

Analysis of Water-Saving Irrigation with Organic Materials at Different Percentages for Rice Cultivation

Dhinar Yoga Hanggung Legowo^{*}, Fatchan Nurrochmad, Endita Prima Ari Pratiwi

Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta, INDONESIA

Jalan Grafika No 2 Yogyakarta

^{*}Corresponding authors: dhinaryoga@mail.ugm.ac.id

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ABSTRACT Gemolong subdistrict in Sragen Regency of Central Java, Indonesia has a rainfed rice area of 2,047.64 hectares. Water is very limited during the dry season and this usually makes farmers use costly groundwater pumps for irrigation. This means conventional method involving the continuously flooded irrigation combined with chemical fertilizers which are considered water-wasteful and hazardous to the soil is the current practice in the area. However, water saving-irrigation with the addition of organic material has been discovered to be an alternative solution to this problem. Therefore, this study aimed to determine the effect of this method on water productivity using four variations of water-saving irrigation treatment and composition of organic application as well as one control treatment involving conventional method with chemical fertilizers. Meanwhile, composted rice straw was used as organic material and applied at 20% and 40% composition. The results showed the application of organic material boosted rice production while the water-saving method increased water productivity. Applying rice straw to the soil at 20% and 40% was discovered to have increased water productivity by 15% and 19% compared to the control treatment. Moreover, the application of 20% rice straw to water-saving irrigation method saved up to 19% water and increase its productivity by 16.5% in comparison with the control treatment. However, 40% under water-saving irrigation method reduced the water productivity by 2% even though it saved up to 27% water needed for irrigation. It is, therefore, recommended that water-saving methods added with 20% organic material be implemented as alternative rice cultivation procedures during dry season and period of water scarcity.

KEYWORDS System of Rice Intensification (SRI); Continuously Flooded Irrigation; Water Productivity; Composted Rice Straw; Water-saving Irrigation

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1 INTRODUCTION

Gemolong subdistrict in Sragen Regency of Central Java is one of the Indonesian granaries with rainfed lowland rice area of 2,047.64 hectares. Currently, the farmers apply conventional planting methods and this includes continuously flooded irrigation but due to the very limited water during the dry season groundwater pumps are usually applied. The massive groundwater exploitation has the possibility of causing a decrease in its availability (Tularam and Krishna., 2009). Gun and Annukka (2010) reported the use of groundwater pumps to be reducing the discharge of groundwater flow thereby causing seawater intrusion and spring

flow loss. Meanwhile, farmers have to pay extra fees such as 7,000 Rupiah/liter of gasoline to operate the pump. It is important to note that seven liters are required to irrigate a 3000 m² paddy field and this is usually conducted once every 3 days until the harvest period during the dry season. The use of conventional cultivation method was recorded to be producing 3 – 4 tons/ha and this is considered inefficient due to limited water availability and the need to pay more to obtain water. Nurrochmad (2009) also showed the water productivity of rice with the conventional method is 2,348 liters/kg. Moreover, the continuous use of chemical fertilizers by the

farmers has negative impacts on the soil by damaging its structure, increasing acid irrigation, and contaminating groundwater or river bodies to cause eutrophication (Savci, 2012).

Water-saving irrigation of the System of Rice Intensification (SRI) method combined with the application of organic fertilizer has been reported to be the alternative to overcome the problem of excessive water use in the Gemolong District. The SRI method is an intensive and efficient rice cultivation method with the ability to increase productivity (Arianta, 2016). According to Roseline (2012), the rice yield from the SRI method in Girimukti Village increased to 5.7 - 7 tons/ha compared to pure rainfed agriculture's 3 - 3.5 tons/ha and conventional continuous flooded irrigation with 4 - 5.5 tons/ha. The success of the water-saving irrigation system depends on soil's ability to optimally hold water for plants. This water-holding capacity and conditions of the soil such as aeration, structure, and temperate can, however, be increased with the application of organic fertilizer. Rina (2015) showed the greatest water-holding capacity of Bantul soil is based on 1:1.5 or 40% soil to organic matter ratio which was recorded to be 19.14% or 38.29 mm. Moreover, Pranata (2018) also found the use of organic straw compost to have the ability to increase rice production by up to 62%. It also showed the addition of 25% straw compost to soil produced 34 gr rice yield while the soil without compost only produced 21 gr. However, it is possible to reduce the soil evaporation rate by adding appropriate organic materials in the right dosage (Intara et al., 2011). This is supported by Rina (2015) by showing the lowest evaporation of the 1:1.5 or 40% Bantul soil to organic matter mix was 2.25 mm/day while the highest was found to be 2.65 mm/day at 67% organic mixture. Meanwhile, the value obtained for the controlled

soil which was 0% organic fertilizer mixture was 2.5 mm/day.

This research was conducted to determine the effect of water-saving irrigation combined with composted rice straw as organic fertilizer on soil characteristics, rice growth, water balance, and water productivity. This involved the application of four treatment variations based on different irrigation methods and organic fertilizer composition. The methods include a conventional system with the use of continuously flooded and SRI with water-saving or wet and dry irrigation. The composted rice straws were made in 20% and 40% to the soil's weight. Meanwhile, one treatment was made with continuously flooded irrigation and chemical fertilizers as the control being the method currently employed by Gemolong farmers.

2 METHODS

2.1 Research Location

This research was conducted in a greenhouse located in km 16.3 Kaliurang Street in Pakem District, Sleman Regency of Yogyakarta Special Region with coordinates 7°40'28.86" in South Latitude and 110°24'58.52" in East Longitude. Soil samples were obtained at 0 - 20 cm depth from Kwangen Village, Gemolong District, Sragen Regency with coordinates 7°23'36.56" in South Latitude and 110°49'7.24" in East Longitude. Moreover, the soil texture and content were analyzed before and after the planting period by the Indonesian Agency for Agricultural Research and Development (BPTP), Ministry of Agriculture, located at Stadion Maguwoharjo Street, Ngemplak, Sleman. The relative location of the soil sampling to the research is presented in Figure 1.

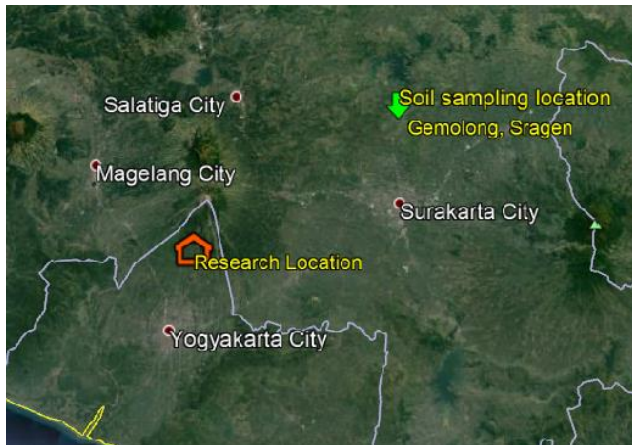


Figure 1. Research and soil samples location

2.2 Research Materials

The materials used include organic material which was compost made from straw, Ciherang rice seeds, chemical fertilizers, and water. The straw was preferred because it is one of the leftovers after rice grains have been harvested and also has the ability to increase soil nutrient levels, fertilize the soil, and loosen the soil to aid nutrient absorption by the plantation (Watanabe et al., 2009). SAN, a coconut water fermentation formula containing beneficial bacteria (probiotics) was added to the straw compost to optimize the activities of the organic material. Moreover, the rice seed used was Ciherang varieties with planting age estimated at 110 to 125 days. The chemical fertilizer used includes urea which is artificial and inorganic serving as the source of nitrogen nutrients and Phonska which is an NPK compound fertilizer with macronutrient element added to the urea

fertilizer. The dosage is usually 100 kg/ha for each but since 0.36 m² area was used in this study, the value used was 0.01 kg/m². The irrigation system close to the greenhouse was employed as the source of water.

2.3 Research Model and Tool

The research was conducted in five 0.6 m x 0.6 m x 0.3 m modeled experimental plots using material from 0.5 mm ORHID semi-rubber PVC. The distance between the rice planted was ±20 cm and this means it was possible to plant 9 rice seeds in one plot area. The mixture of soil and organic materials were placed in the experimental plots at 0.2 m height. The research model from the side and top views is shown in Figure 2. Meanwhile, the water depth for conventional cultivation was as high as 4 cm while the maximum for SRI was 2 cm.

There 5 different treatments based on the organic material composition and water supply method are displayed in Table 1. The organic materials were composed at 20% and 40% based on their weight and that of the soil in dry air. Moreover, there were two variations of water supply which are conventional (Kon) and SRI methods as well as the control treatment which is the method currently used by Gemolong farmers. It involves using the conventional method of irrigation without the addition of organic material. Meanwhile, plant nutrient was obtained from chemical fertilizer.

Table 1. Experiments sample

Sample Name	Soil	Rice Straw Compost	Water Supply Method
Kon Con ¹	100%	0%	Conventional
Kon 20%	80 %	20%	Conventional
Kon 40%	60%	40%	Conventional
SRI 20%	80%	20%	SRI
SRI 40%	60%	40%	SRI

¹ Kon Con is the control treatment which involves conventional irrigation and chemical fertilizer (without rice straw compost)

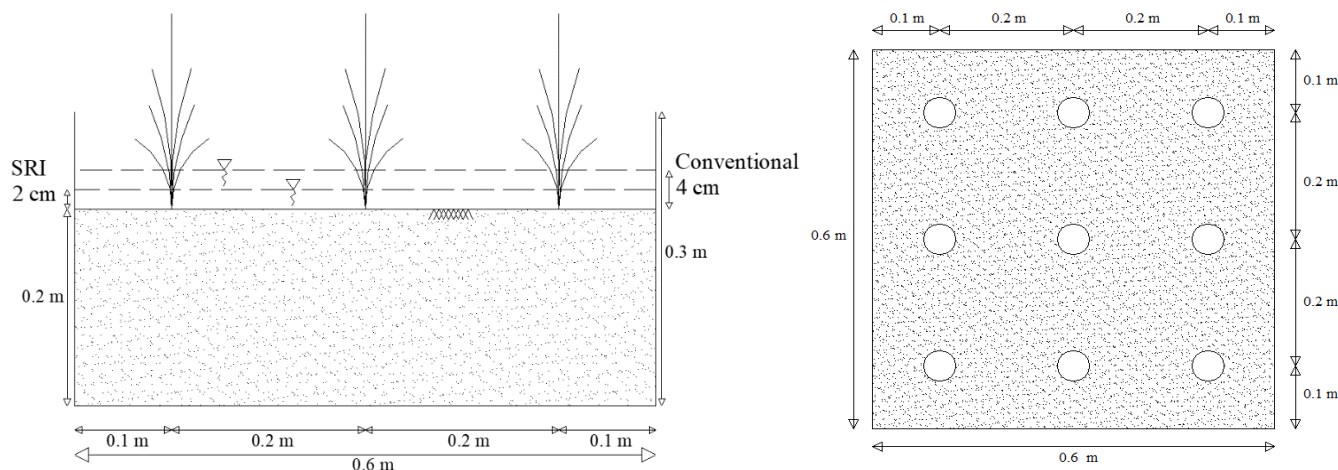


Figure 2. The research plot model from the side and top views

2.4 Research Procedure

2.4.1 Planting media preparation

The wet soil from the rice field was dried under the sunlight for 2 days to determine its dry weight after which the plots were prepared. Soil and organic fertilizer were weighed and mixed in accordance with the designed treatments. The planting media were inserted into the experimental field container at a height of +20 cm and water was provided until they become saturated.

2.4.2 Seed preparation

The first step was to select the rice seed with high quality. The process involved adding the seed into a container with saltwater and drowned seeds were categorized as high-quality while floating ones have poor quality. The selected seeds were cleaned with clean water and planted in a storage container containing 3 cm cocopeat or coconut fibers mixture to facilitate the removal of seedlings during transplanting. The seeding was conducted for 10 to 14 days after seeding (DAS).

2.4.3 Planting

Seedlings with 14 DAS were transferred to the experimental plots. The young seeds were planted to ensure they have more and earlier rice tillers, accelerate the harvest age and extend their age during the vegetative phase due to its influence on the number of rice tillers and quality

of rice grain. The best planting distance of 20 cm x 20 cm was maintained and four seeds were inserted into one planting hole to avoid the problem of dead seed. The seeds were not planted too deep to ensure the free growth of roots.

2.4.4 Irrigation water supply

1. Conventional Method

Water supply for Kon Con samples at Kon 20% and Kon 40% involved using the conventional method to mix chemical and organic materials. The water was supplied continuously to flood the soil at a depth of 4 cm during the growing process. Meanwhile, the drying phase started when the rice started turning yellow.

2. SRI Method

The SRI method includes samples SRI 20% and SRI 40% designed by adding 20% and 40% organic material and irrigated up to 2 cm height. Some of the water experienced evapotranspiration and to ensure the soil was saturated, water was repeatedly added up to ensure it meets the 2 cm height mark up to the end of the planting period.

2.4.5 Maintenance

This involved cleaning the wild plants growing around the rice plantation and by spraying pesticides.

2.4.6 Evapotranspiration measurement and consumptive water needs

The evapotranspiration was measured by reading the ruler installed on every side of the area while the consumptive water was by weighing the irrigation water to be supplied into the experimental field in relation to the depth of the treatment. The values were recorded every morning at about 08.00 a.m. up to the harvest period after which they were subjected to further analysis.

2.4.7 Monitoring of growth

The crop performance was observed every two weeks to understand the rice development process. This involved measuring the plant height, calculating the number of rice tillers, number and weight of grain seed after harvest as well as the plant weight during the harvest.

2.4.8 Harvesting

Preparation was made for harvest after 110 DAP. During this period, the rice was becoming yellow, bent, and the leaves have started withering.

2.5 Data Analysis

2.5.1 Water balance

This the balance between the inflow and outflow of water in a particular area during a specific period to determine surplus and deficit. However, for this research, percolation was 0 because it was not included in the treatment. Water balance is, therefore, calculated using the following Equation (1).

$$\Delta S = I - (ETc + P) \quad (1)$$

Where, ΔS is the storage (mm/day), I is inflow (mm/day), ETc is evapotranspiration (mm/day), and P is percolation (mm/day).

2.5.2 Water productivity

This is utilized in arranging water resources to achieve an optimum result. Efficient water usage is needed to improve water productivity and this

concept is applied to plant production by using less water through the irrigation system. Water productivity is, therefore, calculated using Equation (2).

$$\text{Water productivity} = \frac{\text{Result of Dry Grain Production (kg)}}{\text{Water Supply (m}^3\text{)}} \quad (2)$$

2.5.3 Water-saving ratio

This involves implementing efficient water usage measures and obtaining the same benefit with less water management. Moreover, water-saving irrigation encourages measuring the quality of every method based on the quantity of water supply they can save in the soil composition. The Water-Saving Ratio (WSR) can be calculated using the following Equation (3).

$$\text{WSR (\%)} = \frac{(\text{Conventional Productivity} - \text{SRI Productivity})}{\text{Conventional Productivity}} \times 100 \quad (3)$$

2.5.4 Statistics test

ANOVA involves the statistical assessment of average mean among different groups such as the treatments used in this research. This analysis method is beneficial due to its ability to evaluate differences in more than two groups. It also examines the existence of mean differences among groups in the hypothesis of the research. The results produced using ANOVA is denoted by F-Test value and further compared with the F-critical value. However, a bigger F-test indicates H_1 is accepted while H_0 is rejected and this means there is a significant average mean in all groups.

The Least Significant Difference (LSD) is the further test usually conducted to assess the difference between the average of the simplest and the most commonly used treatment. Meanwhile, any difference bigger than the LSD is considered a significant result and this is calculated using the following Equation (4).

$$\text{LSD}_{A,B} = t_{\frac{0,05}{2-DFW}} \sqrt{MSW \times \left(\frac{1}{n_A} + \frac{1}{n_B} \right)} \quad (4)$$

Where t is the critical value from the t-distribution table, DFW is degrees of freedom

within, *MSW* is the mean square obtained from ANOVA test, and *n* is the number of scores used in calculating the means.

3 RESULTS AND DISCUSSION

3.1 Soil Characteristics

Table 2 shows the lab test results for the Gemolong soil structure and it was recorded to have 18% sand, 40% dust, and 42% clay. This was further plotted into a three-soil classification triangle as shown in Figure 3 and the rice field was classified as clay characterized by grayish-black color, difficulty in absorbing water, and ability to be ground into fine dust in dry condition. Moreover, the lab test using BPTP’s Walkly and Black method also showed there was 1.43% organic-C material in the soil. This is the number of organic substances serving as the source of carbon particles in the soil (Surya and Elsa., 2013). The value obtained shows the Gemolong rice field has low content since it is less than 2%. This is in line with the findings of Las and Setyorini (2010) that approximately 73% of Indonesian farmland contains less than 2% organic-C material. This was associated with high temperatures and a fast decomposition rate.

The result for bulk density, porosity, and available water capacity is presented in Table 3. The most significant bulk density, 1.23 gr/cc, was found in Kon Con while Kon 20% had 1.01 gr/cc, SRI 20% had 1.13 gr/cc, Kon 40% had 1.12 gr/cc, and SRI

40% had 1.09 gr/cc. This means the addition of organic material has the ability to reduce bulk density.

Table 3 also shows the lowest porosity of 42.46% was found in Kon Con. Meanwhile, the soil with the organic matter was discovered to have caused more porosity compared to those with chemicals. A higher organic application rate led to greater soil porosity. Moreover, water-saving irrigation also had greater value compared to the conventional method. The available water capacity is strongly related to porosity as shown in Table 3. The pF 4.2 - pF 2.54 is a water-binding pore with diameters between 0.2 and 8.6 microns (Hardjowigeno, 1992). The results showed the soil with organic materials such as Kon 20%, Kon 40%, SRI 20%, and SRI 40% produced greater available water capacity than soils without it.

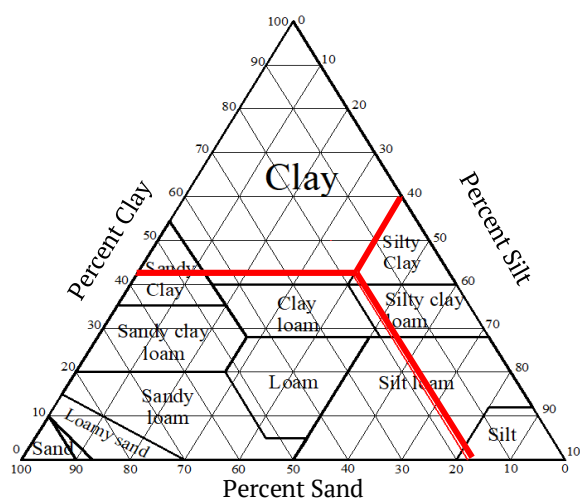


Figure 3. The connection between soil classification triangles and lab test result

Table 2. Sample treatment

No	Test Parameter	Unit	Soil TH. 19. 1150	Method
1	Texture			Hydrometer
	Sand	%	18	
	Silt	%	40	
	Clay	%	42	
2	Organic-C	%	1.43	Walkly & Black IK. 5.4.d

Table 3. Lab test result fort bulk density, porosity, and available water capacity

Number		Bulk density (g/cc)	Porosity (%)	Available water capacity (%)
No	Sample			
1	Kon Con	1.23	42.46	12.09
2	Kon 20%	1.01	45.95	14.63
3	Kon 40%	1.12	51.68	15.82
4	SRI 20%	1.13	48.32	15.15
5	SRI 40%	1.09	55.75	15.69

3.2 Rice Growth

The growth was affected differently by the treatments. Figure 4 shows rice at 22 DAP and the best seed was selected among the 4 seeds. At 36 DAP, the rice was in the vegetative phase and this means there was rapid growth as shown in Figure 5 and Kon Con, Kon 20%, and SRI 20% were observed to have yielded more and had greener tillers. Moreover, Figure 6 shows that, at 64 DAP, rice was in the generative phase and this means it started draining panicles and flowering while Figure 7 shows the rice was ready for harvest at 106 DAP. Green panicles were, however, still found on Kon 40% and SRI 40% and this means they have a slower generative phase compared to the others.

3.2.1 Rice height

The measurement of the average height of the rice plant during the growing period presented in Figure 8 was completed at 84 DAP because, at this age, the rice has stopped growing. A significant growth was recorded during the vegetative phase, 0 to 42 DAP and while there was no significant difference ($\alpha=0.05$) at 0 to 70 DAP, variations were observed at 84 DAP. The highest value of 110cm was recorded for Kon 40% while the lowest, 102.3cm, was with SRI 40%. Meanwhile, ANOVA

produced an F-test $4.52 > F$ critical 3.48 indicating significant differences. Furthermore, the LSD value obtained was 5.49 ($\alpha=0.05$) and any difference between the two treatments greater than this value was categorized as significant.

3.2.2 Rice tillers

Figure 9 shows the average rice tillers laid between 22–67 DAP and the conventional treatment with chemical substance was observed to have produced the highest value of 23 at 67 DAP while the smallest, 19, was recorded at conventional method with 40% rice straw compost.

The added organic material produced a significant effect at 22 and 36 DAPs and SRI 20% was found to have the highest value, 7 at 22 DAP and 13 at 36 DAP. A significant difference was identified by ANOVA between the DAPs as observed from F-test $5.72 > F$ -critical 2.61 for 22 DAP and F-test $7.27 > F$ -critical 2.61 for 36 DAP. Further application of LSD showed SRI 20% is significantly different from Kon Con, Kon 20%, and SRI 40%. Meanwhile, SRI 20% had the highest developing rate in the early vegetative phase.

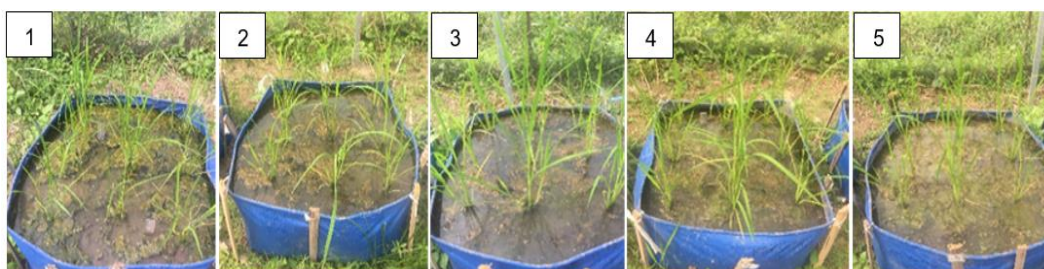


Figure 4. Rice plant at 22 days after planting: (1) Kon Con, (2) Kon 20%, (3) Kon 40%, (4) SRI 20%, (5) SRI 40%



Figure 5. Rice plant at 36 days after planting: (1) Kon Con, (2) Kon 20%, (3) Kon 40%, (4) SRI 20%, (5) SRI 40%

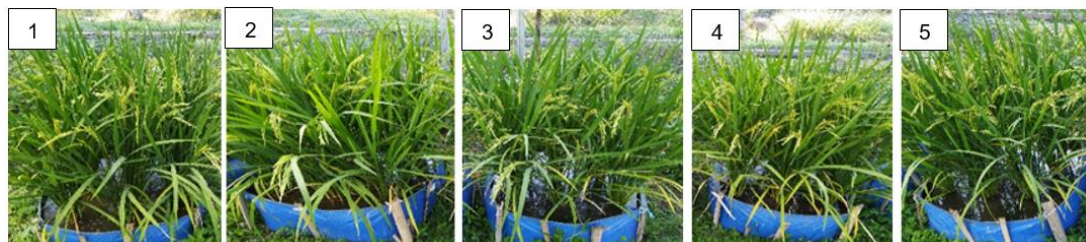


Figure 6. Rice plant at 64 days after planting: (1) Kon Con, (2) Kon 20%, (3) Kon 40%, (4) SRI 20%, (5) SRI 40%

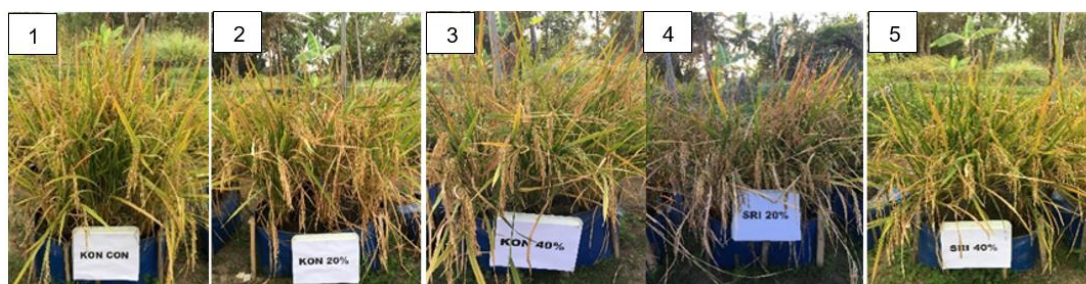


Figure 7. Rice plant at 106 days after planting: (1) Kon Con, (2) Kon 20%, (3) Kon 40%, (4) SRI 20%, (5) SRI 40%

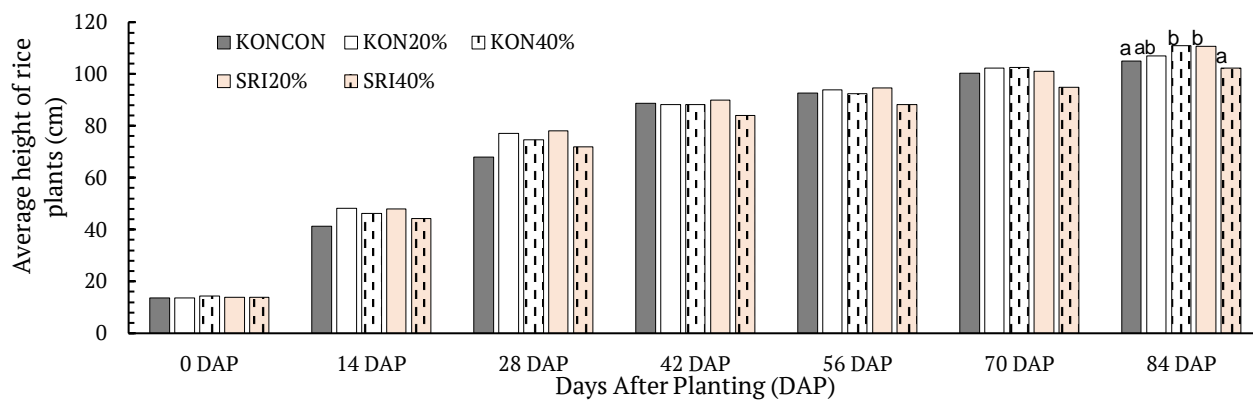


Figure 8. The average height of the rice plant every 14 days. Different letters show significant differences ($\alpha=0.05$)

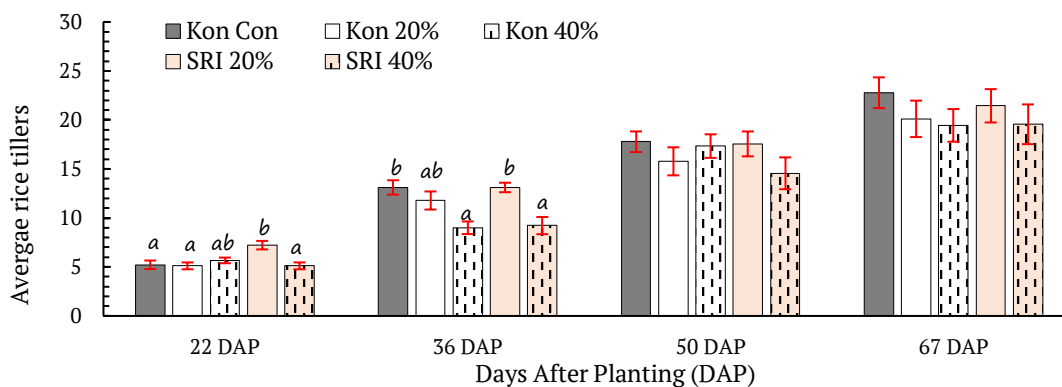


Figure 9. Average rice tillers. Different letters show significant differences ($\alpha=0.05$)

3.3 Crop Production

3.3.1 Crop weight

The average crop weight after harvesting is shown in Figure 10 and the conventional treatment with chemical substance was found to have produced the highest, 228.89 gr, while the SRI treatment with 20% organic material had the smallest, 166.44 gr because the rice has become yellow during the harvesting period compared to other treatments which were green.

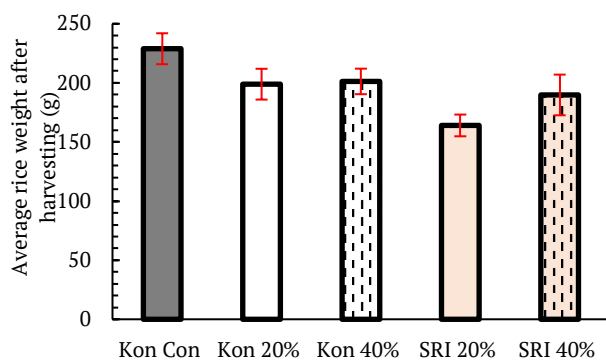


Figure 10. Average rice crop weight after harvesting

3.3.2 Rice yield

The average rice yield is displayed in Figure 11 based on the grain gross weight which is the weight consisting of both failed and filled grains. The results showed the conventional method added with chemical substance had the highest value of 52.67 gr. Moreover, another parameter is the weight of wet grain which is the total weight of undried filled grains without failed ones. The conventional method with 20% organic material produced the highest with 47.22 gr. Furthermore, the weight of grain dried in the sun for 1 day was also measured and the conventional method with 40% organic material produced the highest value at 42.78 gr while SRI with 20% organic material

had 38.22 gr, and conventional irrigation with chemicals fertilizer had 39.56 gr. ANOVA showed there were no significant differences in these average values.

3.3.3 Irrigation water supply

Figure 12 shows the graphics of cumulative irrigation water supply and the highest, 305.1 liters, was found in the conventional method with chemical substances while the smallest, 223.47 liters, was observed with the SRI method with 40% organic material. Moreover, adding 20% and 40% rice straw to soil under conventional irrigation has the ability to save irrigation water by 5% and 13%, respectively. Meanwhile, the SRI method with the addition of 20% and 40% organic material saved 19% and 27% water respectively.

3.3.4 Consumptive use of water

The average rice evapotranspiration measurement during vegetative, generative, and ripening phases is displayed in Table 4. The rate was observed to be increasing as the plant was growing until it approached the maximum vegetative and generative phase where it started declining due to seed maturation.

Figure 13 shows the cumulative evapotranspiration in all treatments and the rate was found to have reduced with rice straw. The SRI 40% had the smallest consumptive water use and total evapotranspiration at 4.29 mm/day and 468 mm respectively. Meanwhile, ANOVA showed there were no significant differences in the evapotranspiration rate.

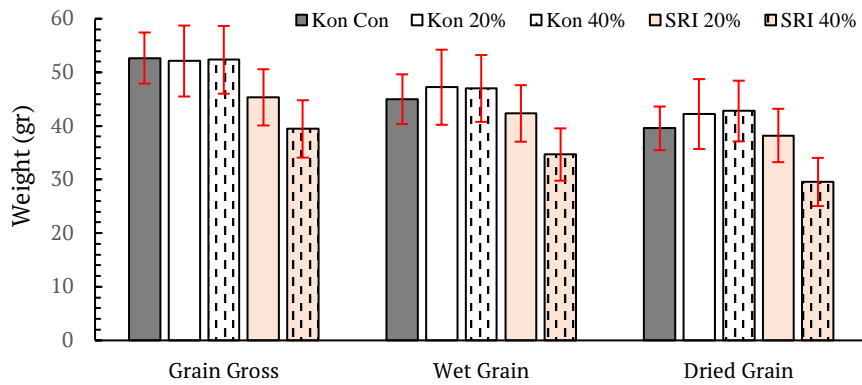


Figure 11. The average yield of harvest result

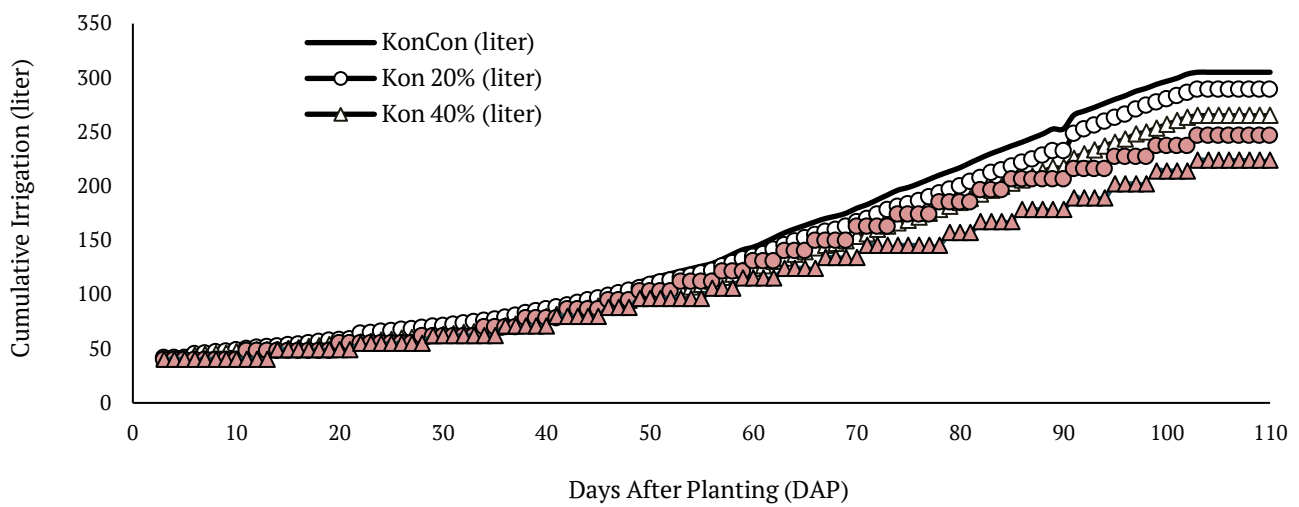


Figure 12. The graphics of cumulative irrigation water supply

Table 4. Average evapotranspiration of rice plant

Sample	Average evapotranspiration of rice plant (mm/day)			Total ETC (mm)
	Vegetative phase	Generative phase	Ripening phase	
Kon Con	3.0	7.4	6.3	560.5
Kon 20%	2.8	6.6	5.8	523.0
Kon 40%	2.3	6.1	5.2	477.5
SRI 20%	3.1	7.4	6.1	515.0
SRI 40%	2.6	6.1	5.3	468.0

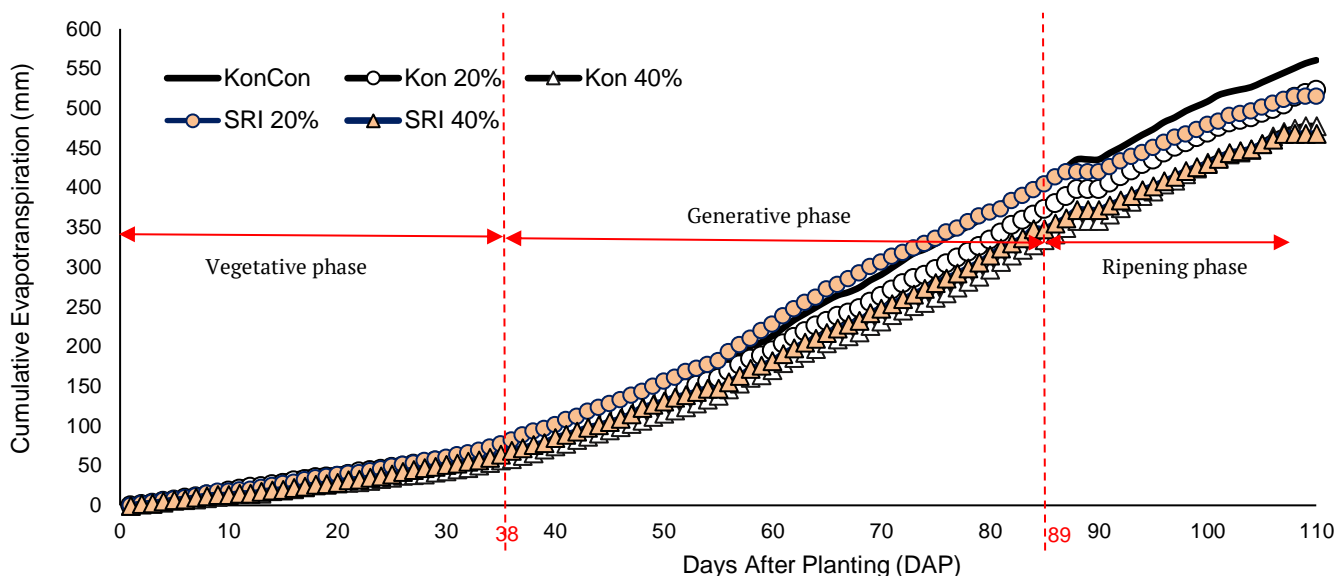


Figure 13. Cumulative Evapotranspiration

3.3.5 Water productivity

The results for Water Productivity are displayed in Figure 14 and Kon Con had the lowest value with 1.17 kg/m³ while Kon 40% had the highest with 1.45 kg/m³. SRIs had higher values compared to Kon Con as evident in 1.4 kg/m³ recorded for 20% and 1.19 kg/m³ for 40%. Meanwhile, ANOVA showed there were no real differences in the average water productivity.

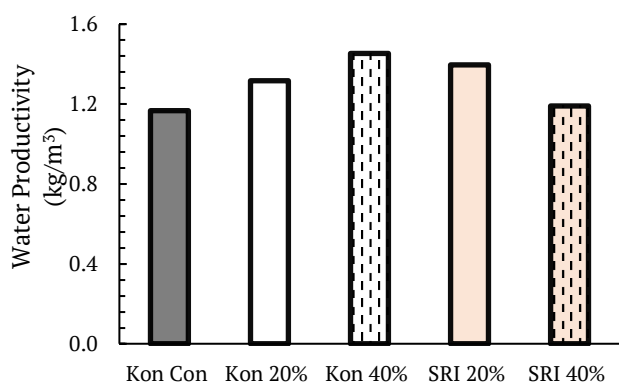


Figure 14. Water Productivity

3.3.6 Discussion

Adding organic matter loosens the soil texture and this reduces the bulk density compared to those without it (Hardjowigeno, 1992). Table 3 shows bulk density was reduced by 18% in the Kon 20% and 12% in the SRI 40% treatment. Moreover,

it has been reported that organic matter has a real effect on increasing soil porosity (Mowidu, 2001). In line with this assertion, the results showed 20% organic matter increased porosity by 12% while 40% addition yielded 24%. Organic matters have also been found to be able to increase the binding power of groundwater and enhance the quantity of water available for plant needs (Jumin, 2002). This was confirmed by this study as evident in the 20% increase in available water capacity by SRI 20% and 24% by SRI 40% treatment.

The use of the conventional method with organic matter has the ability to increase rice plant height when compared to chemical additions (Rauf et al., 2000). This study showed Kon 40% treatment increased rice height by 5% compare to control treatment. SRI 20% also increased the growth but SRI 40% were observed to have reduced the height. These results are consistent with Subekti and Mawardi's (2015) findings that conventional irrigation methods provide better growth than SRIs. Moreover, SRI 20% produced the same rice tillers with Kon Con while SRI 40% reduced the growth due to the fact that the percentage of organic matter applied exceeded the optimum required for the growth and development of rice (Arianta, 2016).

The land productivity with Kon 40% produced the highest yield of 10.69 tons/ha while SRI 40% had the lowest with 7.39 tons/ha and Kon Con had 9.89 tons/ha. This means the organic matter has a better ability to increase yields and this in line with Arianta's (2016) findings. Meanwhile, both SRIs had lower values compared to the control treatment. This means water-saving irrigation has the ability to reduce crop yields due to the use of sub-standard water that does not meet the needs of rice growth. This is in accordance with the results of Syam and Agriculture Observers (2018) that the application of conventional cultivation with chemicals fertilizer had higher grain production, 7.91 tons/ha, compared to SRI with organic matter which was 6.99 tons/ha. The research by Rahmadani (2017) made use of water-saving irrigation Mid-Season Drainage (MSD) method with the addition of 40% organic matter had land production at 4 tons/ha which is lower than conventional methods with same organic matter content which was 4.3 tons/ha.

The use of water-saving irrigation with organic matter saved water by 19% in the SRI 20% treatment and 27% in the SRI 40%. This is in line with Puteriana's (2016) findings that the SRI method in rice cultivation uses water more efficiently compared to conventional methods due to organic matter's ability to hold water. Moreover, the application of organic material has been reported to have the ability to reduce evapotranspiration rate in the soil (Intara et al., 2011). This study showed organic matter inclusion was able to reduce this rate by 8% at 20% and 16% at 40%.

The conventional method with 40% organic matter was also able to increase water productivity by up to 19%. This means it can be applied in a situation where there is water, however, in water-scarce conditions, it is not recommended for use. Moreover, the water-saving method with 20% and 40% organic matter increased water productivity by 16.5% and 2% respectively. These are consistent with Arianta's

(2016) findings that SRI 20% and 40% produced higher water productivity compared to the conventional method. They are also in line with Subari et al.'s (2012) research which showed SRI rice cultivation with organic matter was able to increase water productivity. Therefore, it is possible to use water-saving irrigation with 20% organic matter as an alternative rice cultivation method in the Gemolong area due to the limited water availability.

CONCLUSION

The addition of organic matter has the ability to reduce bulk density, increase soil porosity, and plant water availability. However, the percentage was observed to affect the growth such that values exceeding the required standard can reduce the growth. The application of rice straw to soil at 20% and 40% was able to increase water productivity by 15% and 19% compared to the control treatment while conventional method with 40% organic matter increased yields. However, the conventional methods require a lot of water for irrigation and this means they are not suitable for an area with water scarcity. Moreover, the use of 20% rice straw in water-saving irrigation was able to save water up to 19% and increase water productivity by 16.5% compared to the control treatment. However, applying 40% rice straw in the same condition reduced water productivity by 2% but saved up to 27% water. Therefore, limited water availability condition, SRI with 20% organic material is recommended as an alternative rice cultivation method for Gemolong farmers. It should, however, be effectively monitored because it has the risk of reducing yields.

DISCLAIMER

The authors declare no conflict of interest.

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REFERENCES

- Arianta, R., 2016. *Kajian Irigasi Hemat Air Metode System Of Rice Intensification (SRI) Pada Tanah Sawah Berbahan Organik*. Yogyakarta: Universitas Gadjah Mada.
- Van der Gun, J. and Lipponen, A., 2010. Reconciling groundwater storage depletion due to pumping with sustainability. *Sustainability*, 2(11), pp.3418–3435.
- Hardjowigeno, 1992. *Ilmu Tanah. PT. Mediatama Sarana Pratama*. Jakarta.
- Intara, Y.I., Sapei, A., Sembiring, N. and Djoefrie, M.H.B., 2011. Pengaruh pemberian bahan organik pada tanah liat dan lempung berliat terhadap kemampuan mengikat air. *Jurnal Ilmu Pertanian Indonesia*, 16(2), pp.130–135.
- Jumin, H.B., 2002. *Agroekologi. Raja Grafindo*. Jakarta.
- Las, I. and Setyorini, D., 2010. Kondisi lahan, teknologi, arah dan pengembangan pupuk majemuk NPK dan pupuk organik. In: *Seminar Nasional Peranan Pupuk NPK dan Organik dalam Meningkatkan Produksi dan Swasembada Beras Berkelanjutan*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Bogor. p.14.
- Mowidu, I., 2001. *Pengaruh bahan organik dan lempung terhadap agregasi dan agihan ukuran pori pada psamment*. Universitas Gadjah Mada.
- Nurrochmad, F., 2009. Kajian Pola-Hemat Pemberian Air Irigasi. In: *Civil Engineering Forum Teknik Sipil*. pp.517–529.
- Pranata, M., 2018. *Pengaruh Pemberian Pupuk Kompos Jerami Padi Terhadap Pertumbuhan Dan hasil Padi (oryza Sativa L.) Pada Kondisi Salin*. Yogyakarta: Universitas Gadjah Mada.
- Puteriana, S.A., 2016. *Kajian Sistem Pemberian Air Irigasi Metode Konvensional Dan Metode SRI (System Of Rice Intensificatio) Pada Daerah Irigasi MPakis Kecamatan Pakis Kabupaten Malang*. Malang: Universitas Brawijaya.
- Rahmadani, S., 2017. *Pengaruh Air Pada Tanah Sawah Berbahan Organik Terhadap Produktivitas Air*. Yogyakarta: Universitas Gadjah Mada.
- Rina, M., 2015. *Pengaruh Bahan Organik Terhadap Kemampuan Tanah Sawah Mengikat Air*. Yogyakarta: Universitas Gadjah Mada.
- Roseline, H., 2012. *Kajian Pemanfaatan Irigasi Air Tanah Pada Sawah Tadah Hujan Tanaman Padi Metode SRI DI Desa Girimukti Kabupaten Bandung Barat, Provinsi Jawa Barat*. Bandung: Institut Teknologi Bandung.
- Savci, S., 2012. An agricultural pollutant: chemical fertilizer. *International Journal of Environmental Science and Development*, 3(1), p.73.
- Subari, S., Joubert, M.D., Sofiyuddin, H.A. and Triyono, J., 2012. Pengaruh Perlakuan Pemberian Air Irigasi pada Budidaya SRI, PTT dan Konvensional terhadap Produktivitas Air. *Jurnal Irigasi*, 7(1), pp.28–42.
- Subekti, K. and Mawardi, I.M., 2015. *Prediksi Pertumbuhan Tanaman Padi (Oryza sativa) dengan Metode Irigasi Hemat Air (SRI) pada Skala Pot Tunggul*.
- Surya, Elsa and Riza, 2013. Pengaruh Pengomposan Terhadap Rasio O C/N Kotoran Ayam dan Kadar Hara Tersedia Serta Kapasitas Tukar Kation Tanah (Composting Effect Of Chiken Manure Towards C/N Ratio And Available NPK Nutrient And Soil Cation Exchange Capacity). *UNESA Journal of Chemistry*, 2(1).
- Syam, M. and Pertanian, P., 2018. Kontroversi system of rice intensification (SRI) di Indonesia.

Tularam, G.A. and Krishna, M., 2009. Long Term Consequences Of Groundwater Pumping In Australia : A Review Of Impact Around The Globe. *Journal of Applied Sciences in Environmental Sanitation*, 4(2).

Watanabe, T., Man, L.H., Vien, D.M., Khang, V.T., Ha, N.N., Linh, T.B. and Ito, O., 2009. Effects of continuous rice straw compost application on rice yield and soil properties in the Mekong Delta. *Soil science and plant nutrition*, 55(6), pp.754–763.