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INCREASING RICE PRODUCTIVITY IN DEGRADED PEATLANDS USING IMPROVED PLANTING METHODS AND RICE VARIETIES

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Abstract

'Sonor' farming is a local rice cultivation method practiced by communities in Ogan Komering Ilir district, South Sumatra province, Indonesia. It is a conventional rice cultivation practice that involves slash and burn land clearing without tillage. The use of fire in land clearing increases the level of degradation in peatlands. The practice is environmentally unfriendly and results in low rice productivity. This research, conducted to increase rice productivity by improving planting methods and using new high yielding varieties, was conducted in Perigi village, Pangkalan Lampam subdistrict, Ogan Komering Ilir district, South Sumatra province from December 2019 to April 2020. The research used a split-plot design, where the main plots used direct broadcasting of 25 kg ha^{-1}, direct broadcasting of 75 kg ha^{-1}, the 'Jajar Legowo' 2:1 method with a spacing of 20 x 40 x 10 cm, and transplanting (20 x 20 cm) treatments, with subplots using the Inpari 30 and Inpara 3 rice varieties. Results show improved planting methods increasing rice yields in terms of total number of tillers, number of productive tillers, number of grains per panicle, grain weight per panicle, grain weight per m^2, and plant biomass. The Jajar Legowo treatment had higher productivity than the other planting treatments, with rice productivity of 3.7 tons ha^{-1}. The Inpara 3 rice variety showed better growth and production on degraded peatlands.

Keywords: Degraded peatland, sonor farming, rice cultivation, Jajar Legowo

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1. Introduction

South Sumatra province has a peatland area of 1.28 million hectares (ha), 0.78 million ha of which is degraded peat covered with grasses and scrub [1]. Perigi village, located in Pangkalan Lampam subdistrict in Ogan Komering Ilir district, covers an area of 19,023.47 km², 75% of which is wetlands with a total peat area of 769,000 ha [2]. Peatlands in Perigi village can be classified as degraded, with diminished hydrological, production, and ecological functions. Deterioration of their chemical, physical and biological properties has decreased their productivity, with some areas becoming unproductive [3]. The people in Perigi village have long used timber from trees covering the peatlands and practiced '*sonor*' shifting cultivation in growing rice.

Sonor is the predominant rice cultivation system in Perigi village, which farmers practice during the long dry season when peatlands become very dry. With this system, farmers prepare land for rice cultivation by burning vegetation above the soil. They consider burning more effective as it reduces land preparation costs and provides a nutrient source for their rice crops. After burning, farmers broadcast rice seeds, and usually harvest the resulting rice crops in February-March [4]. As farmers usually apply this system only once a year, and carry out no crop maintenance from sowing to harvest, their rice production is very low, with average productivity of 1–2 tons ha^{-1}.

Using burning to clear land results in the loss of natural vegetation covering the peat, and impacts negatively on the peat's physical, chemical and biological properties [5]. Peat degraded by fire has low total N [6], a decreased C/N ratio in drained peat [7], and low total organic carbon value [8]. In addition, the risk of pyrite oxidation due to the construction of drainage channels also increases soil acidity [9].

The low fertility levels of peat soils require extra effort to increase rice productivity on degraded peatlands. [10] revealed that innovation and technology to increase plant productivity involve determining fertilization recommendations, the use of new high yielding varieties, and the use of appropriate plant spacing. The absence of spacing in the planting pattern usually applied by farmers can affect plant production components such as panicle length, and number of spikes per panicle, thereby affecting yield per ha. The use of 25 x 25 cm plant spacing is able to produce more tillers, panicles, and grain, where the '*Jajar Legowo*' 2:2 system is able to produce 8.17 tons ha^{-1} [11]. This study aimed to determine the growth and productivity of rice plants on degraded peatlands through improved planting methods and the use of high-yielding varieties.

2. Materials and Methods

This research was carried out on farmers' land in Perigi village, Pangkalan Lampam subdistrict, Ogan Komering Ilir district, South Sumatra province, located at 3° 06.212' S, 105° 03.751' E from December 2019 to April 2020 (Figure 1). Soil analysis was carried out at the Sampoerna Agro Palembang Laboratory, and plant analysis at the Sriwijaya University Faculty of Agriculture's Department of Agronomy Plant Physiology Laboratory. The study used a split-plot design with two treatment factors and three replications. Planting methods in the main plots consisted of broadcasting with 25 kg of seed ha^{-1}, broadcasting with 75 kg of seed ha^{-1}, and '*Jajar Legowo*' 2:1 planting, and transplanting methods, with sub plots using Inpari 30 and Inpara 3 rice varieties.

Land preparation was carried out without burning by clearing land using herbicides and removing plant residues manually. The soil was then prepared using hoes, and plots measuring 3 x 4 m were established and distanced one meter apart. Fertilizers were applied a week before broadcasting seed or transplanting seedlings at doses of 150 kg ha^{-1} urea, 100 kg ha^{-1} SP36, and 100 kg ha^{-1} KCl. Seedling preparation for the *Jajar Legowo* and transplanting treatments was carried out simultaneously with the direct broadcasting treatments. The selected seeds were soaked in water for 24 hours, then drained and incubated in moist conditions for 24 hours until they germinated. For the direct broadcasting planting methods, the germinated seeds were sown directly onto the plots according to the seed doses (25 and 75 kg ha^{-1}). Meanwhile, for the *Jajar Legowo* and transplanting treatments, the germinated seeds were first sown in plastic trays with nursery media. Fifteen-day-old seedlings were then transplanted to the treatment plots.

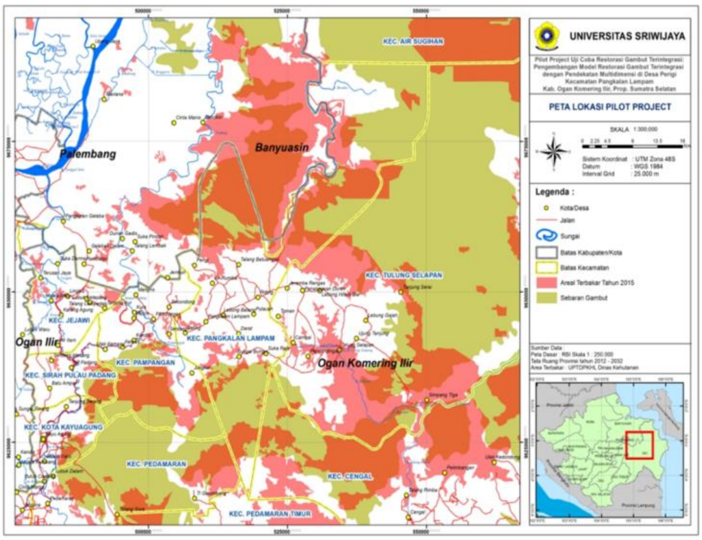

Figure 1. Research location in Perigi village, Pangkalan Lampam subdistrict, Ogan Korering Ilir district

The variables observed in this study were plant height, leaf greenery, number of tillers per m², number of productive tillers per m², weight of 1,000 grains, number of grains per panicle, weight of grain per panicle, weight of grain per m², weight of straw per m², and harvest index. The data obtained were analyzed statistically using analysis of variance, followed by a least significant difference (LSD) test at the 5% level.

3. Results and Discussion

3.1. Research results

The chemical characteristics of the soil in the experimental plots was tested before the treatments were applied, and showed the land to have a low fertility level (Table 1). Soil pH was classified as acidic (pH H_2O 4.39 and pH KCl 4.12) with high contents of Fe and soil Al and very high total organic carbon. This resulted in low nutrient availability, as seen from the low total P_2O_5 and total KCl. A high total N value accompanied by a high C/N ratio indicated low nitrogen availability.

Table 1. Results of the chemical properties analysis for soil at the research site

Soil chemical properties	Analysis method	Results[1)]	Criteria[2)]
pH H_2O	Electrometry	4.39	acid
pH KCl	Electrometry	4.12	acid
Total N (%)	Kjeldhal	1.99	high
Total organic carbon (%)	Walkey & Black	57.81	very high
C/N		29.05	high
Available-P (ppm)	Spectrophotometry	57.08	high
Available- Fe (ppm)	AAS	2,030.54	very high
Total P_2O_5 (mg/100g)	Extraction 25% HCl	114.73	low
Total KCl (mg/100g)	Extraction 25% HCl	32.23	low
Total Fe (mg/100g)	Extraction 25% HCl	716,41	high
Soil Al (Cmol/kg)	Titrimetry	5.4	very high
Conductivity	Electrometry	1,769.33	

[1)] Results of soil chemical analysis at Sampoerna Agro Palembang Laboratory, [2)] Agriculture Department 1983 [12]

Table 2. Results of analysis of variance of observed variables for two rice varieties

N	Observed variables	F-count			Coefficient of diversity	
		Planting method	Variety	Interaction	Planting method	Variance
1	Plant height					
	60 DAP	0.33^{tn}	7.31^{*}	0.29^{tn}	13.66	14.22
	90 DAP	0.74^{tn}	16.86^{**}	3.23^{tn}	7.82	9.81
	Harvest	0.96^{tn}	15.74^{**}	3.94^{tn}	9.28	9.38
2	Leaf greenness					
	60 DAP	0.36^{tn}	9.66^{*}	1.32^{tn}	8.48	3.7
	90 DAP	0.02^{tn}	3.54^{tn}	0.11^{tn}	13.41	4.45
	Harvest	0.11^{tn}	3.15^{tn}	0.13^{tn}	7.25	2.98
3	Number of tillers					
	60 DAP	12.03^{**}	51.84^{**}	7.57^{*}	30.79	1.95
	90 DAP	17.41^{**}	34.68^{**}	24.09^{**}	28.97	3.93
	Harvest	14.09^{**}	78.37^{**}	28.77^{**}	34.47	3.71
4	Productive tillers	7.09^{*}	10.30^{*}	15.17^{**}	38.77	9.96
5	Weight 1,000 grains	0.04^{tn}	0.28^{tn}	0.47^{tn}	17.66	6.61
6	Number of grains per panicle	4.81^{*}	64.61^{**}	8.24^{**}	28.99	6.53
7	Grain weight per panicle	0.38^{tn}	2.12^{tn}	3.19^{tn}	41.45	11.42
8	Percentage of filled grain	0.72^{tn}	14.72^{**}	1.11^{tn}	43.94	10.94
9	Grain weight per m^2	33.93^{**}	6.30^{*}	4.50^{*}	21.17	16.22
10	Straw weight per m^2	18.81^{**}	0.45	6.80^{*}	37.34	5.98
11	Harvest index	4.98^{*}	10.46^{*}	5.76^{*}	11.06	7.65
	F- Table 0.05	4.76	5.32	4.07		
	F-Table 0.01	9.78	11.26	7.59		

Notes: ^{tn}: not significant, *: significant **: very significant. DAP = days after planting.

The results of analysis of variance (Table 2) show planting treatment having a significant effect on the number of productive tillers per m², number of grains per panicle, grain weight per m², straw weight per m², and harvest index, and a very significant effect on the number of tillers per m² at 60 DAP, 90 DAP and harvest. While the two tested varieties showed differences in plant height at 60 DAP, leaf greenness at 60 DAP, number of grains per panicle, productive tillers per m², and harvest index, and very significant effects on the plant height at 90 DAP and productive number of tillers per m² variables. The results also show an interaction between planting treatment and variety on number of tillers per m² at 60 DAP, 90 DAP and harvest, number of productive tillers per m², number of grains per panicle, weight of grain per m², weight of straw per m² and harvest index.

Plant Growth Components

The results show there was no interaction between planting treatment and variety on the plant height variable (Table 3). Although the planting treatment did not affect the plant height variable, average plant heights for the *Jajar Legowo* and transplanting treatments tended to be higher than for the direct broadcast treatments. Of the two varieties tested, Inpara 3 produced higher plant heights than Inpari 30. Meanwhile, the leaf greenness variable also showed no interaction between planting treatment and variety. The Inpara 3 variety tended to have a higher greenery level than Inpari 30 during the observation period (Table 4).

Table 3. Plant height of the two rice varieties in the different planting treatments during the observation period

Treatment	Plant age		
	60 DAP	90 DAP	Harvest
Main plots			
Direct broadcasting 25 kg ha^{-1}	48.06 a	69.67 a	74.60 a
Direct broadcasting 75 kg ha^{-1}	50.38 a	69.60 a	74.22 a
Jajar Legowo 2:1	46.60 a	71.83 a	77.45 a
Transplanting	48.21 a	73.69 a	80.33 a
LSD 5%	9.32	7.89	10.05
Subplots			
Inpari 30	44.52 a	65.34 a	70.83 a
Inpara 3	52.10 b	77.05 b	82.47 b
LSD 5%	6.47	6.58	6.772

Note: Numbers in the same column in each treatment followed by the same letter were not significantly different in the 5% LSD test. DAP = days after planting.

Table 4. Level of greenness of leaves for the two rice varieties in the different planting treatments during the observation period

Treatment	Plant age		
	60 DAP	90 DAP	Harvest
Main plots			
Direct broadcasting 25kg ha^{-1}	39.58 a	41.12 a	36.06 a
Direct broadcasting 75 kg ha^{-1}	39.28 a	40.42 a	35.31 a
Jajar Legowo 2:1	40.98 a	40.70 a	35.99 a
Transplanting	40.70 a	40.57 a	35.59 a
LSD 5%	4.81	7.71	3.66
Subplots			
Inpari 30	39.15 a	40.01 a	35.35 a
Inpara 3	41.12 b	41.40 a	36.12 a
LSD 5%	1.46	1.71	1.00

Note: Numbers in the same column in each treatment followed by the same letter were not significantly different in the 5% LSD test. DAP = days after planting.

Different results were found in the growth comonent of the number of tillers m^{-2} where there was an Different results were found in the numbers of tillers per m^2 where there were interactions between planting treatment and variety at all planting ages. Both Inpari 30 and Inpara 3 showed higher numbers of tillers per m^2 than the other treatments, namely 360.8 and 379.5 respectively, whereas Inpara 3 tended to be higher in these treatments. At 90 DAP and harvest, the *Jajar Legowo* 2:1 treatment showed higher yields for both varieties. Inpari 30 tended to have a higher yield with the *Jajar Legowo* planting treatment at 90 DAP and harvest, while the Inpara 3 variety tended to be higher with the transplanting treatment at 90 DAP and harvest (Figure 1). In general, the *Jajar Legowo* planting treatment produced higher numbers of tillers (Table 5).

Table 5. Numbers of tillers per m^2 for the two rice varieties in the different planting treatments at all ages

Observation variable	Number of tillers (60 DAP)	Number of tillers (90 DAP)	Number of tillers (Harvest)
Main plots			
Broadcasting 25 kg ha^{-1}	144.67 a	173.00 a	146.83 a
Broadcasting 75 kg ha^{-1}	168.17 a	202.50 a	191.50 a
Jajar Legowo 2:1	370.15 c	500.50 c	484.55 c
Transplanting	294.17 b	398.33 b	379.58 b
LSD 5%	106.27	130.38	146.38
Subplots			
Inpari 30	237.29 a	303.55 a	280.48 a
Inpara 3	251.29 b	333.63 b	320.75 b
LSD5%	4.47	11.79	36.23

Notes: Numbers followed by the same letter in the same column were not significantly different in the 5% LSD test; DAP = days after planting.

Table 6. Number of productive tillers per m^2 for the two rice varieties in the different planting treatments at all ages

Variety	Planting treatment				Variance
	Broadcasting 25 kg	Broadcasting 75 kg	*Jajar Legowo*	Transplanting	
Inpari 30	83.67 a	109.33 a	336.60 c	221.67 b	187.82 a
Inpara 3	157.00 a	181.33 a	274.45 c	243.33 b	214.03 b
Planting method	120.33 a	145.33 a	305.53 c	232.50 b	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (113.22); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (18.84); numbers followed by the same letter in the planting method were not significantly different in the LSD 5% test (110.05)

Table 7. Total number of grains per panicle for the two rice varieties in the different planting treatments

Variety	Planting treatment				Variance
	Broadcasting 25 kg	Broadcasting 75 kg	*Jajar Legowo*	Transplanting	
Inpari 30	42.60 a	36.63 a	70.30 c	81.40 c	57.73a
Inpara 3	64.70 b	57.97 a	81.15 c	82.56 c	71.60b
Planting method	53.65a	47.30a	75.73b	81.98 c	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (27.08); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (3.98); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (26.49)

Yield Components

Research results on yield components included number of productive tillers per m², number of grains per panicle, weight of grain per panicle, weight of 1,000 grains, weight of grain per m², dry weight of straw per m² and harvest index. The numbers of productive tillers per m² showed interactions between planting treatment and the two varieties. The use of the *Jajar Legowo* planting treatment for Inpari 30 and Inpara 3 varieties resulted in higher numbers of productive tillers per m² than the other treatments, where Inpari 30 tended to perform better with this planting method. Meanwhile, Inpara 3 tended to perform better than Inpari 30 with the transplanting treatment (Figure 2). In general, improved planting methods produced significantly higher numbers of productive tillers than the *sonor* method carried out by farmers. The *Jajar Legowo* 2:1 planting treatment produced higher numbers of tillers than all other planting treatments. Table 6 shows that Inpara 3 generally produced more productive tillers than Inpari 30.

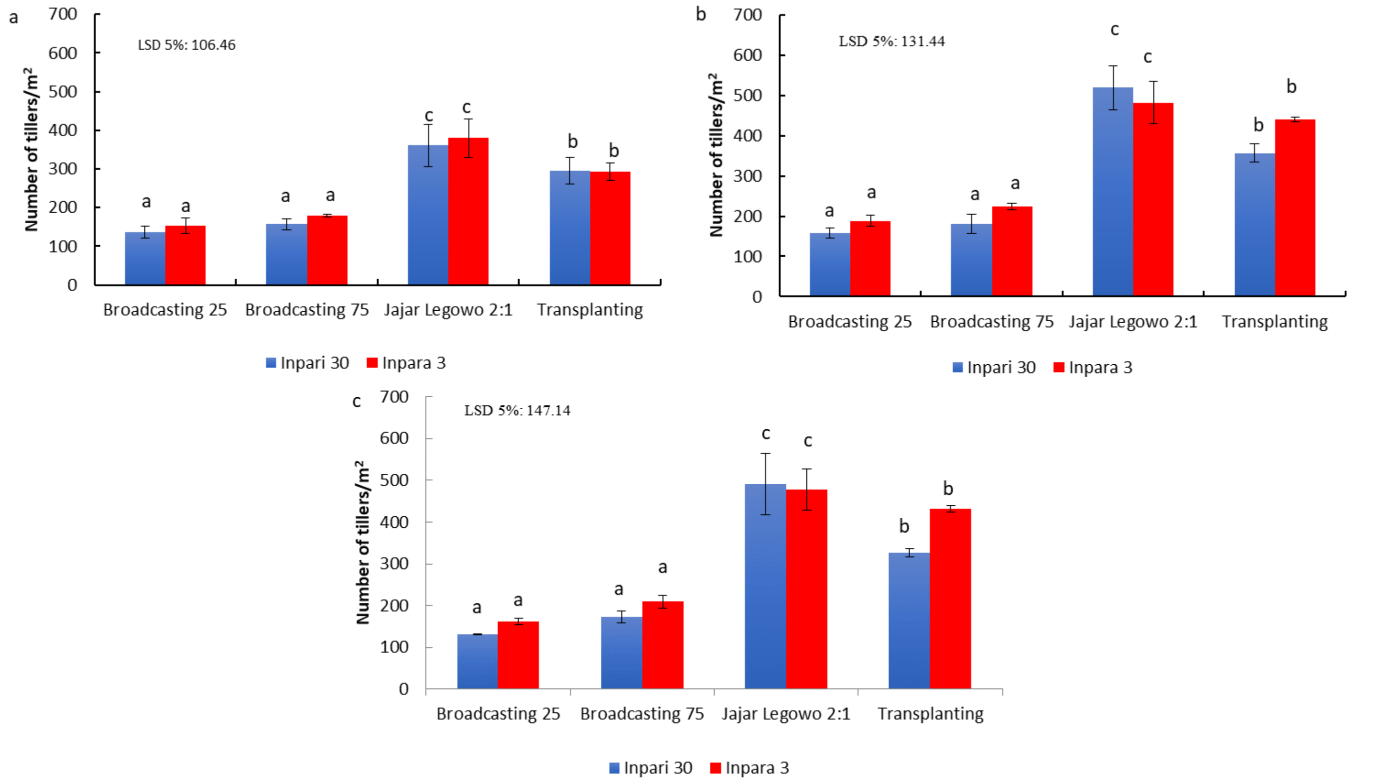

Figure 2. Interaction of planting treatment on number of tillers per m² for both rice varieties at different ages of observation (a: 60 DAP; b: 90 DAP; c: harvest)

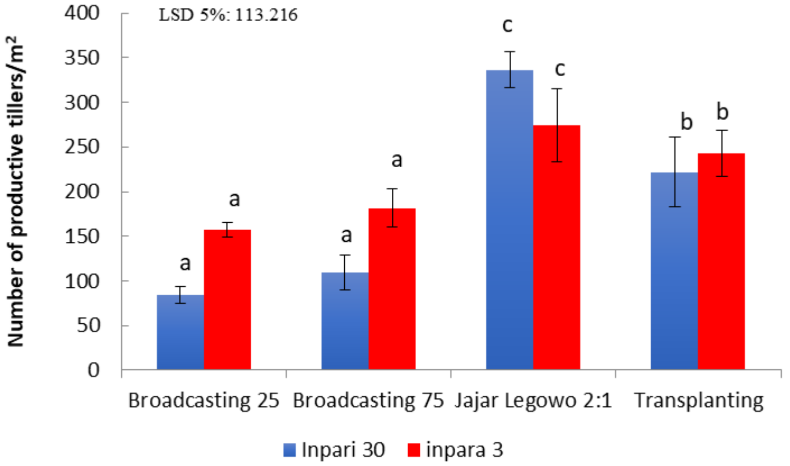

Figure 3. Interactions between planting treatment and rice variety on number of productive tillers per m²

The results of the least significant difference (LSD) test on the number of grains per panicle variable showed the *Jajar Legowo* and transplanting treatments being better than other treatments (Figure 4). Though the transplanting treatment generally tended to produce more grains per panicle with both varieties, transplanting performed better than other treatments, and using Inpara 3 tended to produce a higher number of grains per panicle at 71.6 (Table 7).

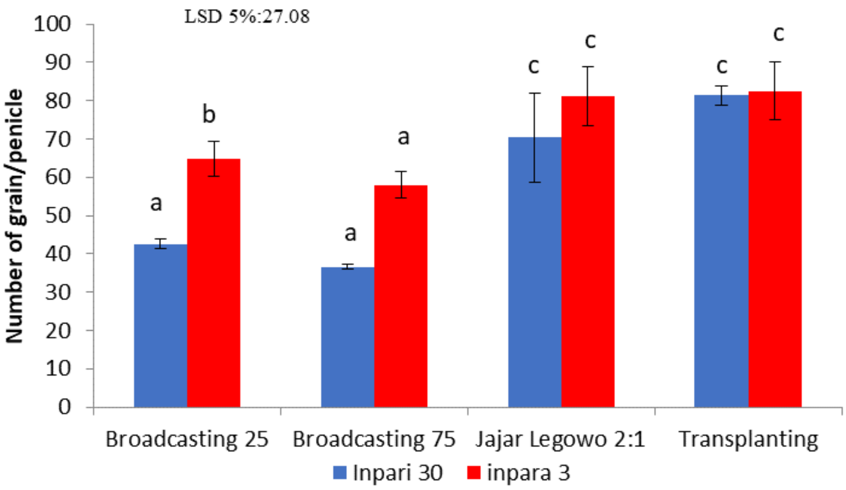

Figure 4. Interaction of planting treatment on number of grains per panicle for both varieties at various ages of observation

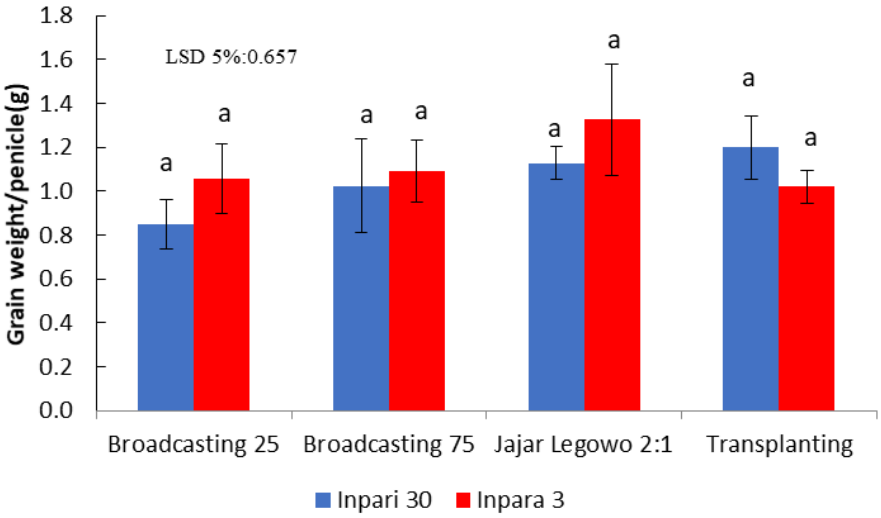

Figure 5. Interaction of planting method on grain weight per plant panicle for both varieties

Table 8. Grain weight per panicle for the two rice varieties in the different planting treatments

Variety	Planting treatment				Variance
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	0.85a	1.02a	1.13a	1.20a	1.05a
Inpara 3	1.06a	1.09a	1.33a	1.02a	1.12a
Planting method	0.95a	1.06a	1.23a	1.11a	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (0.66); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (0.12); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (0.64).

Table 9. Percentages of filled grains for the two rice varieties in the different planting treatments

Variety	Planting treatment				Variance
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	67.75a	70.25a	59.21a	47.77a	61.25b
Inpara 3	50.93a	59,71a	54.10a	41.56a	51.57a
Planting method	59.34a	64.98a	56.66a	44.66a	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (35.97); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (5.81); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (35.02)

Table 10. Weight of 1,000 grains for the two rice varieties in the different planting treatments

Variety	Planting treatment				Variance
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	24.397 a	23.273 a	25.490 a	24.437 a	24.399 a
Inpara 3	23.367 a	23.900 a	24.313 a	24.620 a	24.050 a
Planting method	23.882 a	23.587 a	24.90 a	24.528 a	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (6.41); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (1.52); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (6.04)

Table 11. Grain weight per m² for the two rice varieties in the different planting treatments

Variety	Planting treatment				Variance
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	70.73 a	109.31 ab	379.50 e	262.33 d	205.47 a
Inpara 3	165.67 bc	197.75 cd	358.60 e	248.94 d	242.74 b
Planting method	118.20 a	153.53 a	369.05 c	255.64 b	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations were not significantly different in the LSD 5% test (82.66); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (34.24); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (67.03)

Table 12. Weight of straw per m² for the two rice varieties in the different planting treatments

Variety	Planting Treatment				Variance
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	67.25 a	76.04 a	320.52 b	273.97 b	184.45 a
Inpara 3	74.98 a	108.48 a	316.93 b	249.56 b	187.49 b
Planting method	71.11 a	92.26 a	318.73 c	261.76 b	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations are not significantly different in the LSD 5% test (99.20); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (10.47); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (98.10)

Meanwhile, results of the grain weight per panicle yield component showed the *Jajar Legowo* planting treatment tending to produce higher grain weight than other treatments, with grain weight for Inpara 3 tending to be higher than for Inpari 30 using this treatment. Meanwhile, Inpari 30 tended to have heavier grain per panicle weight with the transplanting treatment (Figure 4). The percentage of filled grains yield component was generally influenced by the treatment, with Inpari 30 having a higher percentage of pith than Inpara 3. However, the broadcasting 75 kg ha^{-1} treatment tended to produce higher percentages of filled grains with both varieties (Table 9).

In the grain weight per m² yield component, Inpari 30 and Inpara 3 had higher grain weights (g) per m² in the *Jajar Legowo* 2:1 than other treatments, at 379.5 g per m² and 358.6 g per m², respectively. Inpara 3 had the highest productivity with the *Jajar Legowo* 2:1 planting treatment (Figure 5). High yield of dry grain per m² was inversely proportional to yield index.

In general, this shows the 25 kg ha^{-1} and 75 kg ha^{-1} broadcasting methods having higher harvest indices (0.62 and 0.6 respectively) than the *Jajar Legowo* 2:1 and transplanting 20 x 20 cm treatments (0.54 and 0.49 respectively), with Inpara 3 tending to show higher yield than Inpari 30 (Table 13). These results related to the dry weight of straw component, where *Jajar Legowo* 2:1 resulting in a higher dry weight of straw with the Inpari 30 variety, but in contrast for the transplanting 20 x 20 cm resulting in a higher dry weight of straw with the Inpara 3 variety. In general, *Jajar Legowo* 2:1 and transplanting 20 x 20 cm had heavier dry straw weights than the 25 kg ha^{-1} and 75 kg ha^{-1} seed broadcasting treatments. The *Jajar Legowo* 2:1 treatment produced a slightly heavier weight than the transplanting 20 x 20 cm treatment at 318.728 g per m² and 261.762 g per m², respectively. The 25 kg per m² seed broadcasting treatment resulted in the lowest dry weight of straw, at 71,875 g per m². Inpara 3 had a higher dry weight of straw than Inpari 30 at 187.485 g per m² and 184.445 g per m², respectively (Table 12).

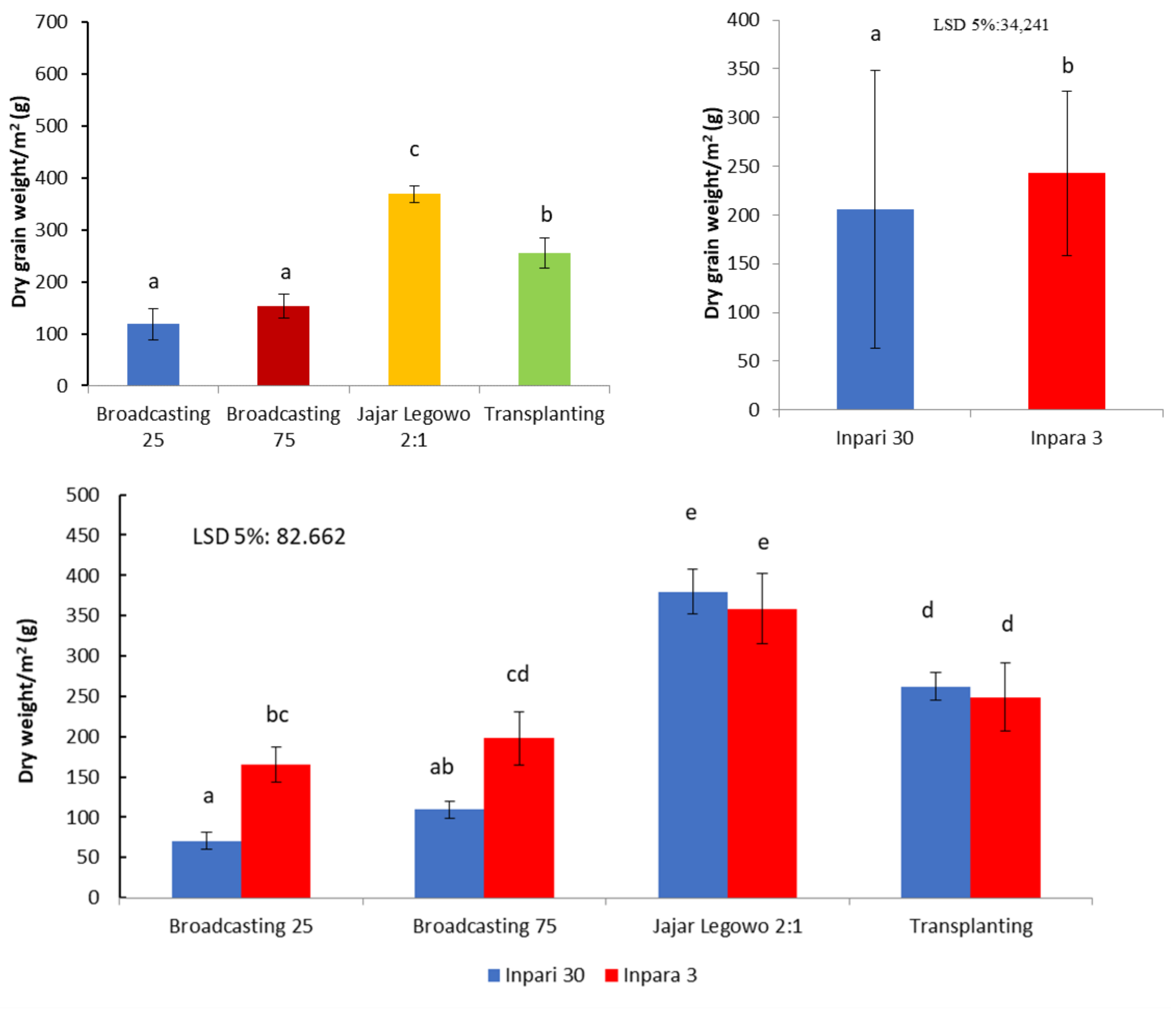

Figure 5. Interaction of planting treatment on dry grain weight per m² for both rice varieties

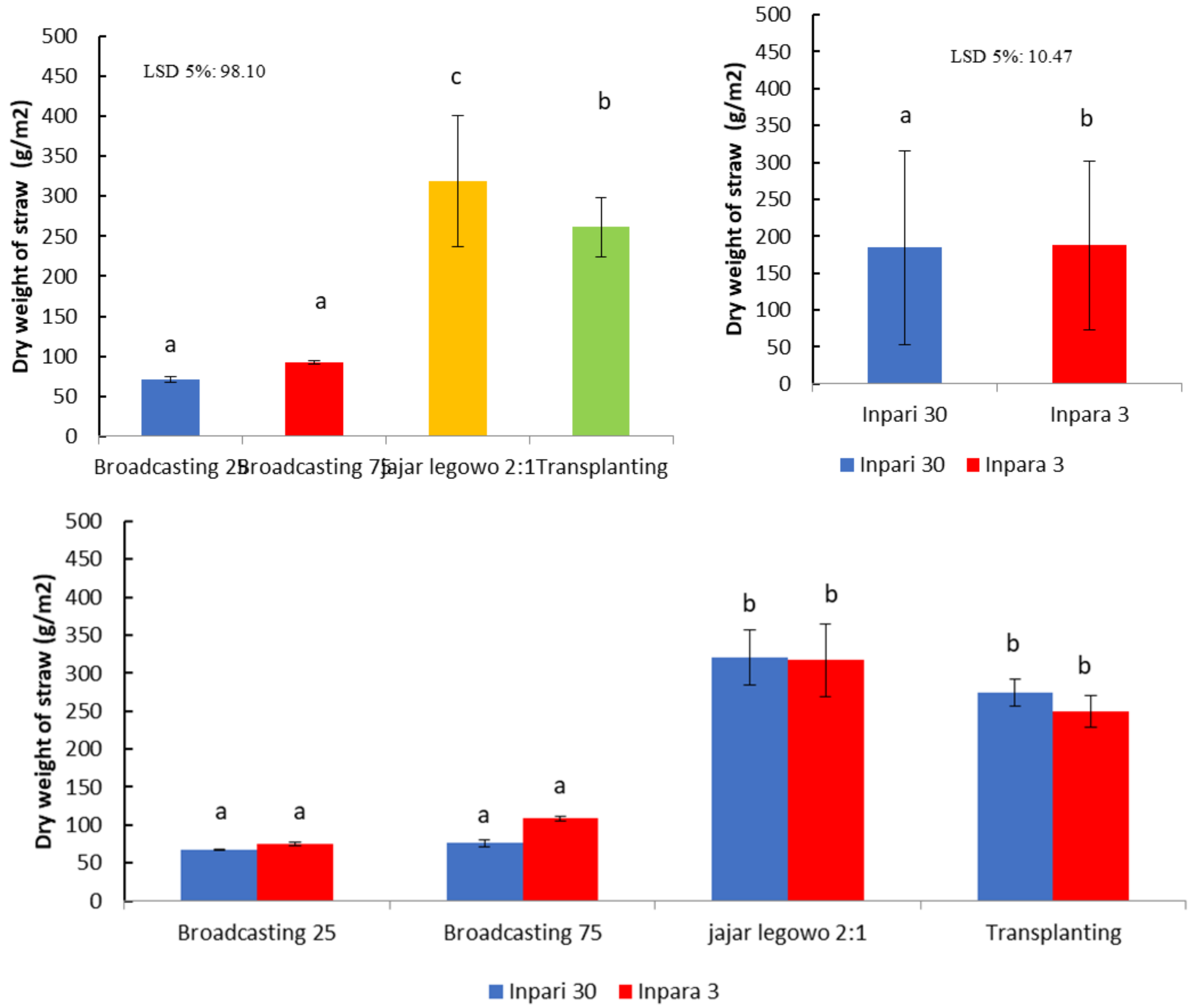

Figure 6. Interaction of planting method on dry weight of straw per m² for both rice varieties

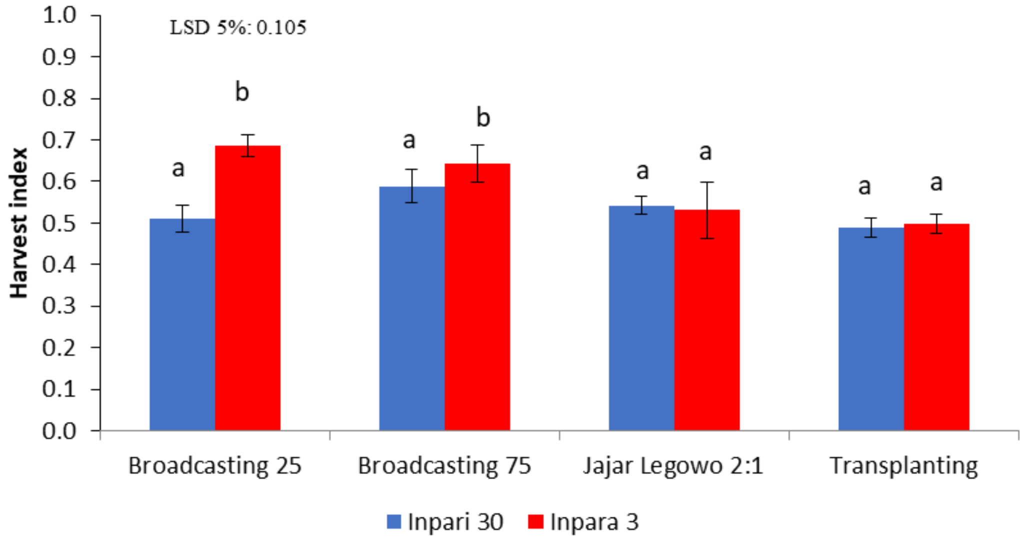

Figure 7. Interaction of planting method on harvest indices for both rice varieties

Table 13. Harvest indices of the two rice varieties in different planting treatments

Variety	Planting treatment				Varieties
	Broadcasting 25	Broadcasting 75	*Jajar Legowo*	Transplanting	
Inpari 30	0.51 a	0.59 a	0.54 a	0.49 a	0.53 a
Inpara 3	0.69 b	0.64 b	0.53 a	0.50 a	0.59 b
Planting method	0.60 b	0.62 b	0.54 a	0.49 a	

Notes: Numbers followed by the same letter in the same row and column, for treatment combinations are not significantly different in the LSD 5% test (0.10); numbers followed by the same letter in the planting treatment columns were not significantly different in the LSD 5% test (0.04); numbers followed by the same letter in the planting method row were not significantly different in the LSD 5% test (0.09)

Peatlands that have been damaged (degraded) undergo changes in their soil physical, chemical and biological properties [3]. Table 1 shows that the degraded peat in the study area has a low pH value of 4.23 (acidic) with a high percentage of total organic C (55%). There is a negative correlation between total organic C and soil pH. [13] explained that peat originating from heaps of organic matter contains high levels of phenolic acid which causes it to become acidic, or even very acidic, accompanied by a decrease in base saturation. Types of phenolic acids found in soil are vanillic, p-coumaric, p-coumaric benzonic, salicylic, gallic, gentisic, and suric acids.

The low pH soil contains metals such as Fe and Al. Table 1 shows soil containing very high levels of Fe and soil Al at 2,040.54 ppm and 5.4 Cmol kg^{-1} respectively, which are sources of the acidity. This also affects the availability of microelements such as Cu, Mn, and Zn [14]. The same thing was conveyed by [15] who indicated low fertility being an impact of lower base content of Ca, Mg and K due to high soil Al. At study, the total of Nitrogen and Phosfor are very high, but they are still in organic form and need mineralization process so that can be absorbed by plants. [14]. This accords with research by [16], which showed high total N accompanied by a high C/N ratio can result in low available N because plants only absorb N in the form of NH^+ and NO_3 where the mineralization process takes place slowly at low pH. From the descriptions above, the peat in the site is degraded, nutrient poor and prone to poisoning.

The use of spacing applied to both Inpari 30 and Inpara 3 varieties had an effect on several growth and plant yield components. Growth components tended to be affected by the ability of both varieties to adapt to the environment. The plant height growth component was classified as low, where rice plants with heights below 110 cm fall into the low category [17]. In the variety description issued by the Indonesian Center for Rice Research (BBPADI), Inpara 3 plants have an optimum height of 108 cm; taller than Inpari 30 at only 101 cm.

This difference in plant height is thought to be the result of the peatlands low pH soil limiting the content of available macroelements (N, P, and K). Nevertheless, Inpara 3 was able to adapt reasonably well due to its slightly acid tolerant nature. [18] said tall plants do not guarantee high yields, and genetic and environmental factors will affect the growth of a plant. Each plant will have a different ability to utilize and adapt to its environment, which can affect crop yield [19]. Plants increase in height with age, but the rate of growth will decrease when the rice plant enters the generative phase.

Different spacings and varieties affect numbers of tillers and rice yield components. This could be seen in the numbers of tillers per m² at all planting ages. Rice tillers are special branches that are formed on the basal internodes of stems that are not elongated and grow independently of the parent stem through their own adventitious roots [20]. The first tillers will emerge from the main stem when the plant enters the fourth phyllochron [21] and will continue to grow until the panicle initiation phase, then there will be a decrease in the number of tillers due to death until the maturity phase [22]. The death of saplings can be due to developing saplings competing with other reproductive organs such as flowers and grains to obtain assimilates. [23] said it is possible that the beginning of the emergence of reproductive organs in the parent stem is a stimulus to induce simultaneous flowering followed by a programmed monocarpic aging process in all tillers.

The broadcasting treatments produced the lowest numbers of tillers compared to the other treatments. Increasing numbers of seeds sown in the hope of increasing the plant population is ineffective as it actually results in competition for nutrients between individual plants and even results in overlapping where some seeds fail to grow or even die. Meanwhile, the use of too few seeds in broadcasting treatments causes a lot of empty spaces which become overgrown with weeds leading to competition between plants and weeds. Such systems, especially in the rainy season, will also result in seed loss due to being carried away by rainwater [24].

With the *Jajar Legowo* treatment at a spacing of 2:1, the number of plants per hectare was 32% higher than with the 20 x 20 cm transplanting treatment. In addition, the *Jajar Legowo* 2:1 treatment had an edge planting effect with better growth and development [11]. The plant spacing resulted in low competition for nutrients and water, and plants being able to receive optimal solar radiation. [11] stated that closely spaced plants are expected to experience stress vigor which can affect the number of tillers. In addition, the presence of overlapping or mutual shading will result in a decrease in the rate of plant assimilation. This is also in line with [25] who shows that in addition to good genetics and a suitable growing environment, appropriate spacing also determines the maximum number of tillers a variety can produce. Narrow spacing will prevent shoots from growing into tillers due to a lack of energy support from primary tillers, resulting in tiller competition in one clump [5]. The large number of tillers produced is expected to produce a greater number of productive tillers where the number of panicles produced will also increase. However, the number of panicles formed depends on the availability of water, sufficient nutrients, solar intensity and optimum temperature [11] and the number of tillers that appear in the primordial phase [26].

The *Jajar Legowo* 2:1 treatment produced a higher dry grain yield than the other cropping treatments, at 369.05 g per m² or 3.69 tons ha^{-1}, with the Inpara 3 variety showing higher average productivity than Inpari 30. The *Jajar Legowo* 2:1 treatment resulted in the highest number of tillers, produced a higher number of panicles, and allowed higher productivity. This accords with [15] who showed yield components such as a higher number of tillers will also produce high grain yields.

The use of spacing in cultivation allows rice plants to take advantage of the existing empty space in utilizing sunlight so that photosynthesis can run optimally. This is in line with [27] where rice production is thought to be influenced by the level of inter-plant density which has implications for the formation of the number of panicles per plant. The use of plant spacing results in changes in the conditions of the microenvironment around the plant [28]. Changes in the microclimate environment will affect the formation of grains, which accord with the rate of plant photosynthesis. The rate of plant photosynthesis is limited by CO_2 levels around the leaves (canopy), so that the use of closer or irregular spacing results in crushing between leaves that affect CO_2 competition in the canopy [5].

Different results were obtained for the harvest index variable, where the direct broadcasting treatments of 25 kg ha^{-1} and 75kg ha^{-1} had higher harvest indices than the *Jajar Legowo* 2:1 and 20 x 20 cm transplanting treatments with values of 0.599 and 0.616, respectively. In general, the varietal factor also had a significant effect, where Inpara 3 had a higher harvest index at 0.59 than Inpara 30 at 0.533. The use of spacing resulted in a lower harvest index than the tabular planting treatments. A lower harvest index means that the grain weight is lower than the total plant weight. The use of spacing encouraged the formation of more tillers, which produced a higher dry weight of straw. This accords with [5], who stated that this occurs because more nutrients go to leaves so plants become more fertile, but yield is reduced due to the large amounts of straw produced. Plants will obtain a high harvest index often with an increase in seed set and weight per panicle. However, the harvest index will decrease if there is an increase in crown mass, panicle length and plant height [29].

The low yield percentages obtained in this study are thought to be due to environmental factors, pests and diseases [30]. The chemical characteristics of the low pH soil in the study site resulted in essential elements such as N, P, and K not being available in sufficient quantities. In rice crops, the P element plays a role in starch formation and grain filling processes that make up ATP, ADP, RNA, DNA and the nucleotides NAD/NADP and FAD. P and K play a role in the grain ripening process, while N plays a greater role in the preparation of amino acids that make up the plant body [31]. So, if a rice plant lacks P, it will produce less panicle grain, and have a higher percentage of pith. Provision of ameliorants is necessary to increase soil pH so that nutrients become available to plants.

4. Conclusion

From the results of this study it can be concluded that the use of spacing in cultivating rice on degraded peatlands produced more favorable results in terms of the number of tillers per m², number of productive tillers per m², number of seeds per panicle, weight of grain per panicle, weight of grain per m², and weight of straw per m² variables. Meanwhile, the direct broadcasting treatments resulted in a higher harvest index. The use of the *Jajar Legowo* 2:1 planting treatment was better for the number of tillers per m², number of productive tillers, grain weight per panicle, grain weight per m², and straw weight per m² variables. The 20 x 20 cm transplanting treatment performed better for the number of grains per panicle variable. The productivity of the *Jajar Legowo* 2:1 treatment was higher than the other planting treatments at 3.7 tons ha^{-1}. In this study, the Inpari 3 variety tended to be more adaptable than Inpari 30.

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