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Assessing the Impact of Terra Preta from Rice Husk on Soil, Rice Plant Growth, and Yield in the System of Rice Intensification (SRI)

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ABSTRACT

The practice of intensive rice field cultivation and excessive chemical fertilizer use often leads to gradual declines in soil quality and fertility, as well as environmental pollution. By employing Tetadi as an ameliorant technology and adopting SRI cultivation techniques, we can mitigate the adverse effects on rice fields. This study aimed to examine the effects of Tetadi soil ameliorant on the physical properties of paddy soil, growth, and rice yield using the SRI method. The experiments were conducted in paddy fields in Pasar Ambacang, Kuranji, Padang city. Tetadi soil ameliorant was applied at A=0, B=5, C=10, D=15, and E=20 t ha^{-1}. Data on soil physical properties and plants were statistically analysed using ANOVA. The results showed that the change has an insignificant impact on soil physical properties, yet decreases BD (Bulk Density) by 28.2%; increases SOM (Soil Organic Matter) by 18.55%; TPS (Total Pore Space) by 13.7%, moisture content by 5.6%, permeability by 34.2%, and Available Water Pores (AWT) by 20%—application of 20 Mg ha^{-1}. Tetadi increased the number of productive saplings by 52.65% and yield by 69.46% compared to the treatment without Tetadi application.

Keywords: Biochar, compost, tomato, physic-chemical properties, sub-optimal land

INTRODUCTION

Paddy fields are land used for rice cultivation, either continuously throughout the year or in rotation, to support food production. However, the current condition of rice fields is affected by declining fertility due to intensive land cultivation and excessive application of chemical fertilizers. In general, farmers continuously cultivate their land and apply relatively high levels of chemical fertilizer to achieve maximum yields.

These practices often cause several problems, such as land degradation and a gradual decrease in soil fertility, and result in adverse environmental impacts, including pollution. Intensive land cultivation and high levels of fertilization yield maximum results even in a short period, leading farmers to become dependent on chemical fertilizers. As a result, excessive fertilization can deplete plant nutrients and lead to a gradual loss of soil fertility.

The solution to overcome this problem is to implement sustainable agricultural practices that maintain ecosystem balance and minimize negative impacts on the land and environment. In rice fields, the use of ameliorant technologies and cultivation techniques is expected to reduce the adverse effects of intensive processing and excessive fertilization.

One effort to provide ameliorant is by using Terra Preta Biochar Rice Husk (Tetadi). Tetadi is a combination of rice husk biochar and compost made from manure and organic waste, which can improve soil fertility (Gusmini et al., 2021; 2022). Biochar is a soil amendment that can increase soil productivity by improving soil physical properties. According to Gusmini, Adrinal, Putri et al. (2021), biochar can reduce soil bulk density, increase soil porosity, and retain water and nutrients, thereby benefiting soil fertility. Apart from that, biochar can increase microbial activity and maintain nutrients in the soil root zone by altering soil physical properties. Overall, improvements in soil properties will contribute to plant productivity.

Manure compost derived from cow dung and market waste always contains nutrients plants need (Karim et al., 2020; Dewi et al., 2017). The availability of nutrients plants need through manure can increase soil organic matter. Apart from that, the provision of market waste at this time will affect the availability of soil microbes that support the nutrient cycle for plant growth.

There is a combination of compost, which can contribute nutrients needed by plants, and biochar which can be a good adsorbant in retaining nutrients, and can be used as an ameliorant to improve the physical condition of the soil so that it can be an alternative for farmers in reducing the dose of artificial fertilizers which have the potential to damage land and minimize environmental pollution.

The System of Rice Intensification (SRI) aims to increase rice yields. SRI is a method of rice cultivation that emphasizes soil, plant, and water management through environmentally friendly practices. SRI has the advantage of reducing production costs and water use. Production costs can be reduced by using 5-10 times fewer seeds than in conventional planting methods (Rozen et al., 2024; Rozen & Kasim, 2018) and by reducing chemical fertilizer costs, as SRI emphasizes the use of organic materials in its cultivation practices. The SRI method can also save up to 50% of water because it requires land in a moist condition, which is very favorable for rice plant growth and development.

Rozen & Kasim (2018) stated that the Agricultural Ministry implemented the SRI method on demonstration plots in the city of Padang and several surrounding areas. The application of these demonstration plots resulted in twice the average production. Especially in the city of Padang, with an average production of 4.5 Mg ha^{-1}, it increased to 8.5 Mg ha^{-1} in research conducted by Musliar Kasim; this SRI research was then continued by Nalwida Rozen, with results of 11.99 Mg ha^{-1}. By combining these ameliorants with the SRI method, farmers can increase paddy field productivity sustainably, without reducing soil fertility or polluting the environment.

This research aims to examine the effect of Tetadi on the physical properties of rice fields planted with the SRI method and to determine the growth and yield of rice plants in SRI method rice fields planted with Tetadi.

MATERIALS AND METHODS

This research was carried out in the rice fields of the Pasar Ambacang community, a sub-district of Kuranji Padang City, and the Soil Physics Laboratory, Faculty of Agriculture, Andalas University, Padang.

This research used a Randomized Block Design (RBD) with five groups and three replications, each comprising 15 experimental units. Each plot was given an ameliorant material. However, the full dosage is as follows: A = No previous; B = 5 Mg ha^{-1} previous; C = 10 Mg ha^{-1} previous; D = 15 Mg ha^{-1} previous; and E = 20 Mg ha^{-1} previous.

The following are the implementation stages undertaken to assess the achievement of research indicators.

Tetadi Making

Production began with rice-husk biochar produced by pyrolysis. Rice husks thaMg have been burned produce charcoal through combustion. Then, making cow dung compost involved air-drying, adding dolomite lime at 1/20 the weight of the cow dung, and evenly adding the bioactivator *Tricoherma sp*. Meanwhile, city waste was shredded.

Next, the results from making rice husk biochar, manure compost, and municipal waste were mixed in a 2:2:1 ratio, then placed in a mixing machine. The ingredients were thoroughly mixed and then fermented for $\geq$ 4 weeks. Compost thaMg has been decomposed was characterized by a color resembling soil, a temperature approaching room temperature (25-30 °C), a C/N ratio < 15, and no strong odor. Next, the mature compost was air-dried and sieved.

Soil Sampling

Initial soil sampling was conducted before application, when the land was plowed and dry, while final soil sampling was conducted after harvest. Two types of soil samples were taken: intact and disturbed. For intact soil samples, they were collected using a ring at 0-20 cm; for disturbed soil samples, they were collected using a *Belgie drill* at the same depth. Each was then repeated three times and composited.

Research Location Preparation

The land used was previously plowed and then flooded, forming mud. Then the rice field was divided into 15 plots, each measuring 2 m × 3 m. The entire plot consisted of 5 treatments with three repetitions; we then gave each plot a mark.

Providing Treatment

Providing treatment to rice fields using Tetadi at a dose of 0 Mg ha^{-1}, 5 Mg ha^{-1}, 10 Mg ha^{-1}, 15 Mg ha^{-1}, 20 Mg ha^{-1}. This dosage refers to research by Gusmini, Adrinal, Putri, et al. (2021), in which the 20 Mg ha^{-1} tetadi treatment was the best. After spreading it over the experimental plot, the soil was stirred to a uniform consistency and incubated for 14 days.

Seeding

Wet seeding was carried out for 1-4 days directly in the rice fields by sowing seeds in the provided plots. Sowing seeds must be spaced so they can grow strong and be easily removed.

Planting and Maintenance of Plants

Rice seeds sown 14 days ago were planted using the SRI method, with a spacing of 25 cm x 25 cm in each plot. Planting was carried out with one seed per planting hole, removing the seeds from the nursery area and transferring them to the field as soon as possible. The recommended fertilizers for rice plants using the SRI method were Urea at 100 kg ha^{-1}, TSP at 100 kg ha-1, and KCl at 100 kg ha^{-1}. Urea fertilizer was applied three times: the first application of 33.33 kg ha-1 was applied 2 days after planting, along with TSP fertilizer at 100 kg ha^{-1} and KCl at 50 kg ha^{-1}. The second application of Urea fertilizer was carried out at 30 HST at a rate of 33.33 kg ha^{-1}, and the last application was carried out at 40 HST at a rate of 33.33 kg ha^{-1}.

The rice plants observed were marked with stakes made from thin wooden sticks, 20 cm long, embedded in the ground to a depth of 10 cm, leaving 10 cm from the stake tip to the ground surface. Apart from being markers, stakes also help measure the height of rice plants. Plant maintenance was done by weeding. In the SRI method, weeds grow very easily due to damp land and water conditions.

Harvest

Harvesting was carried out at 132 HST when the rice panicles were 90-95% yellow. Rice harvesting was done by cutting the rice stalks with a sickle to a height of 10 cm above the ground.

Observation

a) Soil analysis

The observations made included analyses of the initial and final soil samples, including texture, soil organic matter, soil permeability, volume, total pore size, soil moisture, and pore distribution. Texture analysis was performed only once for the initial sample.

The data from this laboratory's analysis of soil's physical properties were averaged. Then, the initial soil data before treatment were compared with the soil physical properties criteria table, while the soil data after treatment were further analyzed using statistical analysis.

b) Agronomic observations

Observations of plant growth thaMg have been carried out were plant height, total number of tillers, and number of productive tillers, while observations of plant production results were crop yield (Mg ha^{-1}).

The data obtained from the calculations were analyzed using the F test. If the calculated F for the treatment was greater than the F table value at the 5% level, the DMRT Multiple Range Test (DMRT) was used at the 5% level.

RESULTS AND DISCUSSION

General Condition of Research Location

This research was carried out in the rice fields of the people of Pasar Ambacang Village, Kuranji District, Padang City, located at 100° 24' 41" E and 0° 55' 50" S, at an elevation of 54 meters above sea level (masl). The land used was a rice field, generally planted with rice and cultivated conventionally, using 3 to 5 seeds that were 4 to 5 weeks old after sowing in one planting hole, and flooded continuously during rice growth. Before planting, paddy fields were muddied twice. In general, local farmers did not add organic materials to their rice fields; they used only inorganic fertilizers to support plant growth. The remaining harvest is usually transported outside the rice field area or burned to prevent the plants from being affected by the weathering of the harvest residue.

Physical Properties of Paddy Soil Before Being Given the Previous Treatment

Based on the analysis of paddy fields before treatment, the soil at this research location has the following physical properties.

In the soil texture observations carried out on the initial soil, see Table 1. The soil texture at the research location is classified as clayey clay. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan (2011) stated that clay texture is very suitable for lowland rice plants, as finer soil texture is more suitable for rice fields. Soil with a fine texture will accelerate the formation of plow-till layers in rice fields. This plow tread layer will help ensure efficient water use, preventing it from easily escaping

Table 1. Initial Physical Properties of Paddy Soil.

Parameter	Value	Class / Criteria
Soil Texture		
- Sand (%)	40.33	
- Dust (%)	19.83	Clay Clay***
- Clay (%)	39.83	
Soil Volume Weight (g cm^{-3})	0.92	Currently*
Total Soil Pore Space (% Vol)	71.7	Currently*
Organic Ingredients (%)	3.20	Currently**
Soil Permeability	0.50	Somewhat Low*

Sources: *) Bogor Soil Research Institute (1979), **) Bogor Soil Research Institute (2009), ***) USDA Texture Triangle

downward and allowing it to be used for muddying. Meanwhile, suppose the soil in rice fields has a rough texture. In that case, it will be very water-wasteful due to the lower number of micro pores compared to macro pores, making it difficult to retain water when cultivated for rice.

The soil bulk density (BD) at the research location falls within the medium range at 0.92 g cm^{-3}. This is because rice fields are generally managed with mud, which affects the soil's Bulk Density (BD). Research conducted by Sulistyo et al. (2016) found that silting reduces the BD of clayey clay soils. Meanwhile, the Total Pore Space (TPS) in paddy fields at the research location is 71.7%, which is classified as medium.

The organic matter content in the paddy soil at the research location is 3.20%. The organic material in the paddy soil at this research location is classified as medium because there is no return of harvest residues to the land; instead, they are generally thrown outside the land or burned. Soil permeability at the research location is classified as relatively low, with a value of 0.50 cm h^{-1}. This is because the soil texture is classified as high clay, which makes the soil dense. This decreases soil porosity and pore-space distribution, resulting in reduced soil's ability to transmit water (permeability) (Prasetyo & Suriadikarta, 2006).

Physical Properties of Rice Soil After Being Given the Previous Treatment

In this research, an Analysis of the physical properties of rice field soil was carried out 6 months after administration of tetadi. There are five groups of administration according to the treatment dose. Analysis of soil physical properties consisting of organic matter, volume weight, total pore size, soil moisture, permeability, pore distribution, and available pore water.

Soil Organic Matter

The soil's organic matter content after treatment is shown in Table 2. The results of analysis of variance and further DMRT tests at the 5 % level show that this application does noMg have a

Table 2. The Effect of Application of *Tetadi* on Soil Organic Matter Content of The SRI Method Rice Fields.

Previous Treatment (Mg ha^{-1})	Soil Organic Matter (%)
Without further ado	3.35 a
5	3.46 a
10	3.69 a
15	3.86 a
20	3.93 a
CV =	18.56%

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

Table 3. The Effect of Tetadi application on BD and TPS of SRI Method Rice Fields.

Previous Treatment (Mg ha^{-1})	BD (g cm^{-3})	TPS (% volume)
0	0.82 a	62.3 a
5	0.81 a	63.9 a
10	0.78 a	64.9 a
15	0.73 a	64.9 a
20	0.70 a	66.4 a
CV =	7.51%	4.39%

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

significant effect on the organic matter content of paddy soil.

This treatment does noMg have a significant effect on the soil organic matter content. However, Table 3 shows that this application tends to increase soil organic matter content. However, the organic matter content of the initial soil differed from that of the previous 0 Mg ha^{-1} treatment. Even though there was no additional application on the initial soil or the 0 Mg ha^{-1} treatment, there was an increase in organic matter value of 0.15 % in the 0 Mg ha^{-1} treatment due to the application of basic fertilizer at the beginning of rice planting and the application of the SRI method, which also caused a difference in the value of organic matter content. Weeds are more likely to grow on land that uses the SRI planting AWPtern because it is always moist but not flooded. Efforts to control weeds are carried out by immersing them in the soil, so that weeds remain in the soil and become rotten, as a result of which the organic matter content in the soil also increases.

Rice cultivation using the SRI method emphasizes the provision of organic materials in its practical application. From Table 3, it can be seen that the higher the tetadi dose, the higher the soil organic matter content. This increase was compared with the treatment with the lowest organic matter value, namely 3.35%, found in the treatment without Tetadi, and with the treatment with the highest organic matter value, namely 3.93%, given with Tetadi at 20 Mg ha^{-1}. The compost in this tetadi improves soil physical and biological properties by supplying nutrients, especially N, P, and K (Vuong et al., 2022). It will ultimately affect the long-term availability of organic material and nutrients, as well as the maintenance of the physical properties and fertility of rice field soil. Biochar applied to soil can bind other nutrients and slowly release them (Gholamahmadi et al., 2023).

Bulk Density and Total Pore Space

The BD and TPS values for each treatment in paddy soil are shown in Table 3. The results of analysis of variance and further DMRT tests at the 5% level showed that this application had no significant effect on the BD and TPS values in paddy fields.

The application of tetadi had no significant effect on BD and TPS in paddy fields, but there was a tendency to decrease BD and increase TPS with increasing tetadi dose. The highest BD value was found in the 0 ton/ha treatment, namely 0.82 g cm^{-3}, followed by the lowest TPS value, namely 62.3% by volume, then the lowest BD value was found in the 20 Mg ha^{-1} treatment, namely 0.70 g cm^{-3}, followed by the highest TPS value, which was 66.4% volume. The decrease in BD and increase in TPS were due to increased organic matter (Table 3).

Indriani (2007) stated that the amount of organic material influences changes in soil volume weight; soil rich in organic material has a higher volume weight. The decrease in soil volume weight is caused by organic matter acting as a binding agent for soil particles, improving soil aggregation and creating pore space, thereby decreasing soil volume weight (Lawenga et al., 2015).

Total Pore Space in soil reflects the level of looseness and the number of pore spaces in the soil. Thus, processing paddy fields, which is generally carried out by puddling, will cause the pore space in the soil to be disturbed. The increase in TPS value, often accompanied by an increase in the dose administered, is closely associated with a decrease in the BD value in the soil (Yulnafatmawita et al., 2011). Moreover, Yulnafatmawita et al. (2023) stated that soil bulk density influences total pore space. The higher the soil's total pore space, the lower its volume weight; conversely, the lower the soil's total pore space, the higher its volume weight.

Table 4. The Effect of Tetadi Application on Soil Moisture of Rice Fields SRI Method.

Previous Treatment (Mg ha^{-1})	Soil moisture (%)
0	5.04 a
5	5.05 a
10	5.19 a
15	5.34 a
20	5.34 a

Note: Numbers followed by different lowercase letters in columns. They are significantly different according to the DMRT test at the 5% level.

One of the principles of the SRI method that is very important to observe is prioritizing organic material inputs to improve soil quality (Suswadi et al., 2021). Organic material derived from tetadi helps improve soil physical properties by increasing microbial activity and reducing soil compaction. Soil conditions with low BD and high pore space will expand the root zone, allowing roots to absorb more nutrients and leading to better plant development.

Increasing the pore space in soil can affect its capacity to store water and air. In addition to the effect of increased organic matter from tetadi application, the increase in pore space also occurs because the soil is moist, with pores filled with water. Soil in this moist condition can support rice growth in accordance with the requirements for SRI rice cultivation.

Soil moisture (SM)

SM values in paddy fields for each treatment are shown in Table 4. Results of analysis of variance and further DMRT tests at the 5% level show that this application has no significant effect on the SM value in paddy fields.

Giving Tetadi has not significantly increased soil moisture in paddy fields, but there is a tendency for soil moisture to increase with increasing dose. The lowest soil moisture value was found in the treatment without provision, namely 5.04%, and the highest in the 20 ton/ha treatment, namely 5.34%. This is due to the influence of organic matter contained in each treatment, which affects the soil's ability to store water. The rice husk biochar found in Tetadi has a large surface area, which allows it to bind water more readily. Chairunnisa et al. (2019) and Adrinal et al. (2021) found that rice husk biochar can bind water and nutrients in soil due to its porous structure and large surface area, thereby retaining nutrients and improving soil physical properties.

Water management using the SRI method is not always stagnant or intermittent. Irrigation in this way will help improve soil aeration. With good soil aeration, the groundwater balance will be maintained. This condition will maintain soil water levels suitable for supporting plant growth. Supporting this provision will also increase soil moisture.

Soil Permeability

The permeability values for each treatment in paddy soil are presented in Table 6. The results of the analysis of variance and subsequent DMRT tests

Table 5. The Effect of Tetadi Application on Soil permiability of Rice Fields SRI Method.

Previous Treatment (Mg ha^{-1})	Permeability (cm ha^{-1})
0	0.61 a
5	0.63 a
10	0.70 a
15	0.75 a
20	0.76 a
CV =	21.40%

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

at the 5% level show that this application does noMg have a significant effect on the permeability values. To paddy fields.

Table 5 shows that applying Tetadi to paddy fields does not significantly affect permeability, but there is a tendency for permeability to increase with increasing Tetadi dose. The lowest permeability value was observed in the treatment without 0.61 cm h^{-1}, and the highest was in the 20 Mg ha^{-1} treatment, namely 0.76 cm h^{-1}. Nevertheless, it plays an important role in increasing soil permeability by providing organic matter. By creating looser soil conditions—lower BD and greater porosity— the soil will be able to pass water. According to Yulnafatmawita et al. (2023), a decrease in soil bulk density will increase soil permeability. In general, the increase in permeability is caused by the increasingly axial soil.

When applying the SRI method, the soil is not always flooded with water; the soil is sufficiently moist (Rozen & Kasim, 2018). In this case, the soil pores are not quickly filled with water, and water movement in the soil is better than in soil under flooding. So the rate of soil permeability is better than that of soil that is always flooded. Soil permeability is determined by several factors, including the method and intensity of soil processing and soil texture (Handayani, 2004). Cultivating the soil will create more macro pores filled with air, and when the soil is saturated, these macro pores will allow more water to enter. Based on the rate of soil permeability after administration, this soil's permeability remains relatively low. According to Ristanti & Edi (2023), the permeability of paddy fields must be low enough to prevent water loss, yet high enough to drain (wash away) toxic materials.

Pore Distribution

The distribution of soil pores into Fast Drainage Pores (FDP), Slow Drainage Pores (SDP), and Available Water Pores (AWP) resulting from tetadi application in paddy fields is presented in Table 6. The results of analysis of variance and subsequent DMRT tests at the 5% level showed that this application had no significant effect on FDP, SDP, and AWP values in paddy fields.

The results of the variance analysis of drainage pores showed that the administration of various treatments had no significant effect on FPD and SPD in the SRI method planting. The 5 Mg ha^{-1} treatment yielded the highest FPD. The opposite situation occurred in SPD, where the 5 Mg ha^{-1} treatment produced the lowest SPD. The pores in the soil are closely related to soil organic matter content, with the influence of organic matter not significant (Table 3). The soil's ability to absorb water, influenced by organic matter, affects its water retention capacity, but this effect is not real.

Based on Table 6, this application increased the available water pores (AWP) in the soil, with the lowest value in treatment A (control) at 17.6%, then increasing with additional treatments, reaching the highest value in treatment E at 22.0%. The AWP value is obtained from soil moisture measurements at pF 2.5 and 4.2. The increase in the AWP value is likely due to organic material in the soil, which enhances the soil's ability to retain water available to plants. In line with the opinion of Jumin et al.

Table 6. The Effect of Tetadi Application on Soil Pore Distribution of Rice Field Soil with the SRI Method.

Previous Treatment (Mg ha^{-1})	Pori Drainage		Available Water
	Fast	Slow	
	-----------------(% Volume)-----------------		
0	24.2 a	5.7 a	17.6 a
5	27.4 a	4.8 a	17.7 a
10	25.3 a	6.3 a	19.4 a
15	24.7 a	5.6 a	21.6 a
20	25.8 a	6.1 a	22.0 a
CV =	45.73%	30.05%	35.31%

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

Table 7. Effect of Tetadi Application on Rice Plant Height SRI Method.

Previous Treatment ($Mg\ ha^{-1}$)	Plant height (cm)
0	74.26 a
5	80.37 a
10	88.04 a
15	91.37 a
20	93.59 a
CV =	12.74%

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

(2024), which states that organic materials can bind water up to 2-4 times their original weight, thereby increasing water availability for plants.

The Effect of Giving Rice Tetadi on the Growth and Yield of Rice Plants with the SRI Method

In this study, the agronomic parameters observed were plant height, number of clump tillers, number of productive tillers, and rice yield.

a) Plant Height

Analysis of variance showed that applicationof Tetadi had no significant effect on plant height. However, the increasing dose given tends to increase plant height. As shown in Table 7, the tallest rice plants are observed with $Mg\ ha^{-1}$, namely 93.59 cm, while the shortest were observed without the fixed application, namely 74.26 cm.

Even though there is no significant difference between the previous applications, applying 20 $Mg\ ha^{-1}$ of fixed plants increased plant height by 26% compared to the control. Treatments C to E met the height characteristics of IR-64 rice plants, which have an average height of 85 cm (Romdhon et al., 2021). This increase in plant height is due to improvements in the physical properties of the soil as a result of the application of tetadi, with the condition of the soil having an increased total pore space and a decrease in the volume weight of the soil, allowing plant roots to penetrate deeper layers of soil so that the root range is wider and able to absorb nutrients. More of which is then used for plant growth.

The increase in plant height is also influenced by genetic factors within the plant and by environmental factors during rice growth. One of them is through photosynthesis, the process of cell division in plant cells, which increases plant height. The organic material in tetadi contributes to plants' nutrient needs, so that the more nutrients plants absorb, the higher their photosynthesis, which in turn increases plant growth and development.

Applying the SRI method, seeds are transplanted one by one so that each planMg has space to spread and deepen its roots, reducing

Table 8. Effect of Tetadi application on the Number of Rice Tillers with the SRI Method.

Previous Treatment ($Mg\ ha^{-1}$)	Number of Cubs (stem)
0	24.8 0 a
5	26.13 a
10	27.80 a
15	30.20 a
20	31.87 a
CV =	13.87

Note: Numbers followed by different lowercase letters in columns are significantly different according to the DMRT test at the 5% level.

competition for growing space, light, and soil nutrients (Maida, 2013). Light intensity is an important component of plant growth, as it supports photosynthesis. The wider the spacing between planting holes, the more it minimizes competition for sunlight and nutrients, allowing plant height and root growth to be more optimal.

b) Number of Cubs

The results of the analysis of variance and further DMRT test at the 5% level show that the treatments have no significant effect on the number of rice tillers. Table 8 shows that this provision increased the number of tillers on rice plants, with the lowest number observed without treatment (24.80 stems) and the number increasing with the number of treatments applied. The highest tiller yield in the 20 Mg ha^{-1} treatment was 31.87 stems.

Although there is no significant difference between the previous applications, providing 20 tonnes/ha of fixed rice increased rice seedling growth by 28% compared to no fixed rice. The provision of tetadi functions as an ameliorant, improving the physical properties of the soil by reducing the volume weight, increasing the pore space, organic matter, and available pore water. By creating good physical conditions for plants, optimal plant growth will result. Good soil aeration conditions and the availability of energy for soil microorganisms' activities through the addition of tetradia, so that plants can absorb available plant nutrients and develop the growth of clump seedlings.

According to Rahmayuni et al. (2023), the large number of saplings produced using the SRI method is influenced by the planting of young seedlings. The seeds planted are 14-day-old seeds. Seedlings that are less than 15 days old will adapt and recover more quickly from stress resulting from being moved from the nursery to the field. The number of rice tillers is also closely related to the period during which a set of stems, leaves, and roots forms from the base of the plant (the *phyllochron*). The older the seedlings are when moved to the field, the fewer *phyllochrons* are formed; conversely, the younger the seedlings are when moved, the more *phyllochrons* are produced. Also increasing in number (Chivenge et al., 2020).

Weed control using the SRI method is carried out by turning or burying the weeds back into the soil, as weed growth is particularly vulnerable because the land is not flooded. This soil-turning process will improve soil aeration. According to Rozen and Kasim (2018), compared with conventional methods that control weeds through continuous flooding, this method inhibits plant growth. As a result, the roots do not develop properly because they form aerenchymatic tissue to channel air, so many roots rot.

c) Productive Tillers

The results of analysis of variance and subsequent DMRT tests at the 5% level show that the application has a significant effect on the number of productive tillers in rice plants using the SRI method. In Table 9, it can be seen that the effect of providing tetadi is able to increase the number of productive tillers in one family with the lowest number in the treatment without tetadi, namely 9.53 productive tillers, then increase along with the increase in the value of the treatment given, and the highest number of productive tillers is obtained in treatment 20 Mg ha^{-1} that is 20.13 productive tillers. However, it creates conditions for good soil physical properties for plants by increasing soil fertility. Soil fertility is crucial for rice productivity, and the SRI method emphasizes managing plant nutrition. The soil is low BD, high pore space, and sufficient pore water availability will make it easier for roots to absorb nutrients. Then, providing organic soil material will increase nutrient availability.

The number of productive tillers is also directly proportional to the total number of tillers. According to Wijayanto & Briliawan (2022), the greater the maximum number of tillers, the greater the number of productive tillers. The application of the SRI planting method, by moving seeds to a young age, also affects the number of productive tillers in rice. Research conducted by Gusmini et al. (2021) found that transplanting seedlings at 7 and 14 days old resulted in a greater number of productive tillers than transplanting at 21 days old. This is because seedlings that are younger at the time of transplanting are less likely to experience root damage, allowing the plants to reach a more optimal generative period.

d) Crop Results

The results of the analysis of variance and further DMRT test (5%) show that this application still has a significant effect on rice yields using the SRI method. The lowest yield in the treatment without the previous treatment is 1.82 Mg ha^{-1}; it increased with the addition of the previous treatment, and the highest yield is obtained with 20 Mg ha^{-1} of the previous treatment, namely 5.96 Mg ha^{-1} (Table 10). The yield of rice plants on application remains 20 Mg ha^{-1}, with an average yield already higher than that reported for IR-64. However, in other treatments, it does not exceed the production yield value in either variety description.

Table 9. The Effect of Giving Tetadi on Productive Tillers of Rice Plants SRI method.

Previous Treatment ($Mg\ ha^{-1}$)	Productive Tillers (stem)
0	9.53 c
5	12.53 bc
10	14.60 abc
15	17.87 ab
20	20.13 a
CV =	22.15%

Note: Numbers followed by different lowercase letters in columns are significantly different according to DMRT test at the 5% level.

Table 10. The Effect of Giving Tetadi on Rice Yields with the SRI Method.

Previous Treatment ($Mg\ ha^{-1}$)	Rice Yields ($Mg\ ha^{-1}$)
0	1.82 c
5	3.41 bc
10	4.25 ab
15	4.59 ab
20	5.96 a
CV =	30.95%

Note: Numbers followed by different lowercase letters in columns are significantly different according to DMRT test at the 5% level.

The rice yileds in this study do not exceed the average SRI method results. Research conducted by Palanivell et al. (2015) found that SRI planting produced 8.5 Mg ha^{-1}, rising to 11.99 Mg ha^{-1} in a subsequent study by Rozen & Kasim (2018). Meanwhile, the best result obtained in this study is 5.96 Mg ha^{-1}. This is caused by rat pest attacks, which cause damage to rice plants due to asynchronous planting. The breaking of rice plant stems and leaves characterizes rat pest attacks (Wang et al., 2013), resulting in a decrease in yield per hectare.

There is an increase in rice yileds, allegedly due to a higher Tetadi dose, attributed to the organic material it contributed. So the role of tetadi as an ameliorant in improving the physical properties of the soil can be seen in increasing the total pore space and decreasing the volume weight of the soil, thereby creating more pore space and increasing the capacity to absorb and store water. Thus, increasing available soil moisture will stimulate better plant growth and production by meeting adequate plant water needs. Khodijah (2019) stated that if available water levels increase, production will also increase.

Apart from the influence of tetadi, the SRI planting method can yield higher crop yields than conventional methods. With fairly wide planting spacing, it will reduce population density at each planting point, in accordance with Hermawan et al. (2018), who stated that higher population density limits space for plant growth, resulting in suboptimal plant growth and development. With greater distances between plants and lower population densities, the root range of rice plants widens, enabling them to absorb nutrients more efficiently and affecting rice growth and production. According to Purwanto et al. (2021), the SRI planting method with one seed per planting hole reduces competition among plants, allowing each plant to absorb water, nutrients, CO_2, O_2, sunlight, and space to grow more optimally. In addition to suitable soil texture and the addition of teta, plants can obtain sufficient nutrients.

Under optimal growth conditions, there is a relationship between the maximum number of tillers and the number of productive tillers, resulting in higher yields. In achieving maximum rice productivity through the SRI system and the provision of rice, three rice growth factors are synergistic. These three factors are maximizing the number of tillers, root growth, and providing an adequate supply of nutrients, water, and oxygen for rice plants (Adrianto et al., 2016).

CONCLUSIONS

This application of Tetadi on paddy soil managed by The SRI methods resulted in improvement of soil physical properties, growth, and yierd of Rice. Application of 20 Mg ha^{-1} Tetadi was reduced Bulk Density from 0.92 to 0.66 g cm^{-3}, increased soil organic matter content (3.20% to 3.93%), increasing total pore space (71.7% to 83.1% v/v), soil moisture (5.04% to 5.34% w/w) and soil permeability (0.50 cm ha^{-1} to 0.76 cm ha^{-1}), and available water pores (17.6% to 22.0%v/v).

Application of 20 Mg ha^{-1}. Tetadi resulted in 20.13 productive tillers, (increased of 52.65%), and yield 5.96 Mg ha^{-1}, (increased of 69.46%) compared to zero application of Tetadi.

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