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The Effect of Planting Time and Plant Density on Radiation Use Efficiency (RUE) on Lowland Rice (*Oryza sativa L.*) Cv. Inpari 30

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ABSTRACT

The right planting time and plant density in rice cultivation in the rainy season affect the generative phase, where absorption of solar radiation intensity more efficiently increases productivity. This study aims to improve the absorption of energy efficiency of solar conversion with differences in planting time and planting density. The experiment was carried out from January to June 2019 in the experimental garden of Brawijaya University, Malang City, East Java. The research design used is a nested design with three replication. The main factor is planting time which consists of 3 levels, namely: January (B1); February (B2); March (B3). Nested factor is plant density which consists of 3 levels, namely: 111.111 plant ha^{-1} (T1); 166.667 plant ha^{-1} (T2); 226,667 plant ha^{-1} (T3). Data analysis used variance (ANOVA). If the results are significantly different, then the honest significant difference test (HSD) is continued at the 5% level. The results showed that the differences in total leaf area index, plant dry weight, panicle weight every clump, grain weight every clump, grain weight every harvest plot, yield per hectare, and radiation use efficiency (RUE). The planting time in March has a higher RUE value than the planting time in January or February. Yield per hectare shows the planting time in March is higher than the planting time of January or February planting time. Plant density of 30x30 cm shows yields per hectare higher than planting density of 30x20 cm and planting density of 40x20x12.5 cm.

***Keywords*:** Energy conversion efficiency; Planting density; Rice planting time

INTRODUCTION

Rice (*Oryza sativa L.*) is an important commercial plant because it is one of the staple foods of the Indonesian people. Every year the demand for rice increases, but its production has not been able to meet domestic rice needs. The total population of Indonesia in 2015 increased by 1.49% from the previous year, while the increase in rice production was only 1.24% (BPS, 2016).

Plant growth and development depend on the interaction between internal (genetic) and external (environmental) factors. Internal factors are traits that usually characterize a plant. External factors come from outside the plant, such as water, sunlight, temperature, humidity, nutrients, topography, and climate. Rainfall is one of the climate elements that also determine plant growth and yields (Sitompul & Bambang, 1995).

Rice plants are usually planted in the rainy season because water is available for growth, and development. However, during the rainy season, there is relatively little sunlight that inhibits the process of photosynthesis. In tropical areas such as Indonesia, In the dry season, more solar radiation is available for the photosynthesis process so that rice yields increase.

Constraints in rice cultivation during the rainy season are low sunlight and a dense canopy in which the light received by plants is not optimal. Efforts to overcome these obstacles are manipulating environmental factors where plants grow by adjusting the plant density so that the maximum utilization of solar radiation. Based on opinion (Ariyanto *et al*., 2015), the competition for plants to get sunlight can minimize by adjusting the planting time, spacing, plant density, and pruning leaves. The manipulating the microenvironment around plants, plants can grow and produce optimally. For this reason, efforts are needed to increase rice productivity in the rainy season by treating planting time and planting densities.

MATERIALS AND METHOD

The experiment was carried out from January to June 2019 in the experimental garden Universitas Brawijaya, Jatimulyo, Malang, East Java. The altitude is 460 m above sea level and 3000 mm of rainfall every year and a daily temperature of 20-28ºC.

The research design used is a nested design with three replication. The main factor is planting time (B) which consists of 3 levels, namely: January (beginning of the rainy season) (B1); February (rainy season) (B2); March (end of the rainy season) (B3). Nested factor is plant density (T) which consists of 3 levels, namely: T1: 111.111 plant ha^{-1} (plant spacing 30x30 cm); T2: 166.667 ha^{-1} (plant spacing 30x20 cm); T3: 226,667 plant ha^{-1} (plant spacing 40x20x12.5 cm).

The research implementation includes land preparation, seeding, planting, irrigation, fertilization (urea, SP36, and KCL), and maintenance (pest control and weeding). Observation parameters were leaf area index, plant dry weight, panicle weight per clump, grain weight every clump, the weight of grain every harvest plot, yield per hectare, and radiation use efficiency (RUE).

$$\mathrm{RUE} = \frac{\Delta \mathrm{W.K}}{\mathrm{I.t.PAR}} \times 100\%$$

Radiation use efficiency (RUE) is the difference in plant dry weight (∆W) (g m-2) in one period (t) and the coefficient of the heat of combustion (K) (4,000 cal g-1) to the daily radiation intensity (I) (cal m2 day-1), specific periods (T) (days), and photosynthetic actives radiation (PAR) (0.45).

The yield per hectare with an area of harvest is 1.44 m2. Calculation of the results using the following formula:

$$\mathrm{Yield}(\mathrm{t\ ha^{-1}}) = \frac{1000}{\text{scale of sampling plot}} \times \text{yield of sampling plot}$$

Data analysis used variance (ANOVA). If the results are significantly different, then the honest significant difference test (HSD) is continued at the 5% level (Freeman *et al*., 1985).

RESULTS AND DISCUSSION

Leaf Area Index (LAI)

Based on analysis of variance on leaf area index, there was no interaction between planting time and spacing at all ages of observation. Treatment Planting time and plant density each showed a significant difference in the leaf area index of rice plants (table 1).

Planting time in March showed the highest leaf area index value at all ages of observation compared to planting time in January and February (table 1). The average age of the park 90 HST leaf area for planting time in March is 1968.44 cm^2 with ILD 3,56 and 1834.69 cm^2 for planting time in February with ILD 3.32 and 1756.25 cm^2 for planting time in January with ILD 3.17. The results of research by Mungara and Indradewa (2013) showed that the optimum LAI value for rice plants is 3-8. (Yoshida, 1981) stated that a large ILD is needed to capture solar radiation. Light intensity plays a role in plant physiological processes, especially photosynthesis, respiration, and transpiration. The absorption of solar radiation by rice plants is affected by the angle of incidence of light, leaf area, position, and angle of inclination of the leaves. The more the number of leaves, the greater the solar radiation absorbed by plants for the photosynthesis process

Table 1. Average leaf area index (LAI)

Treatments	Leaf area index (DAP)						
	30	**40**	**50**	**60**	**70**	**80**	**90**
Planting time (B)							
January	0,95 a	1,26 a	1,88 a	2,18 a	2,63 a	2,69 a	3,17 a
February	0,98 a	1,42 b	1,92 a	2,38 b	2,75 b	2,72 a	3,32 b
March	1,09 b	1,77 c	2,59 b	2,84 b	2,93 c	2,98 b	3,56 c
HSD	0,04	0,07	0,05	0,03	0,04	0,04	0,04
Plant density (plant ha^{-1})							
111.111	0,62 a	0,78 a	1,52 a	1,82 a	1,72 a	1,74 a	2,10 a
166.667	0,91 b	1,49 b	1,99 b	2,29 b	2,57 b	2,54 b	3,11 b
226,667	1,49 c	2,19 c	2,87 c	3,29 c	4,02 c	4,12 c	4,84 c
HSD	0,28	0,5	0,33	0,2	0,26	0,27	0,3

Description: Numbers followed by the sama letter in the same row show no significant differences based on the HSD test at the 5% level, DAP = days after plantings

Plant Dry Weight

Table 2 shows that the planting time in March tends to be almost the same as the planting time in February. While January planting time has the lowest dry weight of plants, as well as in planting density, the planting density of 30x30 cm has an average dry weight higher than the planting density of 30x20 cm and planting density of 40x20x12.5 cm. This is as stated by Sitompul & Bambang, 1995, rice with Peta varieties that have a maximum ILD > 6 starts to experience stagnation in the addition of dry matter around the age of 75 HST. Conversely, an increase in dry matter of variety 81-B25 which has a maximum ILD < 6 continues for up to 100 days even though ILD has decreased. (Balai Besar Penelitian Tanaman Padi, 2009), stated that the level of dry weight increase in plants was strongly influenced by environmental factors and the density of tillers in rice plants.

Table 2. Average Plant Dry Weight

Treatments	Plant Dry Weight (g plant^{-1}) at the Age (DAP)						
	30	**40**	**50**	**60**	**70**	**80**	**90**
Planting Time (B)							
January	12,60 a	27,51 a	49,38 a	69,58 a	129,15 a	223,27 a	326,43 a
February	13,18 b	27,99 b	50,25 b	71,48 b	152,38 b	230,91 b	345,40 b
March	14,13 c	28,82 c	51,12 c	72,50 c	188,13 c	285,27 c	412,47 c
HSD	0,15	0,14	0,17	0,29	5,61	5,87	7,36
Plant Density (T) (plant ha^{-1})							
111.111	13,91 b	28,82 b	51,18 b	72,60 b	194,30 b	282,17 b	419,81 b
166.667	13,23 a	27,84 a	49,99 a	70,61 a	145,42 a	235,56 a	341,18 a
226,667	12,77 a	27,66 a	49,58 a	70,34 a	129,95 a	221,71 a	323,31 a
HSD	1,08	1,00	1,20	2,04	39,72	41,59	52,15

Description: Numbers followed by the sama letter in the same row show no significant differences based on the HSD test at the 5% level, DAP = days after plantings

<u>Harvest Analysis</u>

Results of the analysis of variance on rice yields per hectare showed the influence of planting time and planting density. The yield is what is obtained in the area of land in a planting period. Crop yields increased by increasing the total dry weight harvest. Yields can also be an indicator of profit or loss from the current planting period by calculating sales results in fewer expenses or capital. According to Zaini *et al*. (2017), yield is also affected by yield loss at harvest. Yield loss is a factor affecting yield per hectare of rice. Yield loss is affected by harvest age, moisture content, tool fiber, and harvest method. Besides the age that is too ripe with low water content results in unhulled grain during harvest. According to Lubis *et al*. (2013), obtained the level of yield is also determined by the population of tillers, in this case, the need for the regulation of plants that are also used as a population.

In the total analysis, panicle weight per clump (g), grain weight every clump (g), grain weight every plot (g m^{-2}), and yield per hectare (ton ha^{-1}). Shows the real difference between each planting time treatment and planting density. At the time of planting in March, showed higher results, compared with the time of planting rice in January, and the time of planting rice in February, this is because, at planting time in March, the intensity of sunlight is obtained during the higher generative phase so that plants get sunlight maximally. According to research by Purnamasari (2016), agricultural land becomes productive, one of which is by setting the planting time because planting time affects the results achieved.

Whereas, at planting density, planting density is 30x30 cm higher than planting density of 30x20 cm and planting density of 40x20x12.5 cm, this is due to the wide planting distance between treatments where the sunlight intensity becomes more optimal compared to other planting distances. According to Ikhwani *et al*., (2013), The wide spacing provides flexibility for rice varieties to grow and develop well. The difference in planting density in rice cultivation influences the intensity of solar radiation or sunlight received so it has an impact on the productivity of rice plants. According Junaidi & Rahardjo, (2021), Rice planting at a spacing of 20x 40x10 cm provides flexibility for sunlight to enter the plant so that able to increase the growth and development of the rice plant.This agrees with the research of (Alridiwirsah *et al*., 2015), low light intensity at the time of flowering rice can reduce carbohydrates that are formed, causing an increase in empty grains.

Table 3. Average rice crop harvest criteria in the treatment of planting time and planting density

Treatments	Panicle Weight per Clump (g)	Grain Weight per Clump (g)	Weight of Grain per Plots (g m^{-2})	Yield per Hectare (ton ha^{-1})
Planting time (B)				
January	5,19 a	149,59 a	860,82 a	4,7 a
February	6,37 b	210,91 b	1003,46 b	5,5 b
March	6,57 c	303,54 c	1576,09 c	9,1 c
HSD	0,14	14,70	5,31	0,03
Plant density (plant ha^{-1})				
111.111	6,98 b	264,67 b	1235,99 c	7,0 c
166.667	6,11 b	236,54 a	1131,54 b	6,4 b
226,667	5,03 a	162,83 a	1072,83 a	5,8 a
HSD	0,98	104,11	37,58	0,21

Description: Numbers followed by the sama letter in the same row show no significant differences based on the HSD test at the 5% level, DAP = days after plantings

Radiant Use Efficiency (RUE)

The average efficiency of the use of solar radiation due to the treatment of planting time and the planting density is in Table 4. The plant density of 40x20x12.5 cm shows that the radiation use efficiency (RUE) was higher than the plant density of 30x30 cm and planting density of 30x20 cm, this is influenced by the planting density of 40x20x12.5 cm, the intensity of solar radiation absorbed by plants higher, because the intensity of the sun is more efficiently absorbed by plants.

Effective upland rice planting in dry land is to regulate planting density and manipulate plants to increase yields (Faisul-ur-Rasoo *et al*., 2012). Rice productivity is through the application of cultivation technology, namely by regulating the plant population through spacing arrangements, and the row *legowo* planting system (Suhendrata, 2018). Based on the opinion of Shahbaz *et al*. (2015), the *legowo* planting system causes almost all plants such as edge plants, so that the light received by plants increases and the process of photosynthesis increases. Research by Djukri (2006) stated three ways to streamline the use of solar radiation in the field, namely by pruning, adjusting plant populations, and direction of the row of plants (location of planting).

The solar radiation received by the plant canopy is affected by the plant populations. The higher the planting population, the amount of energy that can be captured by the canopy under it will decrease. The plant population affects the growth of rice and grain produced due to competition during the vegetative and generative phases (Ahmad *et al*., 2005). Each plant has a different response to receiving solar radiation. Therefore, plant populations are regulated to increase the utilization of solar radiation. The greater the solar radiation available to plants, the process of photosynthesis increases (Zervoudakis *et al*., 2012). The increasing number of seeds per planting hole causes increased competition for light, space, and nutrients between tillers and between plant clumps to reduce the growth and production of rice plants (Hadiyanti, 2018).

In the treatment of planting time in March, the radiation use efficiency (RUE) values are higher than the planting time in January and February because the intensity of solar radiation in March is higher compared to January and February. In this study, the yields of planting time in March showed higher yields compared to planting time in January and February, which can be seen from the high radiation use efficiency (RUE) values. The efficiency of using solar radiation is the ability of plants to convert solar radiation into plant biomass. Biomass is organic material produced through the photosynthetic process (Pembengo *et al*., 1970).

Table 4. Average radiation use efficiency (RUE)

Treatments	**RUE (%)**
Planting Time (B)	
January	2,82 a
February	3,55 b
March	3,89 c
HSD	0,10
Plant Density (T)	
111.111 plant ha^{-1}	2,83 a
166.667 plant ha^{-1}	3,61 b
226,667 plant ha^{-1}	3,83 b
HSD	0,73

Description: Numbers followed by the sama letter in the same row show no significant differences based on the HSD test at the 5% level, DAP = days after plantings

Radiation that reaches the plant is streamlined to grow, develop and produce while some are reflected and transmitted to the surface. Radiation transmission is influenced by the structure of the canopy, plant type, leaf size, wind, and sun angle. Therefore the radiation deficit caused by shading factors and atmospheric conditions can influence the distribution of solar radiation and its response to plants (Yang *et al*., 2014).

CONCLUSION

The observation of yields per hectare planting time in March showed the highest yields of 9.1 ton ha^{-1} (48.13%) compared to January planting time of 4.7 ton ha^{-1} and 39.56% higher than planting time in February (5.5 ton ha^{-1}). The planting density on spacing 30x30 cm with a yield of 7.0 ton ha^{-1} is 8.57% higher than the planting density on spacing 30x20 cm with yields of 6.4 ton ha^{-1} and 17.14% higher than the planting density on spacing 40x20x12.5 cm with yields of 5.8 ton ha-1. The planting time in March has a higher RUE value than the planting time in January and February. The plant density on spacing 40x20x12.5 cm has a higher RUE value than the plant density on spacing 30x20 cm and 30x30 cm.

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