Effectiveness of solid organic fertilizer (SOF) on lowland rice in Maros, South Sulawesi

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Abstract. Rice is one of the most important staple cereal foods and major food for more than a third of the world’s population. The use of organic fertilizers is needed to improve soil quality and increase crop production. The research objective was to determine the effectiveness of solid organic fertilizer (SOF) on the growth and production of lowland rice. This research was conducted in Lau District, Maros Regency, South Sulawesi, from October 2019-February 2020. Field experiments were arranged in a Randomized Complete Block Design (RCBD) with 8 treatments and repeated four times. The treatments studied were A=without fertilizer; B=NPK 100%; C=NPK 75%; D=NPK 100%+SOF 50%; E=NPK 75%+SOF 100%; F=NPK 75%+SOF 150%; G=NPK 100%+SOF 75%; and H=NPK 100%+SOF 100%. The parameters observed were plant height at harvest time, number of productive tillers, number of panicles, number of filled grains, number of empty grains, the weight of 1,000 grains, and yield of GKP. The results obtained indicate that the treatment of F = NPK 75% + SOF 150% gives the highest yield namely 5.03 t ha⁻¹, with RAE 200%, profit Rp. 10.226.100, and R/C ratio 2.03

1. Introduction

Rice (Oryza sativa) is one of the world's major crops. Rice is a semi-aquatic perennial grass plant and is the most important cereal crop in developing countries. World rice production has tripled in the last five decades from 150 million tons in 1960 to 450 million tons in 2011, due to the Green Revolution of rice in Asia [1]. To achieve higher rice yields, inorganic fertilizers are used with little or no addition of organic fertilizers. Although inorganic fertilizers produce higher yields, excessive dependence on them is associated with decreased soil properties and soil degradation and in turn decreased yields in subsequent periods [2]. In the western world, the current agricultural system relies heavily on chemical fertilizers, growth regulators, and pesticides to increase crop productivity. Several adverse effects on human health and environmental hazards are due to the use of chemical fertilizers [3].

One of the efforts to increase the productivity of the rice is to fulfill its daily needs, that is by fertilizing. Fertilization aims to increase the nutrients needed by plants because the nutrients in the soil are not always sufficient to spur plant growth optimally [4]. As stated by [5], the unbalanced use of chemical fertilizers has affected soil health, leading to a substantial reduction in soil organic carbon. The use of organic fertilizers, especially in the form of compost, has a positive effect on soil health and fertility, which results in an increase in crop yields in the long term [6].

The application of chemical fertilizers together with the application of organic fertilizers is an effective method to increase the available soil N [7]. Organic fertilizers are not only able to supply nutrients for plant needs, but can also improve soil physical properties (soil moisture content, soil aggregation, and structure), soil chemical properties (cation exchange capacity, soil bearing capacity,
and nutrient retention), and soil biology and activity microbial development [8]; [9]. The continuous use of inorganic fertilizers without the application of organic fertilizers can cause an imbalance of nutrients in the soil, low fertilization efficiency, damage to soil structure, and low soil microbiology. In addition, the continuous use of inorganic fertilizers can damage the soil so that it needs to be balanced with the application of organic fertilizers [10];[11].

The use of organic fertilizers can be a solution in reducing the excessive application of inorganic fertilizers due to the presence of organic materials that can improve the physical, chemical, and biological properties of the soil. Improvement of physical properties, namely loosening the soil, improving aeration and drainage, increasing bonding between particles [12], increasing water holding capacity, preventing erosion and landslides, and revitalizing tillage. The function of organic fertilizers on chemical properties is to increase the cation exchange capacity, increase the availability of nutrients, and increase the weathering process of mineral materials. As for the biological properties, namely making a food source for soil microorganisms such as fungi, bacteria, and other beneficial microorganisms, so that their development becomes faster [13].

In addition to supplying NPK nutrients, organic fertilizers can also provide micro-nutrients so that they can prevent micro-element deficiency in marginal soils or soils that have been cultivated intensively with unbalanced fertilization [14]. Organic fertilizers have complete nutrients in small amounts needed by plants and have organic materials that can improve soil properties to maintain long-term productivity. Balanced fertilization is applying fertilizers to the soil to achieve the status of all nutrient elements in the soil and an optimal growing environment for plant growth and yield [15]. Given the condition of rice fields that are always inundated, a fertilization system is needed to improve surface and groundwater quality standards and reduce production costs through increasing fertilizer efficiency [16].

The research objective was to determine the effectiveness of solid organic fertilizer (SOF) on the growth and production of lowland rice.

2. Materials and Methods

2.1. Time and place
The research was conducted in Lau District, Maros Regency, South Sulawesi, from October 2019-February 2020. It is located at the position of 5°00' south latitude and 119°30' east longitude. The average annual rainfall is 347 mm/month, with an average of 16 rainy days starting from October to March, the climate is tropical, with an average temperature of 29°C. Ultisol soil type with a dusty clay texture.

2.2. Implementation of activities
Field experiments were arranged in a randomized block design with 8 types of treatment and repeated four times. The treatment tested was a combination of several levels of solid organic fertilizer (SOF) and inorganic fertilizers (chemical fertilizers). The complete treatment arrangement is as follows:

| Table 1. Arrangement of treatment effectiveness test of solid organic fertilizer (SOF) on lowland rice |
|--------------------------------------------------|---|---|---|---|
| Treatment                                      | Urea | SP-36 | KCl | Solid Organic Fertilizer (SOF) |
| A = Without fertilizer (control)               | 0    | 0     | 0   | 0                             |
| B = NPK 100%                                   | 300  | 100   | 50  | 0                             |
| C = NPK 75%                                    | 225  | 75    | 37.5| 0                             |
| D = NPK 75% + SOF 50%                         | 225  | 75    | 37.5| 2.5                           |
| E = NPK 75% + SOF 100%                        | 225  | 75    | 37.5| 5                             |
| F = NPK 75% + SOF 150%                        | 225  | 75    | 37.5| 7.5                           |
| G = NPK 100% + SOF 75%                        | 300  | 100   | 50  | 2.5                           |
| H = NPK 100% + SOF 100%                       | 300  | 100   | 50  | 5                             |
The soil is thoroughly cultivated with a hand rotary plow (hand tractor), then a plot measuring 5 x 6 m is made, with dividers in the form of bund 20-30 cm wide and 30 cm high. The rice variety used was the Inpari-30 variety, which was planted when the seeds were 17 days old with a spacing of 25x25 cm.

Fertilization application for treatment is carried out by diluting 3 tablespoons of solid organic fertilizer into 14 liters of water, which is applied by spraying all parts of the plant every seven days until just before harvest. Urea fertilizer is applied 3 times, first when the plants are 10 days after planting, the second fertilization is when the plants are 25 days after planting, and the third fertilization is when the plants are 45 days after planting. Meanwhile, SP-36 and KCl fertilization is given at the time of the first fertilization. Irrigation is carried out intermittently (every 3 days) and 10 days before harvest, the intake of water into the fields is stopped.

The first wedding was done manually at the age of 21 DAS and then the plants were cultivated to be weed-free. Pests and plant diseases are controlled before and when there are symptoms of attack by spraying the plants with pesticides or insecticides. Plants are harvested by tuber when the plants have reached maturity, that is, when the grain has been cooked at least 90% using a sickle, then it is knocked out in plastic bags, and the grain is weighed for each experimental plot.

Soil samples were taken in a composite at a depth of 30 cm before the experiment was carried out, to determine the characteristics of the soil in the test location. Parameters observed were: plant height (cm) at harvest time, number of productive tillers (stems), panicle length, number of filled grains per panicle, number of empty grains per panicle, grain yield ha⁻¹ (ton ha⁻¹), the weight of 1000 grains. Unhulled rice, the effectiveness of solid organic fertilizer, and farming analysis of using solid organic fertilizer in rice.

The data that had been collected were tabulated and analyzed using the Variance Analysis to determine the effect of the treatment. Meanwhile, to determine the effect between treatments, the Duncan (DMRT) test was used. To compare the agronomic effectiveness of SOF, it was determined by the RAE method of each standard fertilizer. Cost and income analysis are done by using input-output analysis. R/C is used to measure the feasibility of innovation. R/C > 1 is feasible to be applied whereas if R/C < 1 the innovation is not feasible to be applied (Malian, 2004).

3. Results and Discussion

3.1. Soil Chemical Analysis

Good plant growth depends on a balanced and beneficial mix of environmental factors [17]. The results of the analysis of the physical properties of the soil before the assessment showed that the soil had a dusty clay texture with a sand content of 23%, a dust content of 53%, and a clay content of 21%. The results of the analysis of soil chemical properties showed pH (H₂O) 6.0 was acid, C-organic 1.38% low, N-total 0.11% low, P-HCl % 77 high, and K-Bray 20 low.

The low level of C-organic is related to the rice straw management habits, which generally still throw away the straw or burn it. The nitrogen content in the soil is low. Nitrogen levels generally follow the tendency of the organic matter content, if the organic matter content is low, generally, the nitrogen content in the soil is also low. Cation exchange capacity is the ability of the soil to exchange cations, if the soil CEC is high, the soil's ability to exchange cations is also high. Fertile soil is usually characterized by a high CEC, otherwise, it can be said that the soil is less fertile [13]. The land in the research location has a low CEC. Based on the description above, such as soil CEC, K content, and low organic matter, soil can be classified as low fertility.
Table 2. Soil Characteristics of Lau Village, Maros Baru District, Maros Regency, 2020

| No. | Parameter          | Criteria    |
|-----|--------------------|-------------|
| 1.  | Tekstur (%)        | Dusty clay  |
|     | - Pasir            | 26          |
|     | - Debu             | 53          |
|     | - Liat             | 21          |
| 2.  | pH (H$_2$O)(%) (%) | 6.97 acid   |
| 3.  | C organik (%)      | 1.38 low    |
|     | N (total)          | 0.11 low    |
| 4.  | P$_2$O$_5$ (ppm/100g) | 77 high |
| 5.  | K$_2$O$_5$ (ppm/100g) | 20 low |

3.2. Plant Growth

The results of variance showed that the treatment of SOF had no significant effect on plant height and the number of productive tillers of rice. This is thought to be due to the nutrient available which is still sufficient for the growth of rice plants in the vegetative stage. The highest plant height growth was obtained in treatment F = 75% NPK fertilizer + SOF 150%, which was 95.0 cm and the lowest plant height was obtained in treatment C = 75% NPK fertilizer, which was 86.7 cm. While the highest number of productive tillers was obtained in treatment D = NPK 75% + SOF 50%, namely 24.27, and the lowest was obtained in treatment A = without fertilization (control), namely 15.93. This shows that the combination has higher effectiveness equal to the nutrients available in the treated plots compared to the control plot.

Figure 1. Average plant height growth at harvest
3.3. Crop Yield

Plant yield components include panicle length, number of filled grains, empty grain, 1,000-grain weight, and rice yield. Using SOF had a significant effect on panicle length, the number of filled grains, and the number of empty grains. Meanwhile, for the parameter weight of 1,000 grain and yield of rice, SOF had a very significant effect.

Table 3. The average effect of the combination of inorganic fertilizers with SOF on panicle length, number of filled grains, and empty grain

| Treatment                      | Long Panicle (cm) | Fill Grain (grains) | Number of Unhusked Grain (grains) |
|--------------------------------|-------------------|---------------------|-----------------------------------|
| A = without fertilizer (control) | 24.50 ab          | 67.30 a             | 58.17 a                           |
| B = NPK 100%                   | 24.03 ab          | 94.47 bc            | 37.67 b                           |
| C = NPK 75 %                   | 23.90 a           | 90.83 b             | 36.03 b                           |
| D = NPK 75% + SOF 50%          | 25.13 b           | 92.33 b             | 29.33 c                           |
| E = NPK 75% + SOF 75%          | 24.37 ab          | 94.13 bc            | 27.03 c                           |
| F = NPK 75% + SOF 150%         | 25.27 b           | 97.17 c             | 25.20 c                           |
| G = NPK 100% + SOF 75%         | 24.80 ab          | 94.43 bc            | 36.07 b                           |
| H = NPK 100% + SOF 100%        | 24.03 ab          | 95.27 bc            | 33.17 b                           |

Note: The numbers followed by the same letter are not significantly different at DMRT α 1%

Table 3 shows that the highest average panicle length was obtained in treatment F = NPK 75% + SOF 150%, namely 25.27 cm, which was significantly different from other treatments except for treatment D = NPK 75% + SOF 50%, while the lowest was obtained in treatment C = NPK 75%, namely 23.90 cm. Table 4 shows that the highest average weight of 1000 grains was obtained in treatment F = NPK 75% + SOF 150%, namely 25.23, which was significantly different from other treatments including treatment A = control except treatment G = NPK 100% + SOF 75%. The highest yield (GKP) results were obtained in the treatment F = NPK 75% + SOF 150%, namely 5.03 tons ha⁻¹, significantly different from other treatments including control but not significantly different from treatment G = NPK 100% + SOF 75%. The lowest GKP results were obtained in treatment A = control, namely 3.17 tons ha⁻¹.
Table 4. The average effect of the combination of inorganic fertilizers with SOF on the weight of 1,000 grains and the yield of rice

| Treatment                                | Weights 1000 grains (gr) | Yield (ton ha\(^{-1}\)) |
|------------------------------------------|--------------------------|-------------------------|
| A = tanpa pemupukan (kontrol)            | 22.83 a                  | 3.17 a                  |
| B = berdasarkan rekomendasi NPK 100%     | 23.47 b                  | 4.10 b                  |
| C = NPK 75 %                             | 23.10 b                  | 3.50 a                  |
| D = NPK 75% + SOF Scortlef 50%           | 23.50 b                  | 4.57 b                  |
| E = NPK 75% + SOF Scortlef 75%           | 23.53 b                  | 4.90 c                  |
| F = NPK 75% + SOF Scortlef 150%          | 25.23 c                  | 5.03 c                  |
| G = NPK 100% + SOF Scortlef 75%          | 25.10 c                  | 4.80 b                  |
| H = NPK 100% + SOF Scortlef 100%         | 23.37 b                  | 4.73 b                  |

Note: The numbers followed by the same letter are not significantly different at DMRT \(\alpha 1\%\).

Giving SOF significantly reduced the number of empty grains of rice per panicle, where the lowest amount of empty grain was obtained in treatment \(F = \text{NPK 75\% + SOF 150\%}\) and the highest was obtained in treatment \(A = \text{without fertilization or control}\). Overall SOF nutrient content has a more complete composition. So that it can meet the nutrient composition needed by plants, both micro and macro elements. In addition, SOF also contains ingredients that can control pests in rice plants. These nutrients have a fairly large role in plant growth and yield. This can be seen from the function of each of these nutrients. Micronutrient elements function as an activator of enzyme systems or in plant growth processes, such as photosynthesis and respiration. Likewise, sufficient macronutrient content is available for plant needs, which can increase panicle length and grain yield of rice plants, because these nutrients have a fairly large role in plant growth and yield.

Nutrients have a fairly large role in plant growth and production. Nutrient N plays an important role in the growth and generative phases of plants. [18] said that the nitrogen contained in organic fertilizers is slowly available for plants. The addition of organic fertilizers is expected to increase the height and number of tillers of rice plants, but the treatment has no significant effect but can increase the yield of harvested un-hulled rice.

The application of organic fertilizers to rice plants is thought to accelerate the synthesis of amino acids and proteins, thereby accelerating plant growth. The yield of the grain at harvest is very significantly affected by the treatment given. Fertilizer treatment given can increase the weight of harvested grain by 50\% compared to treatment without fertilization (control). This is following the opinion of [19] that organic fertilizers contain potassium which plays an important role in every plant metabolic process, namely in the synthesis of amino acids and proteins from ammonium ions.

The element potassium also plays a role in maintaining good turgor pressure to allow the smooth running of metabolic processes and ensure the continuity of cell elongation. The element Phosphorus plays a role in storing and transferring energy for the synthesis of carbohydrates, proteins, and the photosynthetic process [19].

The compounds resulting from photosynthesis are stored in the form of organic compounds which are then released in the form of ATP for plant growth. Humic acid and folic acid as well as growth regulators contained in liquid organic fertilizers will support and accelerate plant growth. This also means that the availability of sufficient nutrients for the growth and development of rice plants, so that the seed filling process takes place at a maximum, which in turn produces a better yield component. According to [20], one factor that supports plant growth and production is nutrients. Nutrients must be available in sufficient quantities so that growth and production will be optimal.

3.4. Relative Value of Agronomic Effectiveness (REA)

The effectiveness of SOF fertilizer in rice is known by using the calculation of Relative Agronomic Effectiveness (RAE) with the following formula [21]
The yield on tested fertilizers - yield on control
RAE = \frac{\text{yield on standard fertilizers - yield on control}}{\text{yield on control}} \times 100\% 

The effect of SOF combined with inorganic fertilizers showed a greater RAE value than fertilization based on recommendation (NPK 100%). Thus, it can be said that the addition of SOF results in higher effectiveness than the use of recommended fertilizers alone in producing grain, which is indicated by the highest RAE value (200%) obtained in treatment F = 75% NPK + SOF fertilizer. The RAE value of each treatment can be seen in the table below.

### Table 5. RAE Value Effect of SOF on Rice

| Treatment | Yield (ton ha\(^{-1}\)) | RAE (%) |
|-----------|-------------------------|---------|
| A = without fertilizer (control) | 3.17 | - |
| B = NPK 100% | 4.10 | 100 |
| C = NPK 75% | 3.50 | 35.48 |
| D = NPK 75% + SOF 50% | 4.57 | 150.3 |
| E = NPK 75% + SOF 100% | 4.90 | 186.0 |
| F = NPK 75% + SOF 150% | 5.03 | 200 |
| G = NPK 100% + SOF 75% | 4.80 | 175.3 |
| H = NPK 100% + SOF 100% | 4.73 | 167.7 |

3.5. Farming Analysis

Financial analysis of rice farming with fertilizer treatment was carried out to provide information about the economic feasibility of the tested fertilizers compared to fertilizers that have been or are commonly used by farmers [22]. The profit of rice farming using SOF is calculated from the difference between the sale of unhulled rice as output minus production costs: seeds, fertilizers, pesticides and insecticides, other costs, and labor wages as importers. The highest profit from rice farming using SOF was obtained in the treatment of 75% NPK fertilizer combined with 150% SOF, namely Rp. 10,226,100 with an R/C ratio of 2.03. The analysis of SOF farming combined with NPK fertilizer for each treatment is presented in Table 6.

### Table 6. Analysis of SOF use farming in lowland rice in Lau District, Maros Regency, 2020

| Description | Treatment |
|-------------|-----------|
| Seed Volume (kg ha\(^{-1}\)) | A | B | C | D | E | F | G | H |
| Value (Rp. X 1.000) | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |
| Fertilizer Urea (kg ha\(^{-1}\)) | - | 300 | 225 | 225 | 225 | 225 | 225 | 300 |
| Value (Rp. X 1.000) | 0 | 600 | 450 | 450 | 450 | 450 | 450 | 600 |
| Value (Rp. X 1.000) | - | 100 | 75 | 75 | 75 | 75 | 75 | 100 |
| KCl | - | 50 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 50 |
| Value (Rp. X 1.000) | 0 | 125 | 93.75 | 93.75 | 93.75 | 93.75 | 93.75 | 125 |
| SOF | - | - | - | 2.5 | 2.5 | 2.5 | 2.5 | 5 |
| Value (Rp. X 1.000) | 0 | 0 | 0 | 187.5 | 375 | 562.65 | 281.25 | 375 |
| Insekticide dan pesticide | 1 pack | 1 pack | 1 pack | 1 pack | 1 pack | 1 pack | 1 pack | 1 pack |
| Value (Rp. X 1.000) | 850 | 850 | 850 | 850 | 850 | 850 | 850 | 850 |
| Labor (OH) | 65 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| Value (Rp. X 1.000) | 5.200 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
4. Conclusion

The Application of solid organic fertilizer (SOF) can increase paddy by 30% and the highest yield of harvested dry unhulled rice (GKP) was obtained in the treatment of 75% NPK fertilizer combined with 150% SOF, namely 5.03 tons, with an RAE value 200% and profit Rp. 10.226.100, with an R/C of 2.03.

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