow manure was 2000 kg ha⁻¹. The straw compost was made from straw that was harvested from the same plots.

Measurement of Plant Parameters and Analysis of Soil Samples and Organic Fertilizers

The plant parameters that were measured in the study were plant growth and yield. The plant growth parameters measured were plant height and number of tiller, and the yield parameters measured were the dry weight of straw and grains. Plant height and number of tiller were measured at one and two months after planting, and before harvesting time. Every treatment was applied on three plots as replications, in which the size of each plot was 3 × 4 m. Plant height and number of tiller were measured at ten spots in each plot. The soil samples were taken from the soil profile after soil description in the field. The soil samples were also taken at harvesting time in each treatment. Besides, the organic fertilizers used in the study was also analysed.

Data Analysis

The data of plant growth and yields were analyzed using ANOVA using the SPSS statistical

program. The results of data analysis were further tested using Duncan's Multiple Range Test. In addition, the soil, fertilizer and plant sample data were compared with the standard criteria.

RESULTS AND DISCUSSION

Soil Characteristics in the Study Site

The soil parent material at the study site is acid tuff from Palembang. The landform of the study site is peneplain, with physiography nearly flat (1-3%). The soil profile consists of four horizon layers, *i.e.* 0-19 cm, 19-38 cm, 38-63 cm and 63-100 cm. The soil texture in each soil horizon is sandy loam at 0-19 cm depth, clay at 19-38 and 38-63 cm, and clay loam at 63-100 cm (Table 1 and 2).

Soil pH ranges from 5.01-5.60. The soil pH measured in H₂O extraction is higher than that in KCl 1 N extraction. The result indicated that the soil is negatively charged and can adsorb both added and existing nutrient in the soil. The soil organic-C content is low, probably due to straw burning activity by the farmers. The soil N content is low, as well as Ca, Mg and K contents. Burning of rice straw is not a good practice compared to incorporation of the straw into the soil (Tuyen and Tan 2001). Removal of rice straw from the field in every season without the application of K fertilizer can lead to K deficiency in paddy soil (Dobermann and Fairhurst 2002). The nutrient content in topsoil is higher than that in the subsoil, especially for organic-C, P, Ca, Mg and base

Table 2. Soil characteristics of each horizon layer of the soil profile in Karang Tanjung Village, Padang Ratu District, Central Lampung.

| Characteristic | Unit | Soil depth (cm) | | | |
|---|-------------------------|-----------------|-------|-------|-----------|
| | | 0-19 | 19-38 | 38-63 | 63-100 |
| Texture | | Sandy loam | Clay | Clay | Clay loam |
| Sand | % | 57 | 34 | 35 | 41 |
| Silt | % | 24 | 23 | 21 | 19 |
| Clay | % | 19 | 43 | 44 | 40 |
| pH H ₂ O (1:5) | | 5.39 | 5.60 | 5.05 | 5.01 |
| KCl | | 4.27 | 4.42 | 3.94 | 3.91 |
| Organic-C | % | 0.97 | 0.45 | 0.27 | 0.22 |
| Total N | % | 0.16 | 0.18 | 0.18 | 0.22 |
| Extract HCl 25% | | | | | |
| P ₂ O ₅ | mgkg ⁻¹ | 92 | 46 | 26 | 17 |
| K ₂ O | mgkg ⁻¹ | 17 | 7 | 17 | 27 |
| Bray 1 P ₂ O ₅ | mgkg ⁻¹ | 23.29 | 4.86 | 2.12 | 2.38 |
| Extract of (CH ₃ COONH ₄) 1 M pH 7 | | | | | |
| Ca | cmol(+)kg ⁻¹ | 2.76 | 3.72 | 1.02 | 0.88 |
| Mg | cmol(+)kg ⁻¹ | 0.44 | 1.11 | 0.40 | 0.38 |
| K | cmol(+)kg ⁻¹ | 0.02 | 0.01 | 0.02 | 0.05 |
| Na | cmol(+)kg ⁻¹ | 0.05 | 0.12 | 0.10 | 0.11 |
| CEC | cmol(+)kg ⁻¹ | 3.67 | 6.47 | 6.73 | 5.83 |
| Base saturation | % | 89 | 76 | 23 | 24 |

saturation. The low fertility status of the soil in the study site is determined by the soil parent material, as shown by the low fertility status of the subsoils.

The results of soil analysis showed that the fertility status of paddy soils in Karang Tanjung Village is low. The limiting factors of paddy soils for the growth of rice plants include low organic-C, N and K contents. Nitrogen fertilization increased rice production in rainfed lowland areas in Boyolali, Jakenan and Cianjur about 41.9%, 50.5% and 32.0%, respectively (Kasno *et al.* 2016). Application of KCl at 150 kg ha⁻¹ and dolomite at 50 kg ha⁻¹ on Inceptisol in Muarabeliti can increase K-HCl, exchangeable-K, and rice production (Nursyamsi *et al.* 2000). The study of Agam (2014) showed that application of various dosages of organic fertilizers and goat manure showed no significant effect on the soil physical properties, however there was a significant effect on rice production. The highest rice production obtained was 1.7 Mg ha⁻¹ after application of 500 kg ha⁻¹ organic fertilizer and 5,000 kg ha⁻¹ goat manure.

Nutrient Content of Organic Fertilizers Used in the Study

The characteristics of organic fertilizers used in the study are presented in Table 3. The organic-C content in manure is lower than that in straw compost.

The content of other nutrients, such as P₂O₅, K, Ca, B, and Cu in manure is higher than in straw compost. Nutrients in the organic matter is useful for plant growth. In China, straw application increased rice yields by 9.63% and 12.58% in rainy season and dry season 2012, respectively (Wang *et al.* 2015). Application of straw compost as much as 1 Mg ha⁻¹ contributed about 15.10 kg N ha⁻¹, 2.35 kg P₂O₅ ha⁻¹, and 2.90 kg K ha⁻¹ (Table 3). The organic-C, total-N and Mn contents in straw compost are higher than in manure. However, the content of P, K, Ca, B and Cu in manure is higher than in straw compost.

Application of straw at 5 Mg ha⁻¹ can increase the levels of organic-C, exchangeable-K, soil CEC, K uptake, and dry weight of straw and grains (Nursyamsi *et al.* 2000). Application of urea combined with rice straw compost can increase N-NH₄ in the soil and reduce the potential immobilization of organic matter (Indriyati *et al.* 2007). Application of straw compost combined with NPK fertilizers can increase N uptake, whereas application of only straw compost can increase soil N, plant height and number of tiller (Kaya 2013). The application of rice straw compost at 5 Mg ha⁻¹ along with half of the recommended dose of inorganic fertilizers increased the microbial biomass-C, the activity of dehydrogenase and alkaline phosphatase, and the contents of organic-C and N

Table 3. The nutrient content of organic fertilizers used in the study.

| Characteristic | Manure | Straw compost |
|-------------------------------|---------------------------------|---------------|
| | kg Mg ⁻¹ | |
| Organic-C | 106.85 | 245.05 |
| Total N | 13.45 | 15.10 |
| P ₂ O ₅ | 5.05 | 2.35 |
| K | 8.00 | 2.90 |
| Ca | 5.25 | 3.20 |
| B | 0.10 | 0.042 |
| Mn | 0.75 | 1.343 |
| Cu | 0.023 | 0.007 |

Table 4. Height of rice plants under different soil nutrient management practices applied in the study site.

| Treatment | Plant height (cm) in the first until sixth growing season | | | | | |
|-----------------------------|---|---------|---------|---------|---------|----------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Farmer practice | 86.5 a | 103.1 a | 101.8 a | 97.0 ab | 100.7 a | 103.0 a* |
| Petrokimia rate | 88.2 a | 106.4 a | 102.3 a | 97.0 ab | 105.3 a | 101.4 a |
| 75% NPK + straw compost | 82.9 a | 93.3 b | 101.3 a | 95.8 b | 101.9 a | 98.1 a |
| 75%NPK+manure+biofertilizer | 86.9 a | 101.6 a | 102.3 a | 98.4 ab | 104.0 a | 98.1 a |
| 100% NPK | - | - | - | 99.2 a | 103.6 a | 97.9 a |

Note: The values followed by different letters in the same column are significantly different (p<0.05) based on DMRT.

Table 5. Number of tiller of rice plants under different soil nutrient management practices applied in the study site.

| Treatment | Number of tiller in the first until sixth growing season | | | | | |
|-----------------------------|--|---------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Farmer practice | 20.2 a | 17.6 a | 15.9 a | 14.9 a | 18.9 a | 21.7 a |
| Petrokimia rate | 19.0 a | 16.8 ab | 16.5 a | 15.5 a | 20.1 a | 20.5 a |
| 75% NPK + straw compost | 15.4 b | 15.4 c | 16.0 a | 14.3 a | 19.4 a | 20.0 a |
| 75%NPK+manure+biofertilizer | 17.5 ab | 16.0 bc | 15.8 a | 14.7 a | 19.4 a | 19.3 a |
| 100% NPK | - | - | - | 14.7 a | 19.9 a | 20.2 a |

Note: The values followed by different letters in the same column are significantly different ($p < 0.05$) based on DMRT.

in soil (Goyal *et al.* 2009). The combination of organic and inorganic fertilizers could increase N and P efficiency in paddy soils (Siswanto *et al.* 2015).

The Effect of Soil Nutrient Management Practices on Plant Height

The height of rice plants grown on paddy fields in Karang Tanjung Village is not influenced by soil nutrient management (Table 4). The application of straw compost and manure on the soil can improve soil physical and chemical properties, so that the height of the plants grown on the plots applied with organic matter plus 75% NPK is not different from that in the plots applied with 100% NPK. Therefore, it can be concluded that the use of organic matter can reduce the use of inorganic NPK fertilizers as much as 25%. The study of Abdullah and Azwir (2011) showed that the application of 50% KCl fertilizer based on soil nutrient status (37.5 kg KCl ha⁻¹) and straw compost 1 Mg ha⁻¹ produced the same rice yield as application of 75 kg KCl ha⁻¹ (100% KCl fertilizer). Meanwhile, the study of Padmanabha *et al.* (2014) indicated that the interaction between organic and inorganic fertilizers could increase significantly ($p < 0.05$) the height of rice plant.

The dosage of NPK fertilizers was set up based on soil nutrient status. In high P status soil, the soil

was fertilized with 50 kg SP-36 ha⁻¹ and in medium K status soil, the soil was fertilized with 50 kg KCl ha⁻¹. The dosage of NPK fertilizers in 100% NPK treatment was lower than the dose of NPK fertilizers used for farmer practice and the dose proposed by Petrokimia. The plant height at 100% NPK treatment is similar to that in the plots applied with fertilizer dose used for farmer practice and proposed by Petrokimia. It can be concluded that the efficiency of wetland rice fertilization can be increased by the application of fertilizer dose set up based on soil nutrient status and combined with the use of organic matter. The result of current study is in line with the study of Dewi *et al.* (2013), which showed that the application of organic fertilizer on Tropaequets soil from Sukamandi could significantly increase rice growth and dry weight of grains. However, enrichment of organic fertilizer with iron up to 64.000 mg kg⁻¹ has no significant effect on the growth and yield of wetland rice.

The Effect of Soil Nutrient Management Practices on the Number of Tiller

Soil nutrient management practices applied in the current study did not increase the number of tiller of rice plants (Table 5). The number of tiller of rice plants applied with 100% NPK (187 kg urea and 200 kg NPK ha⁻¹) is similar to that in the plots applied with fertilizers according to farmer rate (200

Table 6. Dry weight of grains under different soil nutrient management practices applied in the study site.

| Treatment | Dry weight of grains (Mg ha ⁻¹) in each growing season | | | | | |
|-----------------------------|--|--------|--------|---------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Farmer practice | 4.67 a | 4.97 a | 5.00 a | 5.53 ab | 8.36 a | 6.31 a |
| Petrokimia rate | 4.90 a | 5.69 a | 4.94 a | 5.72 a | 7.92 a | 6.11 a |
| 75% NPK + straw compost | 4.80 a | 4.50 a | 5.08 a | 4.36 b | 7.78 a | 6.50 a |
| 75%NPK+manure+biofertilizer | 4.87 a | 5.03 a | 4.83 a | 5.11 ab | 8.61 a | 6.67 a |
| 100% NPK | - | - | - | 5.58 ab | 8.33 a | 6.00 a |

Note: The values followed by different letters in the same column are significantly different ($p < 0.05$) based on DMRT.

kg urea, 325 kg NPK, and 450 kg manure ha⁻¹) and Petrokimia rate (200 kg urea, 300 kg NPK and 500 kg Petroganik ha⁻¹). However, the number of tiller in the plots applied with 75% NPK plus straw compost or manure equals to that in the plots applied with 100% NPK. This means that organic matter can substitute 25% of NPK fertilizer applied to increase the number of tiller. Thus, the addition of organic materials can improve the efficiency and effectiveness of fertilization.

Fertilization based on soil nutrient status can increase the efficiency of fertilizer use. Fertilization based on soil nutrient status and plant nutrient requirement is one of the calculation techniques to provide balanced fertilization dose. As a result, fertilization would be more efficient, fertilizer costs can be reduced, yield remains high, and environmental pollution can be mitigated. As well as the use of organic matter in the form of both rice straw residue and manure can increase the effectiveness of inorganic NPK fertilization on the wetland. Application of cattle manure (5 Mg ha⁻¹) in combination with 75% inorganic fertilizer is adequate to reduce chemical fertilizer use (Moe *et al.* 2017).

The Effect of Soil Nutrient Management Practices on the Dry Weight of Grains

Different soil nutrient management applied on paddy fields showed the same effect on the dry weight of grains (Table 6). Production of grains in the first up to fourth growing season is relatively low, while it is higher in the next two growing seasons. The production of grains in the plots applied with 75% NPK plus straw compost or manure is the same as that in the plots applied with 100% NPK. Thus the application of organic matter can reduce the use of NPK fertilizer up to 25%. The increase of rice production in the plots applied with organic matter is an indication of improvement of soil properties that further increases the rice production.

The effect of application of 100% NPK is not significantly different from that of fertilization based on farmer practice and Petrokimia rate that use higher doses of fertilizer. The fertilization rate of 100% NPK was set up based on soil nutrient status and nutrient requirement for rice. Thus, it is a balanced dose of fertilization. Therefore, the yield of rice remains high, the cost of fertilization can be reduced, and the plant growth in water bodies can

Table 7. Dry weight of milled grains under different soil nutrient management practices applied in the study site.

| Treatment | Dry weight of milled grains (Mg ha ⁻¹) in each growing season | | | | | |
|------------------------------|---|---------|--------|---------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Farmer practice | 3.27 a | 3.50 ab | 3.61 a | 4.64 ab | 6.89 a | 5.33 a |
| Petrokimia rate | 3.43 a | 4.39 a | 3.78 a | 5.06 a | 7.61 a | 5.22 a |
| 75% NPK + straw compost | 3.70 a | 3.31 b | 3.78 a | 3.78 b | 6.64 a | 5.11 a |
| 75% NPK+manure+biofertilizer | 3.57 a | 3.64 ab | 3.67 a | 4.31 ab | 7.05 a | 5.53 a |
| 100% NPK | - | - | - | 4.81 ab | 7.06 a | 5.72 a |

Note: The values followed by different letters in the same column are significantly different (p<0.05) based on DMRT.

Table 8. Dry weight of straw under different soil nutrient management practices applied in the study site.

| Treatment | Dry weight of straw (Mg ha ⁻¹) in each growing season | | | | | |
|------------------------------|---|--------|--------|---------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Farmer practice | 6.53 a | 5.92 a | 4.83 a | 7.42 a | 6.39 a | 3.72 a |
| Petrokimia rate | 6.60 a | 5.92 a | 4.22 a | 6.69 ab | 6.31 a | 3.43 a |
| 75% NPK + straw compost | 4.20 b | 4.64 a | 4.92 a | 6.31 b | 6.00 a | 3.30 a |
| 75% NPK+manure+biofertilizer | 4.83 b | 4.81 a | 4.00 a | 6.30 b | 6.11 a | 3.42 a |
| 100% NPK | - | - | - | 6.86 ab | 6.22 a | 3.22 a |

Note: The values followed by different letters in the same column are significantly different (p<0.05) based on DMRT.

be controlled. Fertilization of wetland based on soil nutrient status and rice productivity results in an appropriate dose of fertilizer applied, which can reduce the input of inorganic fertilizers and environmental pollution.

Integrated nutrient management is an effort to combine inorganic, organic and bio fertilizers. The dry weight of milled grains in the plots applied with organic matter in the form of straw compost or manure combined with 75% NPK equals to that in the plots applied with 100% NPK (Table 7). Rice production (dry weight of milled grains) in the plots applied with a combination of 75% NPK and organic matter is similar to that in the plots applied with fertilizers according to farmer rate and Petrokimia rate. It can be concluded that the application of organic matter can decrease the amount of inorganic fertilizer needed for wetland rice. Sutardi and Mustika (2009) indicated that the application of organic fertilizer can increase inorganic fertilizer efficiency. The use of organic fertilizer in the form of processed manure as much as 2.5 Mg ha⁻¹ combined with urea as much as 250 kg ha⁻¹ and 350 kg ha⁻¹, respectively, resulted in the rice yield of 8.31 Mg ha⁻¹ and 8.45 Mg ha⁻¹, respectively, which statistically is not significantly different.

Fertilization rate that is commonly adopted by farmers is not rational, because the rate is set up based on the experiences without considering the status of soil nutrient. Farmers generally only apply inorganic fertilizers with high doses without applying organic matter in order to get the high yield of rice.

The Effect of Soil Nutrient Management Practices on the Dry Weight of Straw

Balanced fertilization is the key factor to increase rice yields and to mitigate environmental pollution. In the first and second growing seasons, the application of 75% NPK fertilization plus straw compost or manure resulted in lower dry weight of straw than the application of fertilizers based on the farmer rate and Petrokimia rate (Table 8). This result showed that the use of straw compost or manure combined with 75% NPK has not been able to substitute the amount of nutrients that equals to that derived from 25% NPK application, so that the dry weight of straw is low. In the next growing seasons there was no difference on the dry weight of straw among treatments.

In the fourth to sixth growing season, the dry weight of straw in the treatment of 100% NPK equals to that in the treatment of 75% NPK plus straw compost or manure. In addition, the dry weight of straw in the treatment of 100% NPK is the same

as that in the treatment of fertilization based on farmer rate and the Petrokimia rate. Fertilization based on soil nutrient status is more efficient, which is shown by the same dry weight of straw in the plots applied with 100% NPK, doses of farmer rate and Petrokimia rate. The rate of NPK (180-90-60 kg ha⁻¹) application appears to be the most optimum dose for rabi rice in deltaic alluvial soils of Andhra Pradesh (Murthy *et al.* 2015).

The dry weight of straw in the treatment of straw compost is the same as that in the treatment of manure. In rice fields with organic-C content <1.0%, application of organic matter is very important to improve soil quality. The type of organic matter used in the current study shows the same effect on the dry weight of straw during six growing seasons.

Fertilization based on soil nutrient status and plant nutrient requirement resulted in a balanced fertilization dose. Fertilization becomes more efficient, rice yields remain high, and environmental pollution can be mitigated. Balanced fertilization is not only determined based on soil nutrient status, but it can also be set up based map of soil P and K status (scale of 1: 250,000), which has been made for 23 provinces in Indonesia. The nutrient status of P and K on paddy fields is grouped into three groups, *i.e.* low, medium and high. Low, moderate and high P status soils contain <20, 20-40, and > 40 mg P₂O₅ 100 g⁻¹, respectively, and for low, medium and high K status soils contain <10, 10-20, > 20 mg K₂O 100 g⁻¹ soil, respectively. The dosage of SP-36 fertilizer for low, medium and high P paddy soils is 100, 75, and 50 kg ha⁻¹. The dosage of KCl fertilizer for low, medium and high K lowland rice fields is 100, 50, 50 kg ha⁻¹ (Setyorini and Kasno, 2013; Nurjaya and Widowati 2015). A recent study showed that the application of biofertilizer at 300-400 kg ha⁻¹ combined with inorganic fertilizer at 75% of crop requirement dose is the best combination in increasing NPK nutrient uptake for rice crop and dry weight of milled grains (Marlina *et al.* 2014).

Application of soil organic matter can improve soil physical properties. Sources of organic materials can be manure, residual crops such as rice straw, and biochar. Application of goat manure can increase the soil organic-C, soil moisture content, and decrease bulk density (Limbong *et al.* 2017).

CONCLUSIONS

NPK fertilization based on soil nutrient status (100% NPK) with lower fertilizer doses results in the same rice yield as fertilization based on farmer

practice and Petrokimia rate. Thus, NPK fertilization based on soil nutrient status is more efficient.

The yield of rice applied with 75% of NPK recommendation rate plus organic matter application is similar to that under farmer practices and Petrokimia fertilization rate.

The reduction of 25 % inorganic fertilizer (NPK) application does not decrease yield, but it can save 25% of fertilizer cost and may increase farmer's income.

Application of organic ameliorant, such as straw compost and manure results in the same effect in increasing rice production in Karang Tanjung Village, Padang Ratu District, Central Lampung.

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