Validating fertilizer recommendation of swamp soil test kit

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Abstract. Soils in riparian swampland are considered marginal and have low nutrient contents. A research on the validation of fertilizer recommendations as a complement to Swamp Soil Test Kit (PUTR) was carried out on shallow inland swamps in Sungai Ambangan Village, Sungai Raya District, Kubu Raya Regency, West Kalimantan, during dry season of 2017. The treatments consisted of 1) complete control; 2) NPK local recommendations; 3) 1 ½ of NPK PUTR recommendation + Dolomite; 4) NPK PUTR recommendation + Dolomite; 5) 2/3 of NPK PUTR recommendation + Dolomite; and 6) NPK of local farmer’s recommendation. Results using PUTR and laboratory equipment showed acidic soils with low to medium nitrogen, medium to high P, and low potassium. Validation showed that highest number of productive tillers was found in treatment of 1 ½ of NPK PUTR recommendation + Dolomite. Plant height showed that there was insignificant difference between treatment with NPK local recommendation, 1 ½ of NPK PUTR recommendation + Dolomite, NPK PUTR recommendation + Dolomite, 2/3 of NPK PUTR recommendation + Dolomite. This was similar to results of harvested dry grain and harvested grind grain. Utilization of PUTR as rapid test tool can be implemented for ricultivation on riparian swampland. Impact of fertilization obtained neck blast attack increased along with the rise of fertilization dose, especially nitrogen.

1. Introduction
Indonesia has quite a lot of agricultural land resources, one of which is swamp land. Swamp land has received attention as potential land for agriculture since 1968. Records from the Directorate of Public Agriculture in 1968 stated that the Government had planned to clear 5.25 M ha of swamplands in Sumatra and Kalimantan over a period of 15 years (1968-1984) for tidal rice fields. In various places in Indonesia, people have been exploiting rice fields with traditional techniques to fulfill their family needs decades ago. At that time, harvest could not be sold because production was very low and rice fields were planted once per year. Low production and cropping index per year in swamplands are caused by several obstacles, including low soil fertility, acid soil reactions, presence of pyrite, high levels of Al, Fe, Mn, and organic acids, P deficiency, poor base cations such as Ca, K, Mg, and limited activity of microorganisms [1].

Development of technologies to support agricultural production allow optimizing potential of swamplands. They can answer challenges for the demand of national foods and increase national income. Application of innovative technology includes construction of drainage and irrigation systems, superior varieties, fertilizers and ameliorants. The existence of drainage and irrigation systems can regulate water. Utilization of short-lived superior varieties allows faster harvesting; hence, single
calendar year can occupy several planting periods. Furthermore, ameliorant is applied to increase soil pH, and to improve soil quality as a growing medium; the same way with fertilizers. However, fertilizer application does not always behave as expected. According to Manjunatha et al. [2], fertilizers are sometimes not optimally be absorbed by plants because fertilizers do not reach target areas. This causes fertilizers to be evaporated, washed away, hydrolyzed, washed off, carried by runoff and degraded by microbes.

Fertilizers as main component of plant growth must be given in the right dose. According to Rurinda et al. [3] fertilizer dosage is important to understand because it greatly affects crop yields and the environment. Swampland soil test kit (PUTR) could be a solution for nutrient management as it helps to determine nutrient levels and to compile recommendations for site-specific fertilizer of rice fields. This tool can be used on potential acid sulfate soils, swamps, and peatlands.

In order to convince agricultural planners and agricultural extension workers about PUTR, fertilizer recommendation validation was carried out. The aim of this experiment was to obtain recommendations that suit site-specific and generally accepted methods in swamplands. In addition, this study specifically estimated response of crop yields to nutrients based on PUTR recommendations.

2. Methodology
Field experiment was carried out in paddy field at riparian wetland of Sungai Ambangan Village, Sungai Raya Sub District, Kubu Raya District, West Kalimantan Province, Indonesia. Prior to the study, soil analysis was carried out at a depth of 0 – 20 cm to determine soil nutrient status.

To validate the recommendation of optimum fertilizer dosage for the best rice production, rice cultivation was carried out with seven treatments (Table 1). We employed swampland soil test kit (PUTR), developed by the Indonesian Agency for Agricultural Research and Development. The soil test kit is useful in rapidly determining fertilization recommendations, thus profitable for farming [4].

| No. | Treatment                                    | Urea (kg) | SP-36 (kg) | KCl (kg) | Lime (kg) |
|-----|----------------------------------------------|-----------|------------|----------|-----------|
| 1.  | Complete control                             | 0         | 0          | 0        | 0         |
| 2.  | NPK local recommendation                     | 217       | 88         | 100      | 0         |
|     | 1 ½ of NPK PUTR recommendation + Dolomite    | 375       | 112.5      | 150      | 500       |
| 3.  | NPK PUTR recommendation + Dolomite           | 250       | 75         | 100      | 500       |
|     | 2/3 of NPK PUTR recommendation + Dolomite    | 167       | 50         | 67       | 500       |
| 4.  | NPK of local farmer’s recommendation         | 88.67     | 27.08      | 16.25    | 0         |

2.1. Soil preparation
Soil tillage was carried out using a hand tractor at a depth of 0 – 20 cm. It proceeded with making a barrier with a height of ± 30 cm according to treatment plot and left for a week. Plot size was about 5 x 5 m². Subsequently, all plots were given basic treatments.

2.2. Seed preparation
We used Inpara 3 rice variety, with following properties: 127 days of plant age, plant height 108 cm, flag leaf shape erect, pera rice texture (non-sticky grains), averaged yield of 4.6 t/ha with yield potential of 5.6 t/ha, resistant to blast, but susceptible to blight and bacteria. Other advantages of using Inpara 3 rice are fairly tolerant to 6 day inundation in vegetative period, and could tolerate Fe and Al poisoning [5].

Soil as a planting medium is placed in a seedling tank at field capacity conditions. Before planting, rice seeds were soaked for 24 hours in the water, then drained on a cloth.
2.3. **Planting**
After 21 days, seeds were transferred to each research plot with spacing commonly used by farmers of 25 x 25 cm.

2.4. **Maintenance**
To prevent plants from being attacked by pests, insecticide was applied to soil surface. Pesticide used in this study was a reagent with active ingredient of fipronil to control pests on rice plants. Weed control was done manually by pulling weeds around rice plants.

2.5. **Harvest**
Harvesting was done after 90% of panicle was fully ripened or based on the description of rice varieties. Appropriate harvesting age of rice is 30 to 35 days after flowering evenly or between 135 to 145 days after planting. Sampling plot was about 4 x 4 m$^2$ for rice production; investigating other components was carried out by removing all plants on 1 m x 1 m tiles, then observed all parts of the plant.

2.6. **Soil sampling**
Soil samples were taken in each experimental plot at a depth of 0-20 cm. Furthermore, analysis of soil properties was carried out directly with a rapid test device and in the laboratory.

2.7. **Observed parameters**
Soil texture was determined by the pipette method [6], while determination of (H$_2$O) and pH (KCl) was done using a pH meter [6]. Total P, Ca and Fe were measured using handheld X-ray fluorescence (Handheld XRF Spectrometer, Bruker, Germany). Soil organic carbon content was observed by burning/ashing method (Indonesian Soil Research Institute, 2005). N-total was determined by Kjeldahl method [6], while P and K contents were measured using a spectrophotometer [6]. Meanwhile, soil CEC pH 7 was observed using neutral ammonium acetate [6].

Measured plant properties included plant height, number of tillers and productive tillers, harvested dry grain, fresh grain and biomass production, weight 1000 grains of grain, panicles length, percentage of sterile grain, and percentage of neck blast.

2.8. **Data processing**
Correlation test was conducted on collected data. The test is considered as real at 5% confidence level. For the scoring system, this real value was set at a value of 75% according to a population of at least 15 examples. For experimental field test, preparation of fertilizer recommendations was carried out with smallest significant difference. We also investigated fertilizer response curve.

3. **Results and discussion**

3.1. **Initial soil properties**
Analysis of initial soil properties (Table 2) indicated that soil texture was silty clay, with soil reaction (pH H$_2$O) of acidic. This is in line with the results of Subagyo [7] which stated that riparian swampland is generally characterized as having high contents of clay and silt fractions, but very low sand content. The C-organic content was classified as very high (>5%), with moderate soil N content, and medium C/N ratio values. Soil P content was low to moderate, but when measured using Bray's method, available P was low. Potential K content was also low.

Riparian swampland had varying CEC values between 23 – 48 me/100 g of soil. This was followed by low to very high basic cations [7]. Elements considerably in medium category were Mg and Na, while very low ones were Ca and K. Medium CEC was obtained, with low base saturation. Low pH resulted in high levels Fe. This is in line with Chesworth *et al.* [8] findings, which argued that low soil pH can cause high soil Fe content.
In accordance with main characteristics of riparian swamp soils which contain high levels of Fe, this research found similar results. In the range of 500-1000 ppm, rice plants were still tolerant to high levels of Fe, provided that Fe was not in the form of Fe\(^{2+}\). Level of available Cu nutrients was sufficient, while Mn and Zn were in deficiency. Generally, in soils with high organic matter contents, micronutrient deficiencies can occur. Source of Zn is organic materials. In lowland swamps, plants that are a source of organic matters, grow from soils with micronutrient deficiencies, especially Zn. From initial soil analysis, it can be concluded that soil fertility was low. According to Noor [9], chemical properties and fertility of riparian swamp soils are classified as moderate to very low. For this reason, in an effort to improve and use them, it is necessary to fertilize and provide ameliorant.

**Table 2.** Results of preliminary analysis of riparian swamp soil

| Parameter                  | Unit         | The calculation results | Value | standard deviation |
|----------------------------|--------------|-------------------------|-------|---------------------|
| Texture (pipette)          |              |                         |       |                     |
| Sand                       | --%--        |                         | 6.3   | 1.15                |
| Silt                       | --%--        |                         | 57.3  | 2.31                |
| Clay                       | --%--        |                         | 36.3  | 1.15                |
| 1:5 extract                |              |                         |       |                     |
| pH H\(_2\)O                |              |                         | 4.92  | 0.08                |
| pH KCl                     |              |                         | 3.87  | 0.05                |
| Organic matter             |              |                         |       |                     |
| Walkey & Black C           |              |                         | 7.21  | 0.50                |
| Kjeldahl N                 |              |                         | 0.58  | 0.09                |
| C/N                        |              |                         | 13    | 1.53                |
| HCl 25%                    |              |                         |       |                     |
| P\(_2\)O\(_5\)             |              |                         | 23    | 7.55                |
| K\(_2\)O                   | --mg/100 g-- |                         | 7     | 4.36                |
| Cation exchange (NH\(_4\)-Acetat 1 N, pH7) |       |                         |       |                     |
| Ca                         |              |                         | 2.21  | 0.48                |
| Mg                         |              |                         | 1.26  | 0.28                |
| K                          |              |-- cmol/kg--              | 0.07  | 0.02                |
| Na                         |              |                         | 1.28  | 0.68                |
| Total                      |              |                         | 4.82  | 0.80                |
| KTK                        |              |                         | 21.99 | 3.14                |
| KB*                        | %            |                         | 22    | 3.46                |
| DTPA                       |              |                         |       |                     |
| Fe                         | --ppm--      |                         | 607   | 42.44               |
| Mn                         | --ppm--      |                         | 0.37  | 0.10                |
| Cu                         |              |                         | 0.42  | 0.37                |
| Zn                         |              |                         | 0.18  | 0.17                |

Initial laboratory analysis showed that pH was acidic, with moderate N, moderate-high P, and K was low (Table 3). Meanwhile, results using PUTR showed that soil was acidic, nitrogen was low, phosphorus was moderate to high, and potassium was low to moderate. For pH, P and K analyses, results were comparable between laboratory and PUTR, except for N. Measured N using PUTR was low, whereas laboratory resulted moderate level. Nitrogen in-situ measurements showed actual conditions at that time. Meanwhile, bringing to laboratory takes time, and possibly alters soil temperature during transportation. Nitrogen is an element that is very easy to change from one form to another [10,11]

**Table 3.** Results of soil analysis using PUTR and in the laboratory

| No. | Parameter     | Laboratory Analysis | PUTR Analysis                          |
|-----|---------------|---------------------|----------------------------------------|
| 1.  | pH            | 4.98 Acidity        | 5 lime requirement 500 kg/ha           |
| 2.  | Nitrogen      | 0.49% Moderate      | Low 250 kg/ha                         |
| 3.  | Phosphor      | 18-22 Moderate – High| Moderate – High 50 – 75 kg/ha         |
| 4.  | Kalium        | 0.08 cmol/kg Low    | Low – Moderate 75 – 100 kg/ha          |
3.2. Plant responses
Height and number of tillers aged 6–9 weeks after planting (WAP) are presented in Table 4. Highest plant height was obtained from 1½ NPK PUTR + Dolomite treatment, while the lowest yielded from complete control treatment. Overall, treatment recommendations based on soil analysis were almost the same as recommendations of PUTR. However, when compared with treatment of local recommendations and treatment of farmers, higher yields were obtained.

Generally, well-grown plants will have good tiller growth. From observations, it can be seen that number of tillers was in the range of 6 – 14 per clump (Table 5). Highest tillers were found in 1½ NPK PUTR + Dolomite with the number of tillers almost 14. Meanwhile, the lowest number of tillers was in complete control treatment. Plant height and number of tillers continue to change with the age. Plants were expected to be harvested at the age of 100 days after planting (DAP).

3.3. Plant height
Fertilizer application has a significant effect on plant height. Highest response at 13 WAP was found in 1½ NPK PUTR + Dolomite treatment, which was 50.45 cm, and the lowest was in complete control, around 35.21 cm (Table 4). During 13 WAP, NPK treatment by local farmers (69.08 cm) was significantly different from control and was lower than other treatments. Fertilizer plays an important role in increasing rice production. It was estimated that 55% of the increase in food comes from the influence of fertilizers [12]. However, it was known that 2/3 of used N fertilizer can be lost through washing, evaporation, denitrification, and carried away by runoff [13,14]; so that in rice cultivation, N efficiency is very low, like P fertilizers. After P nutrients is given, dissolution occurs. Phosphate ions in soil solution react with Ca, Fe, or Al ions, and then precipitate as insoluble compounds or adsorbed in the surface of clay particles [15].

Table 4. Response of plant height to treatment of various recommended technology packages

| No. | Treatment                                      | 6 WAP   | 9 WAP   | 13 WAP  |
|-----|------------------------------------------------|---------|---------|---------|
| 1.  | Complete control                               | 46.52   | 65.02   | 69.08   |
| 2.  | NPK local recommendation                       | 62.78   | 77.95   | 92.08   |
| 3.  | 1 ½ of NPK PUTR recommendation + Dolomite      | 70.36   | 84.15   | 95.90   |
| 4.  | NPK PUTR recommendation + Dolomite             | 68.20   | 81.88   | 93.08   |
| 5.  | 2/3 of NPK PUTR recommendation + Dolomite      | 63.10   | 80.63   | 94.17   |
| 6.  | NPK of local farmer’s recommendation           | 57.90   | 72.40   | 82.68   |
|     | F value                                        | 16.72   | 11.08   | 18.46   |
|     | F table                                        | 2.59    | 2.59    | 2.59    |
|     | C.V. (%)                                       | 4.84    | 4.22    | 3.90    |

3.4. Component of yield

3.4.1. Number of productive tillers
Response of fertilization scheme was significant to the number of tillers. Fatimaturrohmah et al. [16] added the assembly of rice plants, namely plants that have a moderate number of tillers but all of them are more effective products so that all photositates can be accumulated in the formation of rice grains. Analysis of variance showed that there was a significant difference between treatments in the number of productive tillers. Highest number of productive tillers at 6 WAP was found in 1½ of NPK PUTR recommendation + Dolomite and NPK PUTR recommendation + Dolomite treatment, while the lowest was in complete control treatment. Over 9 WAP, the highest number of productive tillers was found in 1½ of NPK PUTR recommendation + Dolomite treatment and the lowest was in complete control treatment. Observing 13 WAP showed that the highest number of productive tillers was found in 1½ of
NPK PUTR recommendation + Dolomite treatment, while the lowest was in complete control treatment (Table 5). Nutrient adequacy during vegetative period can support formation and growth of tillers, resulting in flowering and panicle formation [17].

Table 5. Response of the number of tillers to the treatment of various recommended technologies

| No. | Treatment | Number of productive tillers | 6 WAP | 9 WAP | 13 WAP |
|-----|-----------|-----------------------------|-------|-------|--------|
| 1   | Complete control | 6 a | 7 a | 6 a |
| 2   | NPK local recommendation | 10 cd | 10 b | 12 cd |
| 3   | 1 ½ of NPK PUTR recommendation + Dolomite | 11 d | 12 c | 14 d |
| 4   | NPK PUTR recommendation + Dolomite | 11 d | 11 bc | 12 cd |
| 5   | 2/3 of NPK PUTR recommendation + Dolomite | 9 bc | 10 b | 11 bc |
| 6   | NPK of local farmer’s recommendation | 8 b | 8 a | 9 b |

3.4.2. Harvested dry grain

Treatments on fertilization affected harvested wet grain, harvested dry grain, dry grain harvest, wet straw, and 1000-grain weight. Harvested dry grain is used to determine production capacity per plot which is known as the quality of rice production from converted dry grain yields in hectare. The lowest harvested dry grain (Table 6) was found in NPK treatment recommended by local farmers (2.86 t/Ha) which was significantly different from complete control (2.03 t/Ha), while yield from NPK local recommendation (4.47 t/Ha) Ha), 1½ NPK PUTR recommendation + Dolomite (4.36 t/Ha), NPK PUTR recommendation + Dolomite (4.08 t/Ha), 2/3 NPK PUTR recommendation + Dolomite (4.22 t/Ha) was higher than NPK of local farmer’s recommendation and was significantly different from complete control. The higher the dose of fertilizer given, the higher the nutrients received by the plant, thus the photosynthate results can be used for flowering and grain formation [18].

Table 6. Responses of the components of crop production to the treatment

| NO. | Treatments | Harvested dry grain (t/Ha) | Wet Straw (t/Ha) | Harvested grain (t/Ha) | 1000 grain weight (g) |
|-----|------------|---------------------------|-----------------|-----------------------|---------------------|
| 1   | Complete control | 3.17a | 7.47a | 2.03a | 21.30a |
| 2   | NPK local recommendation | 5.42c | 15.72cde | 4.47c | 23.19b |
| 3   | 1 ½ of NPK PUTR recommendation + Dolomite | 5.72c | 17.28c | 4.36c | 24.44c |
| 4   | NPK PUTR recommendation + Dolomite | 5.31c | 15.86cde | 4.08c | 24.77c |
| 5   | 2/3 of NPK PUTR recommendation + Dolomite | 5.36c | 12.72bc | 4.22c | 24.62c |
| 6   | NPK of local farmer’s recommendation | 4.31b | 11.94b | 2.86b | 22.10a |
|     | F value    | 9.00 | 8.49 | 10.11 | 19.96 |
|     | F table    | 2.59 | 2.59 | 2.59 | 2.59 |
|     | C.V. (%)    | 9.39 | 13.21 | 11.98 | 2.05 |
3.4.3. Biomass production
Observation over wet straw showed that 1½ NPK PUTR + Dolomite lime treatment had the highest wet straw weight compared to other treatments. Meanwhile, the lowest wet straw was in complete control treatment. This showed that essential nutrients in plants can be a limiting factor for plant growth and production. According to Hadisuwito in Kaya [19], the main function of N is to form protein and chlorophyll, while the main function of P helps in development of vegetative phase. In addition, K serves in the formation of proteins and carbohydrates. Fulfillment of these macro nutrients can optimally support growth and production of rice plants; lacking of one of these can inhibit plant growth and production. Moreover, excess nutrients in vegetative phase, especially nitrogen, can soften straw and make plants susceptible to disease and reduce crop quality.

3.4.4. The 1000-grain weight
Rice yield and crop demand in area units have a close relationship with the weight of 1000 grains. Higher grain weight correlates to higher yield. The result of 1000-grain weight (Table 6) showed that recommendations of NPK of local farmer’s recommendation (22.10 g) with complete control (21.30 g) were not significantly different. Locally recommended NPK (23.19 g) was significantly lower than 1½ NPK PUTR recommendation + dolomite (24.44 g), NPK PUTR recommendation + dolomite (24.77 g), ⅔ NPK PUTR recommendation + dolomite (24.62 g). PUTR recommendation has a 1000-grain weight directly proportional to dry weight. However, according to NPK local recommendation, it had a high dry weight of harvest but gained a smaller weight of 1000 grains. This is possible because weight of empty grain and percentage of blast were quite high, so it yielded a lower production quality than others.

3.4.5. Panicle length
Rice yield can be determined from panicle length, grain per panicle, rate of seed formation, and weight of 1000 grains as well as dry matter accumulation, distribution, transportation, and transformation of plant populations [20]. As presented in Table 7, the longest panicle was found in NPK PUTR recommendation + Dolomite (25.49 cm) treatment, while the lowest was found in complete control (21.99 cm). All treatment combinations of NPK PUTR recommendation + Dolomite and NPK of local farmer’s recommendation were significantly higher than local farmers' recommendations (23.54 cm).

3.4.6. Percentage of sterile grain
This research discovered that percentage of sterile grain in each treatment had no significant variation. However, each treatment showed a difference. The highest percentage of sterile grain was found in NPK PUTR recommendation + Dolomite treatment (29.39%) and lowest treatments were in NPK of local farmer's recommendation (14.39%) and complete control (16.55%). Higher percentage of sterile grain indicates lower yield. According to Hai-Yan et al. [20], availability of sufficient nutrients significantly contributes to rice yield. When nutrient deficiency is observed during growth period, panicle filling can be disrupted.

3.4.7. Percentage of neck blast
Blast disease is caused by Pyricularia grisea. Generally, this disease attacks rice plants cultivated in tidal and swamp areas [21]. Neck blast percentage is closely related to growth and production. It reduces grain yield due to small panicles. If there is a sequential attack, rice plants can perish before flowering. The highest percentage of neck blast was found in treatment of NPK local recommendation (32.07%), NPK PUTR recommendation + Dolomite (32.48%), and ½ of NPK PUTR recommendation + Dolomite (38.52%). This could be understood due to application of high nitrogen doses; intensity of blast disease was positively correlated with nitrogen dose. Amir (1985) in Feriadi [22] provided data on plant height in Table 7, which showed ½ of NPK PUTR recommendation + Dolomite had the highest average number of tillers, but did not have a high level of dry grain harvest.
Table 7. Response of plant production components to the treatment of various recommended technologies

| NO. | Treatments                                      | Parameter       | Panicle length (cm) | Sterile Grain (%) | Neck Blast Percentage (%) |
|-----|------------------------------------------------|-----------------|--------------------|-------------------|---------------------------|
| 1.  | Complete control                               |                 | 21.99 a            | 16.55             | 13.67 a                   |
| 2.  | NPK local recommendation                       |                 | 25.07 bcd          | 23.34             | 32.07 c                   |
| 3.  | 1 ½ of NPK PUTR recommendation + Dolomite      |                 | 24.89 bcd          | 18.12             | 38.52 c                   |
| 4.  | NPK PUTR recommendation + Dolomite             |                 | 25.49 cd           | 29.39             | 32.48 c                   |
| 5.  | 2½ of NPK PUTR recommendation + Dolomite       |                 | 24.00 bc           | 17.19             | 28.03 bc                  |
| 6.  | NPK of local farmer’s recommendation           |                 | 23.54 b            | 14.39             | 19.12 bc                  |
|     | F Value                                        |                 | 5.76               | 0.89              | 5.30                      |
|     | F table                                        |                 | 2.59               | 2.59              | 2.59                      |
|     | CV (%)                                         |                 | 3.52               | 43.24             | 20.01                     |

4. Conclusion
1. Rice yield was not significantly different among NPK treatment recommended by local recommendation, 1½ NPK PUTR + dolomite, PUTR NPK + dolomite, 2½ NPK PUTR + dolomite, which ranged between (4.08 – 4.47 t/ha HGG), but significantly different from control (2.03 t/ha HGG) and local farmers’ recommendations (2.86 t/ha HGG).
2. To determine fertilizer dose, farmers can use PUTR as a quick test tool.
3. Complete control treatment had resistance to blast disease with moderate attack rate. Attack rate of blast disease was higher with increasing dose of nitrogen fertilization.

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