Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2019, 6(9):62-69**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Paddy Rice Production Engineering in SRI Method with STSS, Black Silver Plastic Mulch, and Furrow Irrigation

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Abstract The SRI method has succeeded in increasing grain production but has not been maximized because the percentage of productive tillers is still low and difficulties in controlling weeds. This experiment aims to optimize the number of seedlings in a one-one planting system (STSS), the use of mulch and the furrow irrigation system in the SRI method of lowland rice cultivation. The experimental was conducted from March to July 2019 in Lubuk Alung, Padang Pariaman Regency, West Sumatera, consisting of 3 treatment factors using RPPT 3 replications. Factor I, the irrigation system as a main plot 2 levels: intermittent and flooded system. Factor II, uses mulch as a sub plot with 2 levels: without mulch and black silver plastic (PHP) mulch. Factor III, number of seedling clump^{-1}STSS as sub-sub plot with 5 levels: 1, 2, 3, 4, and 5 seedlings. The experimental results, in intermittent irrigation, the highest grain production was obtained with PHP mulch and 5 seedlings clump^{-1}, while in the flooded irrigation the grain production ha^{-1}was higher with PHP mulch and 2, 3, and 5 seedlings clump^{-1}. Overall the best production was obtained on 5 seedlings clump^{-1} using PHP mulch both intermittent and flooded irrigation. So to produce the highest grain production, weed-free and save water, recommended modification of the SRI method with the use of 5 seedlings clump^{-1} STSS, PHP mulch, and flooded or intermittent irrigation system.

Keywords intermittent, flooding, PHP mulch, STSS, tillering

Introduction

Rice as the main food source for the last 5 years, the availability continues to experience dynamics, generally still not fully secure, this is evident from the presence of rice imports by the government in 2014 reaching 1.2 million Mg [1]. National rice production cannot fully guarantee national food security, especially rice, food supplies can be threatened and must be secured with rice import reserves. This condition occurs because of the high level of rice consumption which reaches 139 kg capita^{-1} year^{-1} so that the problem of food security will always experience dynamics. Indonesia's rice production in 2014 reached 70,846,465 Mg and 75,397,000 Mg in 2015 (an increase of 6.42%), whereas in West Sumatera rice production was 2,519,020 Mg in 2014 and 2,550,609 Mg in 2015 (an increase of 1, 23%) [2]. The increase is very low and is not comparable to the needs of rice nationally. So it needs innovation by creating new cultivation techniques and developing and modifying existing cultivation techniques, for example, The System of Rice Intensification (SRI) method.

The SRI method has been able to increase the growth component and grain production, but the use of 1 clump^{-1} seedlings has not been maximized because the number of total tillers and productive tillers is still low. In addition, the use of young seedlings with 1 clump^{-1} seedlings risk of death of seedlings at the beginning of planting. For this reason, it is necessary to increase the number of seedlings clump^{-1} with a one-one planting system (STSS), which is planting 2 or more seedlings in a clump separate 7 - 10 cm apart, aims to increase the number of parent plants and main tillers and prevent early competition, so that it will produce more productive tillers clump^{-1} than the use of 1 seedling clump^{-1} [3].

Attached planting systems both in conventional systems and SRI methods can cause early competition on plants to get nutrients, water, and sunlight. The attached cropping system will produce a dense canopy structure with low sunlight interception because the saplings are formed tightly, while if the inter-plant seedlings are separated, the canopy architecture will be more effective in absorbing sunlight because the saplings are more tenuous so that sunlight interception it will be easier. The results of pot experiments using 2-3 seedlings clump^{-1} STSS can improve the performance all parameters of rice growth and yield [3]. While the use of 4 seedlings clump^{-1} STSS was able to increase the grain production of several rice varieties in the new openings paddy field compared to conventional systems [4-6]. This is in line with reports [7], seedling densities higher than 50 m^{-2} plants are a way to get high yields on aerobic plants. But with the attached cropping system an increase of up to 4 seedlings clump^{-1}in the SRI method did not increase grain yield [8].

An increase in the number of seedlings clump^{-1} STSS is expected to accelerate the emergence of tillers, because the speed at which they appear will affect the productivity level of the tillers, while the speed of tillering is related to the number of parent plants [9]. The use of 1 seedlings clump^{-1} has the potential to reduce the number of productive tillers [10]. This shows that to increase the number of productive tillers and grain yields, it is necessary to increase the number of parent plants by increasing the number of seedlings clump^{-1} STSS to prevent early competition between tillers in the clump (intera-specific). However, it is necessary to determine the optimum number of seedlings clump^{-1} with STSS for maximum results in the field. The application of the SRI method is faced with the problem of difficulties in controlling weeds because the land is not flooded. Manual weed control requires a lot of human labor and chemical control occurs difficulties because herbicides can damage rice plants and pollute the environment. The difficulty of controlling weeds in SRI method is the main problem for farmers to adopt the SRI method.

Utilization of black silver plastic (PHP) mulch can be an alternative to controlling lowland rice weeds. According to [11], the use of inorganic mulch can improve soil air conditioning, maintain water availability for plants, make efficient use of fertilizers, reduce erosion, reduce pest and plant disease, inhibit weed growth, prevent soil compaction, and increase yield per unit area. However, mulching can not be done because it still needs to be flooded. To facilitate the installation of mulch, planting paddy fields needs to be made beds with a furrow irrigation system. The furrow irrigation system can be categorized as an aerobic culture which has many advantages. Rice cultivation in a condition that is not flooded for a long time can streamline water use, and minimize labor requirements and greenhouse gas emissions [12]. The aerobic system in Brazil can increase rice and water productivity, as well as the efficiency of N use compared to flooded systems [13]. In climate regions, the grain production temperate is more than 9 Mg ha^{-1} but in the tropics, it is still below 8 Mg ha^{-1} [12]. With furrow irrigation of wide plant spacing and soil aeration, the results will be better than flooded irrigation during the vegetative growth phase [14]. The wet and dry alternation water logging technique saves water usage during the growth period in the range of 13-16% compared to the continuous irrigation technique [15]. This study aims to obtain the optimum number of seedlings clump^{-1} with STSS, testing the use of PHP mulch and supplying water to the SRI method with intermittent and flooded systems in furrow irrigation.

Materials and Methods

Experiments in this study have been carried out in the irrigated paddy fields of the farmers group, Kelompok Tani Saiyo Bersama, Korong Rimbo Panjang, Kanagarian Lubuk Alung, Padang Pariaman Regency, West Sumatera. The experiment consisted of 3 treatment factors which were placed in the Split-Split-Plot Design (SSPD) with 3 replications. The factor I, the furrow irrigation system (A) as the main plot with 2 levels: intermittent irrigation system (A1), and flooded irrigation system (A2). Factor II, use of mulch (M) as a sub plot with 2 levels: without mulch (M0) and PHP mulch (M1). Factor III, the number of seedlings clumps^{-1} STSS (B) according to [3] placed in sub-sub plot with 5 levels: there are 1 seedling clump^{-1} (B1), 2 seedlings clump^{-1} distance between seedling 7 cm (B2), 3 seedlings clump^{-1} distance between seedlings is 7 cm equilateral triangle (B3), 4 seedlings clump^{-1}with distance 7 cm in square relationship (B4), and 5 sedlings clump^{-1} with 4 seedlings clumps^{-1} are planted square relationship with spacing between seedlings 7cm and 1 seedling is planted at the midpoint (B5) (Figure 1). The soil is rought plowed and finely plowed, then made beds as high as 10 cm, 1.10 m wide and 12 m long, given fertilizer with compost of cow waste with a dose of 15 Mg ha^{-1}, NPK fertilizer (16:16:16) with a dose of 300 kg ha^{-1} and in PHP mulch the square hole size 10 cm x 10 cm is made with a distance between the edges of the hole 20 cm between rows and 15 cm between column, then in 1 bed there are 4 rows of plants (Figure 2). Cisokan variety rice seedlings are planted at 12 days after seedling (DAS) according to factor B. Watering for F1 during the vegetative phase with intermittent systems and flooding from the generative phase until the panicle maturation phase, and for F2 by flooding the furrow during the vegetative phase until the panicle maturation phase. Harvesting is done when panicles have been physiologically manually. Observations in the form of growth and yields components of rice, such as plant height, number of tillers, number of productive tillers, percentage of productive tillers, panicle length, grains number panicle^{-1}, percentage of grains pithy, grain yield weight clump^{-1}, and production grain ha^{-1}. Data observation were analyzed with ANOVA and DNMRT α.0.05 and 0.01, using SPSS 16.0.

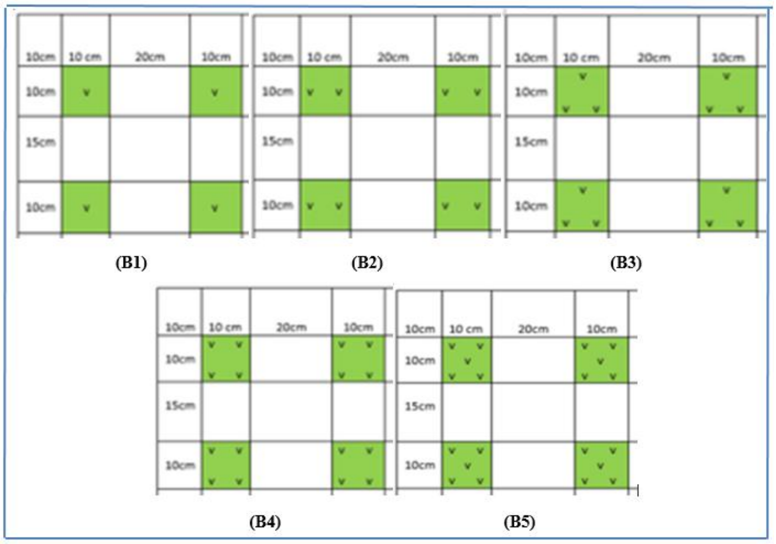

Figure 1: Schematic for planting 1 seedling (B1), 2 seedlings (B2), 3 seedlings (B3), 4 seedlings (B4), and 5 seedlings clump^{-1}(B5) with STSS

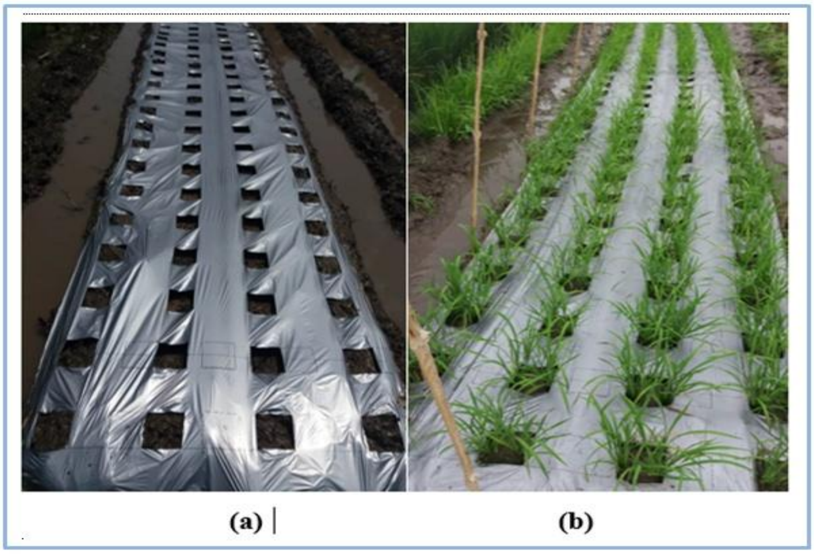

Figure 2: The form of PHP mulch pairs in beds 1.2 m wide and planting hole with equilateral quadrangle (10 cm x 10 cm), with a gap between the edges of the pit 20 cm between row and 15 cm in row, then there are 4 rows of plants. Before planting rice (a) and 2 weeks after planting (b)

Results and Discussion

Plant height, total tillers, number of productive tillers, and percentage of productive tillers

Cisokan variety of paddy plant height was not affected by the furrow irrigation system, the used of PHP mulch, and the number of seedlings clump^{-1}STSS, both single factors, and their interactions, while the total tillers were influenced by the use of mulch and the number of seedlings clump^{-1}STSS, but the number productive tillers are only affected by the number of seedlings clump^{-1} with STSS. The average height of plants obtained from 79.7 to 102.4 cm, the height of this plant is still in the range of average height according to the description of Cisokan rice varieties that is 90-100 cm. Data on the total number of tillers is presented in Table 1 and data the number of productive tillers in Table 2. Using PHP mulch can increase the number of tillers by 9.88% compared to without mulch PHP. This increase occurs because the use of mulch can suppress the growth of weeds which causes a reduction in the competitiveness of rice plants, so that it can spur the formation and development of tillers.

Table 1: Total of tillers clump^{-1}of paddy rice in SRI method using the number of seedlings clump^{-1} STSS with mulch, and furrow irrigation system.

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1}) 1	2	3	4	5
		....................tillers clump^{-1}....................				
Intermittent (A1)	M0	49.7	62.0	75.6	76.0	79.4
	M1	55.0	73.4	82.1	81.7	83.9
Flooding (A2)	M0	45.2	56.6	72.3	79.4	91.4
	M1	63.6	67.2	76.1	81.9	90.6
Average B		53.4C	64.8B	76.5A	79.8A	86.3A
Average M	M0	68.8b				
	M1	75.6a				

Numbers in the same row followed by the same uppercase letters do not differ according to DNMRT α 0.01, and numbers in the same column followed by the same lowercase letters do not differ according to DNMRT α 0.05.

Further increasing the number of seedlings clump^{-1} STSS was able to increase the total number of tillers (Table 1) and productive tillers (Table 2), the use of 3-5 seedlings clump^{-1}STSS increased the total number of tillers 43.37 - 61.73% compared to 1-2 seedlings clump^{-1}. While the increase in the number of productive tillers reached 11.29-27.02% in 3-5 seedlings compared to 1-2 seedlings clump^{-1}. Increasing the number of seedlings clump^{-1}with STSS can increase the total tillers due to a significant increase in the number of parent plants and with the STSS method the plants will avoid early competition due to the availability of sufficient space for the parent plant to develop. In addition, an increase in the number of parent plants will produce more main tillers, then the clump of plants will be dominated by main plants and main tillers and supported by the availability of sufficiently wide space, this condition will spur the formation of productive tillers due to competition plants get nutrients and relative sunlight low, so that photosynthetic activity can be maximized [3, 16-17].

Table 2: Number of productive tillers clump^{-1} of paddy rice in SRI method using the number of seedlings clump^{-1} STSS, mulch, and furrow irrigation system

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1}) 1	2	3	4	5
		.... tillers clump^{-1}....................				
Intermittent (A1)	M0	23.3	25.6	27.0	28.6	31.9
	M1	28.6	27.4	29.3	29.8	33.8
Flooding (A2)	M0	23.2	25.9	24.3	31.1	31.3
	M1	23.9	24.8	29.8	29.4	28.8
Average B		24.8C	25.9BC	27.6ABC	29.7AB	31.5A

The numbers in the same row followed by the same uppercase letters do not differ according to DNMRT α 0.01

Percentage of productive tillers is influenced by the interaction of furrow irrigation factors, mulch application, and the use of the number of seedlings clump^{-1}. In general, an increase in the number of seedlings clump^{-1} decreased the percentage of productive tillers both in the intermittent system and flooding systems in furrow irrigation with mulch or without mulch PHP (Table 3).

Table 3: Percentage of productive tillers of paddy rice in SRI method using the number of seedlings clump^{-1} STSS, mulch, and furrow irrigation systems

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1})				
		1	2	3	4	5
		........................%........................				
Intermittent (A1)	M0	47.2Aa	42.6ABa	35.7Ba	37.6Ba	40.3Aa
	M1	51.9Aa	37.8Bab	35.9Ba	36.4Ba	40.3Ba
Flooding (A2)	M0	51.3Aa	45.7ABa	33.9Ca	39.2BCa	34.3Cab
	M1	37.6Ab	36.8Ab	39.5Aa	35.8Aa	31.8Ab

Numbers in the same row followed by the same uppercase letters and numbers in the same column followed by the same lowercase letters do not differ according to DNMRT α 0.01

In intermittent systems, without mulch, the percentage of productive tillers not patterned with differences in the number of seedlings clump^{-1}, the highest percentage of tillers was 1, 2, 4, and 5 seedlings clump^{-1}, while in intermittent the highest percentage was obtained in 1 seedling clump^{-1}. In the flooded irrigation system without the mulch obtained the highest percentage of productive tillers in the use of 1-2 seedlings clump^{-1}, while the PHP mulch obtained by the percentage of productive tillers not different. Overall the percentage of productive tillers decreased with the increasing number of tillers but the number of productive tillers increased as seen in Table 2. The decrease in the percentage of productive tillers with increasing number of seedlings clumps^{-1} with STSS occurred due to a significant increase in number of tillers which reached 43.37 - 61.73% compared 1-2 seedlings of clump^{-1} (Table 2) so that it starts to cause competition between tillers (intra-specific) in getting nutrients, water, space and sunlight 3; [18:19].

Number of grain panicle^{-1}, the weight of 1000 grains pith, grain weight of clumps^{-1}, and grain production of hectare^{-1}

The number of grain panicles^{-1} was influenced by factors of the number of seedlings clump^{-1} STSS, but it was not affected by the furrow irrigation factor, PHP mulch and the interaction of the three treatment factors. The highest number of grain panicle^{-1}was obtained from the use of 1-2 seedlings clump^{-1}. The number of grain panicle^{-1} was smaller with the increasing of 3 – 5 seedlings clump^{-1} (Table 4).

Table 4: The number of grain panicle^{-1} of paddy rice in SRI method using the number of seedlings clump^{-1} STSS, mulch, and furrow irrigation systems.

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1})				
		1	2	3	4	5
		.... grain panicle^{-1}.....................				
Intermittent (A1)	M0	181.6	174.7	160.1	144.3	161.7
	M1	232.4	186.8	170.4	155.8	148.9
	M0	175.5	168.1	174.5	151.8	151.8
Flooding (A2)	M1	187.9	176.3	168.8	194.3	179.5
Average B		194.4A	176.5AB	168.5B	161.6B	160.5B

The numbers in the same row followed by the same uppercase letters do not differ according to DNMRT α 0.05

The weight of 1000 rice grains was not affected by the treatment of furrow irrigation, use of mulch, and the number of seedlings clump^{-1} with STSS and their interactions. Data on the 1000 weights of pithed grain are presented in Table 5. Weight of grain yields of clump^{-1} and grain production hectare^{-1}is influenced by the interaction of furrow irrigation factors, the use of PHP mulch and the number of seedlings clump^{-1}with STSS.

The weight of the grain yield of clump^{-1} does not differ with the difference in the number of seedlings clump^{-1} STSS in intermittent irrigation system without PHP mulch, but with the use of PHP mulch, there is an increase in grain weight in the use of 2, 3, and 5 seedlings clump^{-1} STSS. In the flooded irrigation system without mulch there was an increase in the weight of the grain clump^{-1} with the use of 2-3 seedlings clump^{-1} STSS, but by giving PHP mulch the yield of grain weight clump^{-1} was relatively similar to the number of different seedlings clump^{-1}, except in 4 seedlings clump^{-1} STSS the relative weight of grain weight clump^{-1} was obtained (Table 6). Increased weight yield of grain clump^{-1} is supported by an increase in the number of tillers clump^{-1} and the number of productive tillers (Table 1 and Table 2), so that although there is a decrease in the number of grain panicle^{-1}, it is able to be followed by a significant increase in the number of productive tillers, as a result, weight of grain yield increases.

Table 5: Weight of 1000 grains of paddy rice in SRI method using the number of seedlings clump^{-1} STSS, mulch, and furrow irrigation system

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1})				
		1	2	3	4	5
		.... g DMG*..				
Intermittent (A1)	M0	21.82	21.57	21.56	20.94	20.23
	M1	21.76	22.21	21.26	19.44	21.65
Flooding (A2)	M0	22.79	21.63	22.4	20.73	21.00
	M1	20.96	23.57	20.91	21.79	21.98

*MC = 11.81%

Table 6: Weight of grain yield clump^{-1} of paddy rice in SRI method using the number of seedlings clump^{-1} STSS, much, and furrow irrigation system.

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1})				
		1	2	3	4	5
		....g DMG* clump^{-1}..				
Intermittent (A1)	M0	40.22Ab	46.11Abc	45.53Ab	43.44Ab	48.22Aa
	M1	43.00Bb	46.78ABab	54.11Aa	44.56Bb	46.00ABa
Flooding (A2)	M0	43.78Bb	38.11Bc	46.44ABab	54.44Aa	51.78ABa
	M1	52.67Aba	54.44Aa	53.92Aa	45.33Bb	48.33Aba

Numbers in the same row followed by the same uppercase letters and numbers in the same column followed by the same lowercase letters do not differ according to DNMRT α = 0.05

*MC = 11.81%

The use of 1 seedlings clump^{-1} is the best in flooded furrow irrigation system was with PHP mulch, while the use of 2-3 seedlings clump^{-1} STSS with PHP mulch on both irrigation systems resulted in higher grain weight compared with without mulch. In the use of 4 seedlings clump^{-1}, the highest grain weight clump^{-1} was obtained in the flooded irrigation system without PHP mulch (Table 6). But in general, the yield weight of grain clump^{-1} increases in SRI method with the use of PHP mulch, flooded system in furrow irrigation and use of 2.3, and 5 seedlings clump^{-1} STSS, but the use of 5 seedlings clump^{-1} STSS produce 5 seedlings clump^{-1} STSS, but the use of 5 seedlings clump^{-1} STSS produce more stable grain weight in all furrow irrigation systems and mulch used. Increased weight of grain clump^{-1} occurs due to increased population of parent plants which will stimulate the formation of main tillers [3, 16, 20] which are supported by the opening of space in the clump so that plants form effective canopy structures to capture sunlight so as to increase plant photosynthesis which can stimulate panicle filling [3, 12, 20, 21]. Besides the increase in plant photosynthesis is also supported by the use of mulch which prevents competition from weeds, reduces pest and disease attacks, improves soil air system and groundwater, reduces erosion, and prevents soil compaction [11]. In addition, irrigation with grooves creates aerobic conditions around the roots. Under aerobic conditions, it can encourage the development of wider and deeper plant root systems [9, 14, 21]. With the increase in yield weight of grain clump^{-1}, the opportunity to increase production grain ha^{-1} will be even greater because the population of mother plants and the main tiller is getting bigger.

The highest grain production in intermittent furrow irrigation system either using mulch or without PHP mulch was obtained on the use of 5 seedlings clump^{-1} with STSS. In the flooded furrow irrigation system without mulch PHP obtained grain production increased in 4-5 seedlings clump^{-1} STSS. In the flooded irrigation system using PHP mulch, grain production increased with the use of 2, 3, and 5 seedlings clump^{-1} STSS, whereas if without mulch application, grain production increased in the use of 3-5 of seedlings clump^{-1} with STSS (Table 7). But overall the use of 5 seedlings clump^{-1} STSS with PHP mulch and intermittent or flooding irrigation system resulted in the highest grain production compared to all other treatment combinations.

Table 7: Production of rice grain hectare^{-1} of paddy rice in SRI method using the number of seedlings clump^{-1} with STSS and furrow irrigation system

Furrow Irrigation (A)	Mulch (M)	Number of Seedling STSS(B) (seedling clump^{-1})				
		1	2	3	4	5
		....Mg DMG*ha^{-1}..				
Intermittent (A1)	M0	3.755Ba	4.019Bb	3.844Bc	3.446Bc	4.805Aab
	M1	3.587Ca	4.639Bab	4.66Bab	4.619Ba	5.487Aa
Flooding (A2)	M0	3.571Ba	3.333Bc	3.97ABbc	4.604Aab	4.411Ab
	M1	3.831Ca	5.004Aba	4.983ABa	4.422BCb	5.197Aa

Numbers in the same row followed by the same uppercase letters and numbers in the same column followed by the same lowercase letters do not differ according to DNMRT α = 0.05

*MC = 11.81%

Conclusion

The use of PHP mulch single can increase tillers by 9.88% compared to without mulch. The use of 3-5 seedlings clump^{-1} increased 43.37 - 61.73% tillers compared to 1-2 seedlings of clump^{-1}, but the highest number of grain panicle^{-1} was obtained in 1-2 seedlings clump^{-1}. The interaction of the furrow irrigation system, mulch application and the number of seedlings clump^{-1}with STSS occurred on the percentage of productive tillers, yield weight of grain clump^{-1} and grain production hectare^{-1}. In intermittent system irrigation, higher grain production was obtained with application of PHP mulch and 5 seedlings clump^{-1} STSS, while in the flooding irrigation system, the grain yields clump^{-1} and grain production ha^{-1}was higher with application PHP mulch and the use of 2, 3, and 5 seedlings clump^{-1} STSS. Overall the best production was obtained from the use of 5 seedlings clump^{-1} STSS with application of PHP mulch and both intermittent and flooded irrigation systems. Thus, to produce high grain production, weed-free and save water use it can be recommended to use 5 seedlings clump^{-1} with STSS, using PHP mulch and intermittent or flooding irrigation system in the SRI method.

Acknowledgements

We wish to thank DRPM, Ministry of Research, Technology and Higher Education, Republic of Indonesia, who has funding this research via applied research scheme by DIPA No.018/K10/KM/KONTRAK-PENELITIAN-J/2019, tanggal 29 Maret 2019. Thanks also to Mr. Reski Ardiansyah, farmers group leaders of Kelompok Tani Saiyo Bersama as our partners, and Sudirman and Rumambi our students for they support and help on the field work.

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