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The Effects of Planting Range and Weed Management on Growth and Yield of Rice (*Oryza sativa* L.) Using Modified SRI (*The System of Rice Intensification*)

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***Abstract*— Using modified SRI (*The System Rice of Intensification*) was aimed at determining the optimum planting range and frequency of weeds management that could increase rice productivity. The research was consisted of two factors, planting range and frequency of weeds management. The trials were arranged in factorial using Randomized Block Design (5x4) and three replications. The first factor was five levels of planting range, 20 x 20 cm; 20 x 25 cm; 25 x 25 cm; 25 x 30 cm; and 30 x 30 cm. While the second factor was four levels of weeds management (manually) frequency, once (30 days after planting (DAP); twice (20; 40 DAP); 3 times (20; 30; 40 DAP); and 4 times (10; 20; 30; 40 DAP). Parameters measured were the maximum number of tillers, crops growth rate, net assimilation rate, number of productive tillers, the weight of 1000 seeds, seeds weight per clump, and seeds weight per hectare. The result showed that planting range 20 cm x 25 cm and three times frequency of weeding per planting season was the best interaction with the productivity 9.005 t ha^{-1}. Rice cultivation technique by giving the height of water surface 10 cm under the soil surface, a distance of furrows 2 m, the dosage of compost 10 ton/ha, planting range 20 x 25 cm , and frequency of weeding three times per planting season could increase rice yield as much as 50.08 %.**

***Keywords*— rice; SRI (*The System Rice of Intensification*); planting range; weed; productivity**

I. INTRODUCTION

Rice is an important staple food in the world mainly in Asia. Rice is one of the factors that can increase poverty and decrease food sustainability in Asian countries. Research done by world bank indicated that only 5% of global produced rice is traded in the international market. Therefore, the rice price fluctuates sensitively based on supply and demand, and even rice is exported only by three countries, Thailand, India, and Vietnam [1]. For the reasons, the countries consuming rice, majority Asian countries, should increase national rice production which one of them is increasing rice productivity.

The System of Rice Intensification (SRI) is one of technique that has been tested from various researches and field applications that can increase rice productivity. SRI method does not require higher external input compared to conventional system. SRI needs much lower chemical fertilizers and seeds. One crucial thing in SRI is using less water (water available enough for growth and development of rice, not necessary flooded) compared to a conventional method that needs much water in the field during most of the rice growth. Reducing water use and using less external input make SRI suitable to the concept of LEISA (*Low External Input Sustainable Agriculture*) and could save water resources [2].

SRI is one of intensification method that can optimize the expression of plant genetic capability. Rice cultivation using SRI has been practiced for a long time in Indonesia to increase the yield of rice. However, it still needs improvement to reach optimum yield. Modification on SRI was done in a pot by giving water 10 cm under the soil surface, and this showed prospective results. 28.7184 ton dried seed. A further application in rice field showed that the productivity was still high, 8.288 ton dried seed per ha. This indicated that there was 38.13 % increase in productivity of a variety of rice, Batang Piaman, compared to its description which was 6 ton per ha. In order to increase rice productivity, there was one of possibility, i.e., combining planting range and frequency of weeding by modifying SRI method. Rice

field was not flooded, but instead, it was watered 10 cm below soil surface.

One of suggestion for SRI is giving wider planting range. However, some researchers stated that planting range was determined by varieties, texture, structure, and soil fertility. Implementing planting range that also determines the number of plant population varies. According to Prihatman [3], planting range was adjusted with local condition like 20 cm x 20 cm (250.000 population ha^{-1}), 22.5 cm x 22.5 cm (200.000 population ha^{-1}) and 25 cm x 25 cm (160.000 population ha^{-1}). Based on the guideline of integrated resources plant management, the planting range was 20 cm x 20 cm, 25 cm x 25 cm and for *legowo* 4:1 (10 cm x 20 cm) or 400.000 population ha^{-1}. Further, a researcher from IRRI reported that there were some weaknesses in SRI, one of them was using wider planting range which reduced plant population so that the solar radiation capture converted to seed became less [4]. The weeds growing in ricefield could decrease yield up to 34 % [5].

The weeding in SRI system has many variations. It depends on soil condition and local climate. The weeding intensity on the SRI system was four times. The first weeding should be carried out 10 days after seedling, and another weeding was implemented in accordance with the growth and development of weeds. Directorate General of Land and Water Management [6] recommended the time of application of weeding in SRI system were 10, 20, 30 and 40 days after seedling. According to CIIFAD [7], the productivity of rice without the weeding was obtained 6.0 t ha^{-1} and increase to 7.7 t ha^{-1}, 7.4 t ha^{-1}, 9.1 t ha^{-1} and 11.8 t ha^{-1} respectively with the increase in the frequency of weeding applied from one time to four times.

The main purpose of weeding was to improve aeration of paddy soil, so the supply of oxygen was adequate into the ground. The ground will be more fertile, and toxic gases in the soil can get out so that the soil will be crumblier. Weeding was done by removed and then buried of the weeds growing in rice field into the soil [8].

This research aims to determine the effects of interaction between planting range and frequency of weeding by modifying SRI method on growth and yield of rice.

II. Material and Method

The research was done in ricefield of BBI Pantai Marpoyan, Pekanbaru, Riau Province from April to September 2013.

Research was conducted in factorial consisting of two factors, planting range and frequency of weeding done manually. It was arranged using Ramdomized Block Design with three replications. Factor I consisted of five levels of planting range (TI), T1 = 20 x 20 cm; T2 = 20 x 25 cm; T3 = 25 x 25 cm; T4 = 25 x 30 cm; and T5 = 30 x 30 cm. Factor II consisted of four levels of weeding frequency, G1 = 1X (30 days after planting (dap)); G2= 2X (20; 40 dap); G3= 3X (20; 30; 40 dap); and G4= 4X (10; 20; 30; 40 dap). There were 60 trial plots. The plot settings were presented in Fig. 1.

A. Research Procedure

1) Land Preparation: Plots for trial was plowed semi-mechanically using hand tractor and manpower, and made in muddy condition. While plowing, the land was flooded for ± 21 days, and weeds were removed. Then the plots were arranged such a way by giving water in ditches 10 cm under the soil surface, and distance of ditches were 2 m. Compost was given using dosage 10 t ha^{-1}. Planting range was made into five levels as in treatments. Then the plots were ready for planting using SRI method.

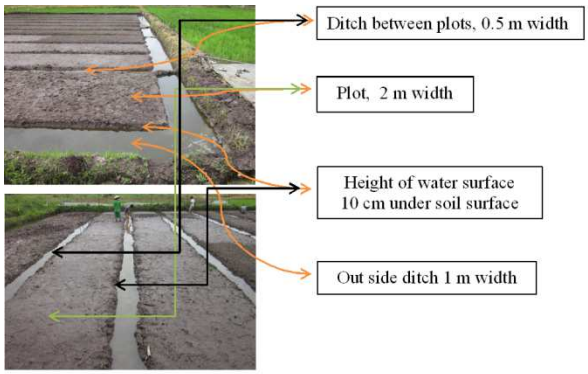

Fig. 1 Condition in field before planting rice

2) Preparation of Nursery and Seeds: Nursery was prepared near trial plots in damp condition with size 1m x 5m = 5 m^2, and given 0,5 kg compost (1 t ha^{-1}). Seeds were soaked for two days, and the ones are floating were discarded. Then seeds were cleaned, dried, and sowed evenly in the nursery.

3) Planting: The seedlings were planted after 12 days in the nursery with a depth ± 2 cm. In one hole there was only one seedling. In different planting ranges, there were a different number of the individual plant. Number of individuals in planting range 20 x 20 cm was 100 plants, in 20 x 25 cm was 80 plants, in 25 x 25 cm was 64 plants, in 25 x 30 cm was 48 plants, in 30 x 30 cm was 36 plants.

4) Irrigation: Water was managed based on soil condition. The height of water surface was 10 cm under the soil surface. Water management was designed such a way so that height of water surface was kept in 10 cm under the soil. At the time rice was in its maturity, the land was dried totally.

5) Fertilization: Two weeks before planting, compost was applied 10 ton ha^{-1}. Synthetic fertilizers applied were 200 kg Urea ha^{-1}+ 100 kg SP-36 ha^{-1}+ 100 kg KCl ha^{-1}. Urea, SP-36 and KCl were given 0.80 g, 0.40 g, and 0.40 g per plant for treatment of planting range 20 cm x 20 cm, 1.00 g, 0.50 g, and 0.50 g for planting range 20 cm x 25 cm, 1.25 g, 0.625 g and 0.625 g for planting range 25 cm x 25 cm, 1.50 g, 0.75 g, and 0.75 g for planting range 25 cm x 30 cm, 1.80 g, 0.90 g, and 0.90 g for planting range 30 cm x 30 cm. A half of urea and all SP-36 and KCl were given at the time of planting, and the rest of urea were divided into two, then were applied 21 and 42 days after planting (dap).

6) Plant Protection: Weeding was done by four different frequencies, 1) once; 30 days after planting (dap), 2) twice; 20 and 40 dap, 3) three times; 20, 30 and 40 dap, and 4) four times; 10, 20, 30 and 40 dap. All plots were treated with *Curater 3-G* for pest control applied at the time of planting using dosage 17 kg ha^{-1}.

7) Harvesting: Rice was harvested when all panicles had

been 80 % yellow. After being harvested, seeds were dried for three days to get water content 14 % -16 %. Then the seeds were observed and scaled.

8) Parameters Measured:

Characteristics of plant growth:

- Total number of tillers, in every sample the number of tillers was counted.
- Crops growth rate (CGR) (g.m^{-2}day^{-1}), the increase of weight gained was compared with land width per time unit.
- Net assimilation rate (NAR) (mg.cm^{-2}day^{-1}), total leaf weight was measured using *leaf area meter*.

Characteristics of yield components and yield of rice:

- The number of productive tillers. All tillers producing panicle were counted at harvesting time for each sample.
- The weight of 1000 seeds (g). This was conducted at the same time measuring production.
- The weight of seeds per clump.
- The weight of seeds per plot. This weight was then converted into hectare.

9) Linear Model of Observation: This was factorial research consisting of two factors. Factor I was five levels of planting range, and factor II was four levels of weeding frequency, with three replications so that there were 60 observation units. The design used was Randomized Block Design of Environment. Based on environment design and treatments, the linear model was as follow:

$$Y_{ijk} = \mu + \delta_k + T_i + G_j + (TG)_{ij} + \in_{ijk} \quad (1)$$

Where:

Y_{ijk} = Result from effects of planting range, weeding frequency, and their interaction.

μ = Average general value

δ_k = Effect of block k

T_i = Effect of planting range i

G_j = Effect of weeding frequency j

$(TG)_{ij}$ = Effect of interaction between planting range i and weeding frequency j

$\in_{ijk}$ = Error term

Two weeks before planting, compost was applied 10 ton ha^{-1}. Synthetic fertilizers applied were 200 kg Urea ha^{-1}+ 100 kg SP-36 ha^{-1} + 100 kg KCl ha^{-1}. Urea, SP-36 and KCl were given 0.80 g, 0.40 g, and 0.40 g per plant for treatment of planting range 20 cm x 20 cm, 1.00 g, 0.50 g, and 0.50 g for planting range 20 cm x 25 cm, 1.25 g, 0.625 g and 0.625 g for planting range 25 cm x 25 cm, 1.50 g, 0.75 g, and 0.75 g for planting range 25 cm x 30 cm, 1.80 g, 0.90 g, and 0.90 g for planting range 30 cm x 30 cm. A half of urea and all SP-36 and KCl were given at the time of planting, and the rest of urea were divided into two, then were applied 21 and 42 days after planting (dap).

III. Results and Discussions

A. Plant Growth

The interaction between planting range and frequency of weeding showed an effect on rice growth like net assimilation rate (NAR), crops growth rate (CGR) and total number of tillers (TNT) (Table 1–3). The wider planting range and higher frequency of weeding, the higher TNT, CGR, and NAR became. The highest TNT, CGR, and NAR were found in the interaction between planting range 30 x 30 cm and frequency of weeding four times.

TABLE I
TOTAL NUMBER OF TILLERS (INDIVIDUALS) GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding frequency			
	1X	2X	3X	4X
	----------individuals----------			
20 x 20 cm	26.78 b B	27.78 ab B	28.81 a C	28.83 a C
20 x 25 cm	28.89 b A	30.22 ab A	31.11 a B	30.77 a B
25 x 25 cm	29.45 b A	29.22 ab A	31.45 ab B	31.56 a B
25 x 30 cm	29.22 b A	30.11 ab A	31.11 ab B	32.22 a B
30 x 30 cm	29.44 b A	31.44 ab A	34.76 ab A	35.22 a A

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

Generally, in each treatment of planting it was seen that the total number of tillers increased as the frequency of weeding increased which meant 4X weeding frequency gave the best result. Higher frequency of weeding caused the weed not to develop and could decrease weed seed bank in the field, and it, of course, gave benefit for rice not to compete with weed to get more nutrients which resulted in more tillers produced because nutrient around plant could be absorbed optimally. According to Sudianto [9] periodically weeding could decrease the accumulation of weed seed bank in ricefield.

Generally, in each of weeding frequency treatment as the width of planting range increased, the total number of tillers became higher. Planting range 30 x 30 cm was better than other ones. In wider planting range, plants did not overlap each other so they could use sunlight optimally. Further, in wider planting range the roots of rice did not also overlap each other so there was no competition to get nutrients from the soil so that most of the nutrients could be absorbed optimally by each plant.

The highest number of tillers was obtained from the interaction between planting range 30 x 30 cm (35.22 plants) and weeding frequency 4 times because weed did not develop and sunlight energy could be used optimally by rice.

TABLE II
CROPS GROWTH RATE GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- g.m^{-2}day^{-1} ----------			
20 x 20 cm	7.87 b A	8.22 ab AB	8.37 ab A	8.57 a AB
20 x 25 cm	6.68 b AB	8.15 a B	8.01 a B	8.43 a B
25 x 25 cm	7.45 b AB	8.16 ab B	8.51 ab A	8.67 a AB
25 x 30 cm	6.27 b B	8.38 ab A	8.37 ab A	8.68 a AB
30 x 30 cm	6.33 b B	8.39 a A	8.51 a A	9.36 a A

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

It is clear that from each of planting range level as weeding frequency increased, crops growth rate was higher. The best weeding frequency was four times. The higher the frequency of weeding, the population of weed around plants could not develop or the surface of the soil around plants was free from weed. This condition could give the advantage to plant growth because nutrients around plants could be absorbed optimally by plants. On the contrary, the more weed grew around rice plants, the more competition for nutrients between weed and plants. This could be seen from low crops growth rate on one time weeding frequency. From each of weeding frequency, plants growth rate was found to increase as the width of planting range increased, except at weeding frequency one time.

For the treatment of one time weeding frequency done 30 days after planting, before weeding the weed grew faster and densely and even higher than rice plants. This condition also occurred from the age of rice plants 40 days until harvest (111–114 days). At this condition, rice plants were unable to compete with weed in obtaining nutrients and sunlight as a source of energy. Further, at one time weeding, crops growth rate at wider planting range (25 x 30 cm and 30 x 30 cm) was significantly lower compared to narrow planting range (20 x 20 cm, 20 x 25 cm, 25 x 25 cm). At wider planting range, weed grew faster because sunlight fell directly to weed or surface of the soil. Weed development would be maximum if sunlight fell directly to weed. However, in general, at four, three, and two times weeding, crops growth rate was higher as the width of planting range increased. Wider planting range was better than a narrow one. The best crops growth rate was found at the interaction between planting range 30x30 cm and weeding frequency four times (9.36 g.m^{-2}day^{-1}).

TABLE III
NET ASSIMILATION RATE GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- mg.cm^{-2}day^{-1} ----------			
20 x 20 cm	0.41 b A	0.42 ab B	0.42 ab B	0.44 a B
20 x 25 cm	0.42 c A	0.42 c B	0.43 b AB	0.44 a B
25 x 25 cm	0.41 b A	0.43 ab AB	0.45 a AB	0.46 a AB
25 x 30 cm	0.35 b B	0.42 ab B	0.45 ab AB	0.49 a AB
30 x 30 cm	0.33 b B	0.44 a A	0.46 a A	0.52 a A

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

In general, at weeding frequency four, three, and two times, net assimilation rate was higher at wider planting range. The best net assimilation rate was at planting range 30 x 30 cm. Relatively good interaction was between planting rate 30 x 30 cm and weeding frequency four, three, and two times which gave the results 0.52 mg.cm^{-2}day^{-1}; 0.46 mg.cm^{-2} day^{-1}, and 0.44 mg.cm^{-2}day^{-1}.

B. Component of Yield and Yield of Rice

The interaction between planting range and weeding frequency affected the total number of productive tillers (Table 4), the weight of seeds per clump (Table 6), and weight of seeds per plot (Table 7), but did not affect the weight of 1000 seeds (Table 5).

Generally, in each of planting range, the higher frequency of weeding, the higher the weight of seeds per plot. Weeding frequency of four and three times was better than two and one time weeding. This case was in accordance parameters of NAR, CGR, the total number of tillers, number of productive tillers, and weight of seeds per clump because the parameters were the basic components to form weight seed per plot.

In each of weeding frequency, the narrower the planting range, the higher weight of seeds per plot. This fact was contrary to the parameter of seed weight per clump. The highest weight seeds per clump were found in wider planting range, while the highest weight per plot was in narrow planting range. This occurred because in narrow planting range there were more clumps than in wider one within the same size of plots so that more clumps would result in a higher weight of seeds per plot.

The best interactions that gave the highest weight of seeds per plot were between planting range 20 x 20 cm and weeding frequency four times (3600 g), planting range 20 x 20 cm and weeding frequency three times (3602 g), and planting range 20 x 25 cm and weeding frequency four times (3409.6 g).

TABLE IV
TOTAL NUMBER OF PRODUCTIVE TILLERS GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- individuals ----------			
20 x 20 cm	20.07 b C	20.07 b C	21.69 a B	22.66 a B
20 x 25 cm	22.19 b B	23.88 b B	23.57 ab B	24.37 a B
25 x 25 cm	24.54 b A	24.88 b AB	26.54 a A	27.25 a A
25 x 30 cm	24.89 bc A	24.42 c AB	26.69 ab A	27.47 a A
30 x 30 cm	24.37 b AB	26.53 ab A	27.19 a A	28.50 a A

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

Statistical analysis showed that there was linearity between the number of productive tillers with the total number of tillers, the higher the total number of tillers the higher the number of productive tillers. It was shown in Table 4 that number of productive tillers in each treatment of planting range was affected by weeding frequency, and also the total number of tillers in each treatment of weeding frequency was affected by planting range. The higher the frequency of weeding and the wider of planting range, the higher the number of productive tillers.

TABLE V
WEIGHT OF 1000 SEEDS PER PLOT GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- gram ----------			
20 x 20 cm	27.67	27.00	27.33	27.00
20 x 25 cm	27.00	27.00	28.33	27.33
25 x 25 cm	27.00	27.33	27.33	27.33
25 x 30 cm	27.67	27.00	27.33	28.33
30 x 30 cm	27.33	27.33	27.67	27.67

Table 5 showed that weight of 1000 seeds was not affected by different planting range and weeding frequency. Therefore, it was concluded that the weight of 1000 seeds could not be affected by environmental factors such as planting range and weeding frequency, but it is controlled by a genetic factor. It was shown in the description of a variety of rice Batang Piaman that weight of 1000 seeds was ±27 g which was more or less the same as the result of this study. Manurung and Ismunadji [10] stated that weight of rice seed relatively fixed because the size of husk (lemma and palea) is determined by a genetic factor. Further, it was supported by the result of research done by Bambang and Anggit [11] that kind of fertilizers did not affect the weight of 1000 seeds of rice. This happened because of genetic characters attaching on varieties of rice.

In each treatment of planting range, the higher frequency of weeding the weight of seeds per clump was higher. The frequency of weeding four and three times was better than two and one time. This was in accordance with parameters of NAR, CGR, the total number of tillers, and the number of productive tillers, because these parameters were the basic components which resulted in forming seed weight in a clump.

TABLE VI
SEED WEIGHT PER CLUMP GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- gram ----------			
20 x 20 cm	34.23 b B	34.14 b B	36.02 a C	36.00 a C
20 x 25 cm	38.10 b AB	40.62 a B	41.48 a BC	42.62 a BC
25 x 25 cm	46.52 b A	45.29 b A	49.19 ab AB	50.82 a AB
25 x 30 cm	48.69 b A	49.84 ab A	50.20 ab AB	51.79 a A
30 x 30 cm	48.26 b A	49.66 ab A	53.20 a A	53.43 a A

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

In each of weeding frequency, the wider the planting range, weight of seed per clump was higher. It could be seen that in general planting range 30 x 30 cm, 25 x 25 cm and 25 x 25 cm were better than 20 x 25 cm and 20 x 20 cm. This was in accordance with parameters of NAR, CGR, the total number of tillers, and the number of productive tillers which were the basic components for forming seed weight per clump.

The best interaction for seed weight per clump was between planting range 30 x 30 cm and weeding frequency four times (53.43 g), planting range 30 x 30 cm and weeding frequency three times (53.20 g), and planting range 25 x 30 cm and weeding frequency four times (51.76 grams).

TABLE VII
SEED WEIGHT PER PLOT GIVEN TREATMENTS OF PLANTING RANGE, WEEDING FREQUENCY AND THEIR INTERACTION ON BATANG PIAMAN VARIETY OF RICE

Planting range	Weeding Frequency			
	1X	2X	3X	4X
	---------- gram ----------			
20 x 20 cm	3423.00 b A	3414.00 b A	3602.00 a A	3600.00 a A
20 x 25 cm	3048.00 b AB	3249.60 ab A	3318.40 ab A	3409.60 a A
25 x 25 cm	2977.28 b AB	2898.56 b AB	3148.16 a AB	3252.48 a AB
25 x 30 cm	2580.57 b B	2641.52 ab BC	2660.60 ab B	2744.87 a BC
30 x 30 cm	2123.44 b B	2185.04 b C	2340.88 ab C	2350.92 a C

Numbers followed by same lower case letter in same row or same capital letter in same column were not significantly different based on DNMRT at 5% level of confidence

Generally, seed weight per plot in each planting range was higher as the frequency of weeding was higher. Weeding frequency four and three times were better than two and one time. This was in accordance with parameters of NAR, CGR, the total number of tillers, number of productive tillers and weight of seeds per clump because these parameters were the basic component for forming seed weight per plot.

In each weeding frequency, the weight of seeds per plot was higher as the planting range was narrower. This fact was contrary to the parameter of seeds weight per clump. The highest weight of seeds per individual clump was found in wider planting range, while the highest weight of seeds per plot was found in narrow planting range. This could happen because seeds weight per plot was counted from the total individual clump, and in the same size of plot there was a higher number of clumps using narrow planting range that resulted in the higher weight of seeds per plot.

The highest weight of seeds per plot was found in the interaction between planting range 20 x 20 cm and weeding frequency four times (3600.00 g), 20 x 20 cm and frequency of weeding three times (3602.00 grams), and 20 x 25 cm and frequency of weeding four times (3409.60 g).

Parameters of NAR and CGR related with other parameters such as total number of tillers, number of productive tillers and weight of seeds per clump. The higher the value of NAR and CGR, the higher the total number of tillers, number of productive tillers and weight of seeds per clump. In general, all parameters showed a better response to wider planting range and higher frequency of weeding. The best interactions for a total number of tillers was between planting range 30 x 30 cm and weeding frequency four times (35.22 individuals), for a number of productive tillers was between 30 x 30 cm and frequency of weeding four times (24.50 individuals). Relatively good interaction for the weight of seeds per clump was between 30 x 30 cm and weeding frequency four times (53.43 g), 30 x 30 cm and weeding frequency three times (53.20 g), and 25 x 30 cm and weeding frequency four times (51.76 g).

Physiological process and growth of rice will be disturbed if the nutrients absorption is not optimum, mainly nitrogen absorption. According to Sitompul and Guritno [12], nitrogen availability influences much the index value of leaf width and plant biomass production. The index value of leaf width determines net assimilation rate and crops growth rate. When index value of leaf width is low, photosynthesis rate becomes low; bud formations are impeded so that the number of tillers formed decreased. This case is in accordance with the finding of Hadirochmat [13] that the decrease and increase of NAR relate to the development of leaf width and availability of nutrients could be absorbed. The wider the planting range the competition of rice plants for nutrients absorption becomes low and even could be no competition among rice plants at planting range 30 x 30 cm because of root distribution laterally less than 30 cm. Besides that, the higher weeding frequency causes the weeds less developed. Thus, at the interaction between planting range 30 x 30 cm and weeding frequency three and four times, rice plants could absorb nutrients more optimum that will cause NAR and CGR higher compared to other interactions. This case was in accordance with Oghalo [14] who compared three planting range, 40 cm x 30 cm, 30 cm x 30 cm and 30 cm x 20 cm, and the result indicated that planting range 30 x 30 cm performed good growth and the highest productivity. Further, based on Hoque *et al.* [15], weeding done three times could increase the yield of rice compared to weeding frequency two times.

According to Gardner *et al.* [16], leaf area index was the ratio between leaf width and soil width. Index of leaf width shows the amount of assimilating of a plant and function as a primary value to determine growth characters like NAR and CGR. Net assimilation rate is a pile of dried weight per unit leaf width and time. Net assimilation rate shows the average of leaf photosynthesis efficiency. The higher net assimilation rate, the pile of dried materials will be more.

The yield of rice plants is determined by growth, and good growth will give high yield [17]. Results of this research showed that better rice growth was found in the interaction between wider planting range and more frequent weeding which caused a higher number of productive tillers and weight of seeds per clump (Table 4 and 6). The interaction between planting range and frequency of weeding gave different significant effects on seeds weight per clump. Wider planting range and more frequent weeding resulted in high seed weight per clump.

The yield of seeds relied on size and efficiency of assimilation surface area available after flowering, dried material produced which was stored in vegetative organ, and duration of the process [18]. Assimilate available in the stem and other parts after flowering was combined and translocated into the seed. Implementing SRI method, rice plants have more tillers per clump, more seeds produced and bigger root size [16]. Further, Suseno [20] stated that the number of productive tillers mostly determined during the vegetative phase. Starch in seeds comes from two sources, (a) products assimilated and accumulated in stem and leaves before blooming stage, then are converted into sugar and translocated to seeds (called accumulated starch) and (b)

products assimilated and produced during maturing stage.

The high weight of seed per clump was obtained from the interaction between planting range 30 x 30 cm and weeding frequency four times (53.43 g), 30 x 30 cm and weeding frequency three times (53.20 g), and 25 x 30 cm and weeding frequency four times (51.76 g). This was caused by high yield component (number of productive tillers). According to Suseno [20], rice seed product is a function of three yield components, (1) number of panicle per plant (2) number of filled out seeds per panicle, and (3) average weight of one seed. Then, Pratama *et al.* [21] stated that the characters of plants such as height, the age for blooming, the age for harvest, number of tillers per clump, number of productive tillers, the total number of seeds per panicle, and weight 1000 seeds, related strongly with yield.

After seed weight was converted into width unit (seed weight per plot) it could be seen that the highest weight was obtained from the interactions between 20 x 20 cm and weeding frequency four times (3600.00 g), 20 x 20 cm and weeding frequency three times (3602.00 g), and 20 x 25 cm and weeding frequency four times (3409.60 g). Different from yield of high seeds weight per clump, it was found from the interaction between wider planting range and more often weeding, i.e. between planting range 30 x 30 cm and weeding frequency four times (53.43 g), 30 x 30 cm and weeding frequency three times (53.20 g), and 25 x 30 cm and weeding frequency four times (51.76 g). This case was caused by more population at narrow planting range compared to wider one, even though for clump individually the wider planting range was better compared to narrow one.

Furthermore, after being converted into width unit per hectare, the best interactions were found between narrow planting range and more often weeding, *i.e.* between planting range 20 x 20 cm and weeding frequency four times with population 250,000 (9 t ha^{-1}), 20 x 20 cm and weeding frequency three times with population 250,000 (9.005 t ha^{-1}) and 20 x 25 cm and weeding frequency four times with population 200,000 (8.524 t ha^{-1}). This result agreed to the statement of Mondal *et al.* [22] that the best planting range was 20 cm x 20 cm with productivity 8.53 t ha^{-1}. The productivity of rice in this study was higher compared to the description of rice variety of Batang Piaman (6 t ha^{-1}).

IV. Conclusion

The interaction between planting range and weeding frequency statistically affected the total number of tillers, crops growth rate, net assimilation rate, number of productive tillers, seeds weight per clump, and seeds weight per plot. The interaction did not affect the weight of 1000 seeds. The best interaction for growth and productivity of rice was between planting range 20 x 25 cm and weeding frequency three times. Implementing modified SRI method in planting rice giving 10 cm water under the soil surface, a distance of ditch 2m, the dosage of compost 10 t ha^{-1} using planting range 20 x 25 cm and weeding frequency three times, could increase rice yield 50.08 %.

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