SRI (Rice Intensification System) water management of rice productivity

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Abstract. Rice crop production in the field is influenced by water availability, nutrients, and rice seedlings. The application of the SRI (System of Rice Intensification) method is a method of rice cultivation that is water-efficient and can provide optimal rice crop yields. Various irrigation systems have been applied to regulate water in rice plants in SRI cultivation with varying yields. It shows that water management in the SRI method determines the production yield. The purpose of this study was to assess water management in SRI rice cultivation with varying availability of water and nutrients (the size of the growing media volume varies). The method used polynomial regression statistics on high variables, and the number of tillers was also descriptive methods on other parameters. The observations showed that irrigation management and media size affected production yields on SRI method of rice cultivation.

1. Introduction

Food needs are increasing in line with the increasing population in Indonesia. Increased rice production also has an impact on the growing use of water because rice is one of the plants that require a lot of water. According to Fuadi et al. [1], activities for success in rice production influenced by water availability. Water availability in Indonesia is highly influenced by seasons because, in Indonesia, it is an area with a tropical climate. Water is only available enough for rice cultivation only in the rainy season, while in the dry season, the water is not enough for rice cultivation (rainwater approaches zero per month). While the average water requirement for rice cultivation is 2000 l/kg, quite a lot of water needed for rice cultivation. According to Djaenuddin et al. [2] To carrying capacity of the land, the diversity of pedo-agro-climate regions in Indonesia will determine the type of agricultural commodity suitable for cultivation in that location. Global warming in which the rainfall patterns changed in Indonesia getting worse the problem of water availability for rice cultivation activities. Changes in rainfall patterns will affect the success of agricultural sector production, especially rice production. Water management technology will support the success of rice cultivation in increasing rice production in Indonesia. According to Surmaini et al. [3], to reduce the impact of the season on aquaculture activities, it is necessary to adjust planting time, superior varieties that are resistant to drought, submergence, salinity, and appropriate water management technology. According to Chapagain et al. [4], SRI method is one of paddy cultivation to increase water productivity, and it does not impact total production of paddy. Otherwise, according to the results of Chapagain and Uphoff [5] and Chapagain and Yamaji [6], water management activities will affect the yield of rice production and water
production [7], it will also affect fertilizer efficiency [8]. The purpose of this study was to determine the effect of water management applications, varieties on the production of SRI methods of rice plants.

2. Methods

This research was conducted in the Wageningen Laboratory of the Bogor Agricultural University, West Java, from August to December 2018.

2.1. Tools and materials

The tools used are buoy faucet, control tub, electric hand drill, emitter, hacksaw, PVC pipe cutter grinder, reservoir (3-meter height), stop valve. Materials used are PVC in PVC pipe, 3 mm plastic hose, seeds used (variety of Batang Piaman and Inpari 42), cow manure, soil growing media, Urea and NPK fertilizer, insecticide, pesticides.

2.2. Methodology

The method used in this study were the polynomial and the factorial randomized design method. The response of rice plants (plant height, number of tillers) was regressed using the polynomial regression method. The factorial randomized design method with 2 factors (Variety and system and media size) each element consists of 2 levels (Batang Piaman (A1) and Inpari 42 (A2)) and three levels (PSB = subsurface Irrigation (subsurface irrigation) water management according to the size of the planting media volume of 27555.4 cm³), (PSI = drip irrigation system, soil media volume size = 20759 cm³, (PSI2 = drip irrigation, soil media volume size = 6965.7 cm³). Each treatment factor was repeated five times with the hypothesis, Ho; there was no significant effect between the irrigation system + soil media volume on production variables (number of tillers), plant height, dried grain yields (potential rice unhusked grain yields) on SRI rice plants. This research used a pot with an irrigation system that was carried out in open land, which was influenced by climate by rainfall. Seeding starts from 1 August 2018, the method used is the SRI method, transplanting is carried out at ten days nursery age. In the SRI method the water is not left inundated (subsurface irrigation, the water depth set at 40 days after planting after planting is set to 0 cm (the same as the surface of the soil media), while the drip method is to provide water with a field capacity of 3 mm/hour starting with the rice seedlings. The buoy (a semi-automatic control) controlled the drip irrigation system arrangements (flowing water in the event of evaporation in the control basin). Observation of rice production (height, number of tillers) is analyzed using a polynomial regression method to determine the effect of testing on the growth of rice plants, especially in the vegetative phase, and other parameters discussed with descriptive purposes.

3. Results

3.1. Plant Height and Tiller Numbers

Figure 1 shows that the growth of the paddy (the height and the tiller numbers) effected the water management method (irrigation system) than paddy variety. Respond paddy has caused water management methods than type (variety of paddy). It is consistent with the statement from Fuadi, [1] that the water management system greatly influences rice production, especially in the vegetative phase (height increase and tillers in rice cultivation).

3.1.1. Regression analysis

The coefficients of the polynomial for height and tillers number respond of treatment (paddy variety and irrigation system treatment) showed in Table 1.
Figure 1. Plant Height and Tiller Numbers for Planting in subsurface irrigation and volume for Batang Piaman with water management according to the size of the planting media volume of 27555.4 cm³ (a), Planting of subsurface irrigation system with soil media volume size = 27555.4 cm³ for Inpari variety (b), planting Batang Piaman variety of paddy at drip irrigation method with volume size 20759 cm³ (c), planting paddy Batang piaman variety in drip irrigation method and (d), planting Inpari variety of paddy and drip irrigation with soil media volume size = 6965.7 cm³ (e), and planting Inpari variety of paddy and volume soil at subsurface irrigation with soil media volume size = 6965.7 cm³ (f)
All of the variables showed that all variables correlate because R² value has ranged from 0.92052 to 0.99478. The height parameter indicates that the highest R² value is the PSB-V1 treatment (subsurface irrigation system treatment with rice straw pithy varieties), and the lowest R² was in the PDI-V2 treatment (treatment of drip irrigation systems with Inpari 42 rice varieties). It showed that the irrigation management system factors and types of rice plants could influence the growth of rice plants (height increase and tillers number of rice during rice plant growth from 0 to 80 days after planting). The height of rice plants in the variety of Piaman stem is 95 cm [9], while the results of the study obtained an average of height of rice varieties Batang Piaman are 133.6 cm (it used water management in subsurface irrigation systems) and 114.43 cm (in water management in drip irrigation systems). Batang piaman variety rice plants grow better in the vegetative phase (plant height and the number of tillers) compared to Inpari varieties 42. The height growth and addition of the number of rice tillers in the Piaman type various experiment were on the subsurface irrigation system (PSB). The addition of paddy tillers number showed that the water needs for paddy cultivation met when vegetative growth in the subsurface irrigation when compared to the drip irrigation system. The increasing number of rice tillers can decrease if the water demand reduced from the water content of the field capacity [10].

Table 1. The coefficients of the polynomial for tiller number and height respond of paddy variety and irrigation system treatment

| Treatment | a3  | a2   | a1   | a0   | R²  |
|-----------|-----|------|------|------|-----|
| PSB-V1    | 0.00061 | -0.07018 | 3.17878 | 8.70485 | 0.95742 |
| PSB-V2    | 0.00055 | -0.06676 | 3.15607 | 7.18405 | 0.93245 |
| PDI-V1    | 0.00011 | -0.01087 | 1.40506 | 8.15051 | 0.94609 |
| PDI-V2    | 0.00008 | -0.01105 | 1.50247 | 10.40576 | 0.92052 |
| PDL2-V1   | 0.00006 | -0.00721 | 1.33893 | 10.04033 | 0.93979 |
| PDL2-V2   | 0.00006 | -0.00721 | 1.33893 | 10.04033 | 0.93979 |

3.2. Factorial randomized block design results on variable plant height and rice tillers (age 81 days)

3.2.1. Variable plant height. Treatment (irrigation system and soil media size) significantly influence plant height (significance value ≤ 0.05). The amount of the significant correction model means that the model can explain the effect of the treatment considerably on the most vital variable. Variety treatment did not significantly affect plant height variables and interaction of varieties, systems, and soil media size did not significantly affect plant height. Irrigation system treatment and soil media size affect substantially plant height variables, so the test continued with Duncan's real difference test, shown in table 2 below:
Table 2. The results of Duncan’s Real Difference test showed that the irrigation system treatment and the size of the planting media were variable

| Number | Treatment | Irrigation system and volume of soil media | The height average of rice (81 days) | Significant Difference Test Results |
|--------|-----------|-------------------------------------------|------------------------------------|------------------------------------|
| 1      | PSB       | Subsurface, 27555.4 cm³                   | 129.4                             | a                                  |
| 2      | PSI       | drip, 20759 cm³                           | 114.4                             | b                                  |
| 3      | PSI2      | drip, 6966.7 cm³                          | 108.4                             | b                                  |

The test results show that the treatment of PSB gives the best growth results of plant height (age 81 days) when compared to other treatments. The treatment of irrigation systems and soil media of different sizes will give respond to product results yields of paddy crops. Treatment PSB (subsurface irrigation system and soil media size 27555.4 cm³) gave significantly different results compared to treatment PSI (drip irrigation system and soil media size 20759 cm³) and PSI2 (drip irrigation system and soil media size 6966 cm³). While the treatment PSI (drip irrigation system, soil media size 20759 cm³) and PSI2 (drip irrigation system, soil media size 6966 cm³) show that the variable yield of plant height (age 81 days) is not significantly different. Figure 1 shows the average height of rice plants at the age of 81 days, all irrigation system treatments, and soil media size on vegetative growth.

In Figure 2 shows that the highest growth of plant height is in the PSB treatment, this is due to plant height growth is essential to plant nutrition (in PSB treatment in addition to the availability of water that is quite a lot also there is a size of the volume of planting media that is larger than in PSI treatment. In treatment PSB, the soil volume size is 27555.4 cm³, while in treatment PSI, it is 20759 cm³, and in treatment, PSI2 is 6966 cm³. Reduction in the size of the planting media volume will affect the availability of utilities and water availability for plants that will affect the growth of SRI rice plants. The growth of rice plants influenced by the availability of rice plants, especially water [1, 11], and rice plant nutrition.

3.2.2. Variable rice tillers number. The results of an analysis of variance in testing irrigation system variables and the size of the volume with the number of tillers show that the test variables have a very significant effect on the addition of the tillers number. So that the test continues with the Duncan method further tests contained in the following table 3.
Table 3. Duncan further test results 5% irrigation system treatment and media capacity on the number of rice tillers

| Number | Code | Irrigation system and soil media size | tillers Number | Duncan's Real Difference Test Results 5 % |
|--------|------|-------------------------------------|----------------|------------------------------------------|
| 1      | PSI  | Drip irrigation, 20759 cm³          | 32.1           | a                                        |
| 2      | PSB  | Subsurface irrigation, 27555.4 cm³  | 23.6           | b                                        |
| 3      | PSI2 | Drip irrigation, 6966 cm³           | 17.1           | b                                        |

The results of observations of the average number of tillers in the testing of two varieties and system + media sizes, respectively, in figures 3 and 4 show different results.

![Figure 3](image3.png)  
**Figure 3.** Graph of the average number of tillers between Batang Piaman (V1) and Inpari 42 (V2) varieties

![Figure 4](image4.png)  
**Figure 4.** Number of tillers in irrigation systems and different sizes of soil media volumes (B treatment), PSB (subsurface irrigation system according to size of the soil media volume of 27555.4 cm³), PSI (drip irrigation system, soil media volume of 20759 cm³), PSI2 (drip irrigation system, soil media volume size 6965.7 cm³)

New improved varieties may not be optimal for growth with site-specific conditions where plants cultivated so that when they grew, their growth will be less than optimal [12]. Each rice variety will provide vegetative growth results following the specific characteristics of each location. The number of tillers will affect the yield in the generative phase because optimal vegetative growth will produce an optimal generative phase production, and vice versa. The results of the analysis of variance analysis provide information that treatment B (irrigation system + size of the planting media volume) will have an authentic effect. Rice plant characteristics will influence according to the different attributes in production according to genetic factors, especially in the vegetative phase [5, 11].

Vegetative phase production results (number of tillers) shows that the most optimal irrigation system is a drip irrigation system with a planting media size of 20759 cm³. At the beginning of the activities of rice cultivation was a dry condition, in August, whereas after August, especially in October, the availability of water for plants was very high at the cultivation site so that between PSB (Subsurface irrigation system and 27555.4 cm³) and PSI2 (drip irrigation system and 6965.7 cm³), the number of tillers approached the same. It supported by further tests with the Honestly Significant Difference test in treatment B that the average number of tillers of PSB treatment was not significantly different from treatment PSI and PSI2, while the average number of tillers in treatment PSI was very significantly different from treatment PSI2. Although the irrigation system used is the same as the drip irrigation
system, the availability of water in PSI2 is less when compared to PSI. The PSI treatment gives the most optimal vegetative production yield compared to other treatments. It happens because water storage in treatment PSI is more optimal for vegetative growth, especially in the production of rice seedlings in climatic conditions when cultivating rice. The most optimal irrigation system in the growth of paddy tillers is drip irrigation, while in PSI2 treatment, the size of the soil volume is smaller than PSI. The drip irrigation method (PSI and PSI2) shows that if the soil media does not hold water according to the water needs of the plant, the growth of tillers will suffer. In treatment PSB, especially in the wet month (October), there is often excessive waterlogging due to more frequent rainfall (Table 1). High rainfall causes excess water in the subsurface irrigation system, so this causes an effect on the growth of tillers. Whereas the PSI2 treatment differs from PSB only in the size of the planting media. The size of the growing media will provide different nutrient availability and holding capacity, so the number of tillers produced will be different. This shows that the irrigation system and the size of the planting media will affect the yield of the number of tillers produced in the SRI method of rice cultivation. It supports testing by Barison and Uphoff [5] that irrigation management will affect rice production. Irrigation systems used in SRI aquaculture and drip irrigation management will be more effective in fields with high rainfall conditions when compared to subsurface irrigation. The physical condition of the soil contained in the test has the same bulk density (0.63 gram/cm³) with a permeability of 3,502 cm/hour with a water holding capacity of 28.14%. The average rate of drip irrigation is 3 mm/hour so that it will provide water for plants close to the water content of the field. The condition of groundwater content in the planting media by the Van Genuchten method is in Figure 5.

![Figure 5](image_url)

**Figure 5.** Water content (water availability) in the planting media from the analysis of the physical properties of the soil in the planting media by the Van Genuchten method

The availability of water in the planting media will provide optimal conditions by the needs of cultivated rice plants. Laboratory test results showed that the water content in the field capacity was 45.4% (Figure 5). From the observation that drip irrigation with a speed of 3 mm/hour fulfills this condition when compared to the subsurface irrigation method (treatment PSB), the average planting season. Whereas in PSI2 treatment, the size of the planting medium is smaller than that of PSI with the same drip irrigation system. The condition of the availability of water and nutrients is insufficient for the growth of tillers in the PSI2 treatment when compared to the PSI treatment. The number of tillers changed, especially when the seasons change (Figure 6).
Figure 6. The addition of tillers number from 5 days to 81 days after planting in the variety and irrigation system treatment + soil media size

Figure 6 shows that the most optimal growth of tillers in the tillers number was in the PSI-V1 treatment. It shows that the best treatment for this treatment is the interaction between the drip irrigation system and the volume of the planting media = 18376.5 cm³ with the Batang Piaman variety. At the age of rice under 46 days, the number of tillers is almost the same, but at the age of the plant 58 days, the tillers number shows varying amounts. It happens because rainfall at 58 days of rice age is October (total rainfall of 411 mm), in Table 3. So the growth of rice tillers in the most optimal water management testing of 3 tests is in the drip irrigation system with the availability of water in the medium with the highest capacity of holding water and nutrients when compared with other tests. The highest yield of tillers was PSI-V1 treatment. Rice plant characteristics will influence according to the different attributes in production according to genetic factors, especially in the vegetative phase [5, 11].

Figure 7. Interaction between the treatment of rice varieties and treatment of irrigation water management and size of soil media
Figure 8. Total Rainfall from August to December 2018 (source: BMKG station in Bogor city)

Figure 7 shows the highest tillers number was the PSI-V1 treatment than other treatments. Rainfall also affects the number of tillers during the SRI rice growing period (figure 8). Water that had provided in the subsurface irrigation system will often flood so that it will affect the SRI rice tillers number. In the drip irrigation system, percolation will occur continuously, so that runoff and percolation will not cause excess water due to the speed of the water provided do not exceed the ability of the soil to store water to meet water needs for rice plants. The use of technology must take into account the suitability of the specific local location [13].

In treatment, PSI (drip irrigation system, volume soil media was 20759 cm$^3$) and PSI2 (drip irrigation system, volume soil media was 6965 cm$^3$) is significantly different because the size of the planting media PSI is larger than the planting media at PSI2. It causes the availability of water for plants to decrease. Besides, the PSI2 treatment will cause the availability of nutrients for rice plants, also getting smaller compared to the PSI treatment. It will affect the growth of rice plants, especially on vegetative growth (tillers). The most optimal growth of tillers number is Batang piaman variety (local variety) compared to Inpari 42 variety. If it is needed optimally in the number of tillers (in the production of tillers number), it will be better to use a variety of Batang piaman than Inpari 42. rice varieties will affect the growth of paddy tillers [12].

3.3. Dried grain yields (potential rice unhusked grain yields)

3.4. We find the potential paddy yields obtained from this research shown in Figure 9. Figure 9 shows the potential of unhusk rice highest is PDI-V1 (drip irrigation system with soil media volume of 20759) than the other treatments. It shows that irrigation systems affected paddy production for generative phase. Even though in vegetative stage the paddy production (yield) the highest yield for the paddy height and tillers number is (PSB-V1 (subsurface irrigation system according to size of the soil media volume of 27555.4 cm$^3$ and Batang piaman paddy variety). This shows that in the PDI-V1 test the water supplied by the irrigation system fulfills the saturated water condition until the hair dries (water condition is cut off) which is optimal when compared to other tests. this condition causes the soil media in optimal aeration conditions. this aierating condition causes the water available in the soil media. Provision of irrigation water by managing irrigation and drainage according to crop water needs per phase will provide appropriate water and oxygen circulation for plant growth [14]. Good aeration conditions and rising soil temperature conditions will increase the permeability of root cells thereby increasing nutrient absorption by plants [15].
Figure 9. Possible of unhusked rice (kg/ha/season) of each treatment B (PSB-V1 (subsurface irrigation system according to size of the soil media volume of 27555.4 cm³ and Batang piaman paddy variety), PSI (drip irrigation system, soil media volume of 20759 cm³, PSI2 (drip irrigation system, soil media volume size 6965.7 cm³)

The conclusion of this research were:
- Optimal production for tiller and height of paddy used subsurface irrigation system and Batang Piaman Variety of paddy
- Optimal grain production used drip irrigation (with the optimal volume of soil) and Inpari 42
- The availability of water would affect paddy production
- Management water would impact paddy production
- Based on this research, the suggestion for future research to optimize the production were using SRI method with subsurface Irrigation and batang piaman variety. Beside that, unhusked with SRI method could use Drip irrigation and Inpari 42 variety

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