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Response of Various Promising Lines of Red Rice to Two Levels of Watering following Different P Fertilizer Doses

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***Abstract*— *This study aimed to examine the response of various red rice promising lines on several levels of watering and residues of P fertilizers of the preceding rice by conducting a pot experiment testing two treatment factors, i.e. red rice genotypes (19 promising lines) and levels of watering (220 or 330 ml/pot per application), and used residues of P fertilizer doses (0, 100 and 200 kg/ha SP36) applied to the preceding rice plants as the blocks (replications) under Randomized Complete Block design. The results indicated that there were significant interaction effects of the treatment factors on grain yield and weight of 100 grains of the red rice. The P fertilizer doses applied to the preceding rice plants also affected grain yield of red rice, and reduction in levels of watering significantly reduced grain yields, most possibly due to significant increase in the percentage of unfilled grains, which had the most significant negative relationship with grain yield. The genotypes showing the highest yield potential under sufficient watering appeared to be most adversely affected by reduction in levels of watering, such as G1, G2, G8, G9, and G18, with grain yield of 20.47, 18.04, 17.86, 16.85 and 18.27 respectively. However, there were three genotypes having relatively high grain yield showing non-significant effect of reduction in watering level, i.e. G4, G5 and G17. Levels of P fertilization to the preceding rice plants also significantly affected grain yield of the following rice plants, most probably due to their effects on the percentage of unfilled grain number.*

***Keywords*—Red rice, promising lines, watering, P-fertilizer doses**

I. INTRODUCTION

As a staple food crop, rice is consumed by over 5 billion people in the world [1]. In Indonesia, rice (*Oryza sativa* L.) is the most common staple food crop. Although white rice is the most common in the market, in terms of the color of the kernel, there are other types of rice produced in Indonesia, including under research projects conducted by the staff of the Faculty of Agriculture, University of Mataram, i.e. red and black rice. According to Handayani et al. [2], these types of colored rice or pigmented rice contain antioxidant compounds, and the color of the kernel is due to anthocyanin pigment contained in different layers of pericarp, seed coat and aleurone [1]. Anthocyanins are phenolic compounds including flavonoid group and act as antioxidants, which also play an important role for the plant itself as well as for human health. The roles of antioxidants for human health are many, such as to prevent liver disease (hepatitis), colon cancer, stroke, diabetes. They are also essential for brain function and reduce the effects on brain aging. Anthocyanin content in red rice is in a range of 0.34 to 93.5 mg/g [3, 4]. Currently, the need for red rice continued to increase in line with public awareness of the health benefits from consuming red rice and its products [5].

In Indonesia, red rice is one of the germplasms which existence is increasingly scarce due to the planting of new (white) rice varieties. Cultivation of red rice by the farmers is generally at high altitudes, grown as upland rice, which has a low yield (2 tons/ha), also with low quality [6]. To increase the rice production in Indonesia the government now needs to think about the utilization of dry land and/or marginal land, because the total area of irrigated land is getting narrow as a result of the continuing high rate of conversion of fertile paddy land into non-agricultural lands, which is still unstoppable, especially for housing, offices and shops around towns [7, 8]. As a consequence, the production of food crops in the future, especially rice, will have to be implemented on sub-optimal land areas, which are in the forms of dry land and marginal land. Therefore, to achieve self-sufficiency in food production, especially rice, innovative production technology that can take advantage of dry land and marginal land will be needed.

To achieve food self-sufficiency, in order to keep pace with population growth in Indonesia, there is no choice except to take advantage of the available dry land for production of rice, which is the main staple food for Indonesian people. Therefore, developing drought tolerant rice varieties needs to be done. This study aimed to examine performance of various red rice lines under different watering and residues of P fertilizer doses applied to the preceding upland red rice in pot culture.

II. MATERIALS AND METHOD

In this study a pot experiment was carried out in the plastic house built in the experimental farm of the Faculty of Agriculture, University of Mataram, which is located in Narmada (West Lombok, Indonesia). The experiment was conducted from September to the end of December 2015.

This experiment was carried out following a pot experiment examining the effects of two levels of watering and three doses of SP36 (36% P_2O_5) fertilizer (0, 100 and 200 kg/ha SP36) on growth of several upland red rice lines (in which 150 kg/ha SP36 was the recommended dose) [9]. Therefore, in this study, the experiment was arranged according to Randomized Complete Block Design with three blocks (replications) in the three levels of P fertilization doses of the previous experiment, and in this experiment, there were two treatment factors tested, namely genotypes (G) of various red rice lines (19 genotypes: Amp-G1, Amp-G2, M-G3, Amp-G4, M-G5, M-G6, M-G7, M-G8, M-G9, Amp-G9, Amp-G10, M-G11, M-G12, M-G13, M-G14, M-G15, M-G16, M-G17, M-G18) and levels of watering (W), consisting of 2 treatment levels, i.e. watering with 200 ml/pot (W1) and 300 ml/pot (W2), during the vegetative stage.

During the first experiment, the soil used as growing media to fill the pots was taken from topsoil of different dryland paddocks located in Tempos village of Gerung district (West Lombok, Indonesia), in which different crops were grown on different paddocks (cassava, maize and peanut), but the soil in all paddocks are in the category of entisol soil type. However, the pots used to grow various red rice lines in this experiment were those which were filled with top soil taken from the groundnut paddock. The procedures for the implementation of the preceding and this experiment are as explained in Nurlaili et al. [9], except for the P dose applied in this experiment was only half the recommended dose (75 kg/ha SP36).

Observations were made on growth variables (plant height, number of leaves, number of tillers), filled grain number per pot, dry grain yield per pot, weight of 100 grains, and percentage of unfilled grain number. ANOVA and Tukey's HSD at 5% level of significance were used to analyze the data using CoStat for Windows ver. 6.303.

III. RESULTS AND DISCUSSION

Based on the results of ANOVA summarized in Table 1, there was a significant residual effect of the previous P fertilizer treatments which functioned as blocks in this experiment, except for the tiller number at 5 weeks after seeding (WAS). Levels of watering had significant effects on all measurement variables. Genotypes are also significantly different except in terms of average growth rate (AGR) of plant height and percentage of unfilled grain number. However, there were significant interaction effects between genotypes and levels of watering on grain yield per pot and weight of 100 filled grains. Furthermore, from the influence of each treatment factor (main effect), it appears that only a few genotypes shows significant differences in growth variables and yield components, while the level of watering shows significant effects on all observation variables, in which the higher level of watering resulted in higher growth variables as well as higher yield and yield components of red rice (Table 2).

Table 1. Effects of treatments and blocks on growth and yield of various promising lines of red rice

Source of variation	Plant height 5 WAS	Leaf number 5 WAS	Tiller number 5 WAS	AGR of plant height [1]	AGR of leaf number	Filled grain number	Dry grain yield	100 grain weight	%-unfilled grain number
Block (P residue)	*	*	ns	*	*	***	***	***	***
Genotypes	**	*	**	ns	*	***	***	**	ns
Watering	***	***	***	***	***	***	***	*	***
G x W	ns	ns	ns	ns	ns	ns	**	**	ns

Remarks: [1)] data were transformed into √x; ns = non-significant; *, **, *** = significant at p<0.05; p<0.01; p<0.001, respectively

Table 2. Main effects of genotypes of red rice line (G) and watering levels (W) on plant height, leaf number, and tiller number at 5 WAS, and average growth rates (AGR) of plant height and leaf number, and filled grain number, dry grain yield, weight of 100 grains, and percentage of unfilled grain number of various red rice lines

Treatments	Plant height (cm) 5 WAS	Leaf number 5 WAS	Tiller number 5 WAS	Plant height AGR (sqr cm) [1)]	Leaf number AGR	Filled grain number per pot	Dry grain yield (g/pot)	100-grain weight (g)	%-Unfilled grain number
Genotypes:									
G1	43.1 b	51.3 ab	16.0 ab	0.89 b	1.76 ab	733.7 a	15.64 abc	2.08 ab	34.69 a[2)]
G2	49.4 ab	51.5 ab	16.0 ab	0.97 ab	1.83 a	575.2 abc	13.23 abcd	2.27 ab	31.94 a
G3	44.9 ab	54.7 a	17.0 a	0.95 ab	1.88 a	557.8 abc	12.83 abcd	2.28 ab	32.95 a
G4	46.2 ab	47.5 ab	15.7 ab	0.92 ab	1.68 ab	598.3 abc	14.80 abcd	2.52 ab	35.17 a
G5	51.2 ab	43.5 ab	13.2 ab	1.01 ab	1.47 ab	641.5 abc	14.24 abcd	2.24 ab	33.10 a
G6	44.8 ab	47.3 ab	15.3 ab	0.90 ab	1.71 ab	468.2 c	11.92 abcd	2.55 a	29.11 a
G7	46.5 ab	39.2 ab	11.2 b	0.98 ab	1.36 ab	572.5 abc	11.05 bcd	1.93 b	34.01 a
G8	46.6 ab	43.5 ab	16.0 ab	0.97 ab	1.49 ab	631.0 abc	14.16 abcd	2.30 ab	26.80 a
G9	52.8 a	44.3 ab	13.2 ab	1.03 ab	1.53 ab	637.7 abc	13.28 abcd	2.05 ab	32.83 a
G10	46.9 ab	44.5 ab	13.7 ab	0.94 ab	1.55 ab	521.7 bc	11.57 abcd	2.24 ab	34.09 a
G11	47.7 ab	47.5 ab	14.0 ab	0.99 ab	1.62 ab	577.5 abc	13.78 abcd	2.36 ab	31.13 a
G12	49.4 ab	46.3 ab	14.0 ab	1.01 ab	1.57 ab	706.5 ab	16.45 a	2.34 ab	34.31 a
G13	51.2 ab	41.8 ab	13.3 ab	1.07 a	1.46 ab	489.5 c	10.11 d	2.04 ab	35.09 a
G14	46.7 ab	46.2 ab	15.5 ab	0.96 ab	1.63 ab	721.8 ab	16.38 ab	2.31 ab	36.42 a
G15	46.3 ab	44.2 ab	14.3 ab	0.93 ab	1.55 ab	550.5 abc	10.95 cd	2.00 ab	32.51 a
G16	44.7 ab	53.3 a	16.2 ab	0.95 ab	1.83 a	491.7 c	9.90 d	1.98 ab	37.04 a
G17	45.8 ab	51.0 ab	15.8 ab	0.96 ab	1.77 ab	630.5 abc	15.01 abcd	2.39 ab	29.69 a
G18	47.5 ab	46.7 ab	15.0 ab	0.95 ab	1.62 ab	612.7 abc	13.80 abcd	2.29 ab	23.40 a
G19	46.1 ab	34.8 b	11.3 b	0.98 ab	1.20 b	539.0 abc	10.69 cd	1.95 ab	31.04 a
HSD	8.7	17.4	5.4	0.17	0.58	203.4	5.39	0.61	14.89
Watering:									
W1	42.5 b	38.2 b	12.2 b	0.86 b	1.28 b	481.2 b	11.03 b	2.28 a	37.23 a
W2	51.9 a	54.4 a	16.9 a	1.07 a	1.92 a	703.8 a	15.27 a	2.15 b	27.54 b

HSD	1.5	3.1	1.0	0.03	0.10	36.1	0.96	0.11	2.64
<u>Blocks (P residue)</u>:									
P0	45.8 b	43.6 b	14.0 a	0.94 b	1.51 b	548.8 b	11.70 b	2.13 b	33.73 a
P100	48.2 a	46.6 ab	14.3 a	0.97 ab	1.61 ab	658.0 a	15.54 a	2.37 a	26.94 b
P200	47.7 ab	48.6 a	15.3 a	0.99 a	1.69 a	570.6 b	12.20 b	2.14 b	36.48 a
HSD	2.3	4.5	1.4	0.05	0.15	53.0	1.40	0.16	3.88

Remarks: [1)] For analysis, data were transformed into √x; [2)] Data in each column followed by the same letters are not significantly different between levels of each treatment factor; AGR = average growth rate (average increase in plant height, or leaf number, per week)

In terms of grain yield per pot, the highest average was found in G12 and the lowest one was in G16. This was most probably related to the number of filled grains per pot, which was also the lowest in G16, while the percentage of unfilled grain number was also the lowest in G16, although there was no significant different in the percentage of unfilled grain number among the genotypes tested (Table 2). From the results of correlation analysis summarized in Table 3, it can also be seen that the variable showing the highest correlation coefficient with grain yield is filled grain number per pot followed by spikellet number per pot. This means that grain yield of a rice genotype is highly correlated with or determined by the grain-filling capacity of the genotype. In contrast, filled grain number was negatively correlated with the percentage of unfilled grain number, and this also related to the grain-filling capacity of rice plants. These three variables (grain yield, filled grain number and percentage of unfilled grain number) would be related to the photosynthetic capacity of the rice plants because higher photosynthetic capacity, especially during the grain-filling stage of rice growth, should result in higher grain-filling capacity. Leaf is a photosynthetic organ of rice plants; therefore, leaf number at the end of the vegetative growth stage would determine the photosynthetic capacity of rice plants. It can also be seen from Table 3 that leaf number and AGR of leaf number show significantly positive correlation with filled grain number and grain yield per pot.

Table 3. Summary of correlation analysis between observation variables

Variables	Correlation coefficients and *p-value* for each observation variable										
	height	1	2	3	4	5	6	7	8	9	10
1 AGR height	0.940										
p-value	**0.000**										
2 Leaf number	0.359	0.402									
p-value	**0.000**	**0.000**									
3 AGR leaf no.	0.403	0.437	0.988								
p-value	**0.000**	**0.000**	**0.000**								
4 Tiller no at 3 wk	0.238	0.189	0.587	0.608							
p-value	**0.011**	**0.044**	**0.000**	**0.000**							
5 Tiller no at 4 wk	0.471	0.459	0.727	0.777	0.557						
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**						
6 Tiller no at 5 wk	0.343	0.368	0.797	0.826	0.597	0.814					
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**					
7 100 grain weight	-0.184	-0.253	0.046	0.026	0.128	-0.078	0.004				
p-value	**0.049**	**0.007**	0.628	0.784	0.174	0.411	0.964				
8 %-unfilled grains	-0.401	-0.372	-0.266	-0.300	-0.260	-0.335	-0.311	-0.121			

p-value	**0.000**	**0.000**	**0.004**	**0.001**	**0.005**	**0.000**	**0.001**	0.199			
9 Filled grain no.	0.526	0.548	0.487	0.494	0.189	0.485	0.455	0.018	-0.374		
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.044**	**0.000**	**0.000**	0.851	**0.000**		
10 Spikellet no.	0.334	0.380	0.362	0.351	0.046	0.332	0.310	-0.036	0.127	0.864	
p-value	**0.000**	**0.000**	**0.000**	**0.000**	0.627	**0.000**	**0.001**	0.705	0.178	**0.000**	
11 Grain yield	0.370	0.356	0.449	0.445	0.230	0.376	0.397	0.474	-0.378	0.883	0.739
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.014**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

In addition to the significant effects of watering level on growth and yield of red rice, the residue of P treatments on rice plants in the previous experiment, which was assigned as the blocks in this experiment, also had significant effect on almost all variables except on tiller number at 5 weeks after seeding (Table 1). However, the highest yield potential such as average grain yield, filled grain number and weight of 100 grains were highest on rice plants grown following P fertilization with 100 kg/ha SP36, while the percentage of unfilled grain number was lowest following that treatment (Table 2).

In relation to grain yield as affected by the levels of watering, when they are plotted in each red rice line to show the G*W interaction effects, it appears that almost all lines or genotypes show significant responses; only a few lines shows a non-significant response. This means that almost all the genotypes tested are adversely affected by reduction in watering level, especially in terms of grain yield response to levels of watering (Figure 1). Among the 19 lines tested, G4, G5, G11 and G17 are the only genotypes showing relatively high grain yield but with non-significant yield differences between watering levels. In contrast, many genotypes such as G1, G2, G3, G8, G9, and G 18, when received sufficient irrigation water (W2), produced a lot higher yield than under the lower watering level (W1), and some genotype produced around the highest grain yield among the lines tested, but under the lower level of watering their grain yield was significantly very low, especially that of the G1, G2, G8 and G18 lines (Figure 1). This could probably due to the contrastingly very low filled grain number per pot under W1 than under W2 treatment, especially in G8 and G18 (Figure 2).

Interestingly, G8 and G18 do not show significant differences in the percentage of unfilled grain number between the two levels of watering, although all genotypes produced higher percentage of unfilled grain number under lower level of watering, especially G2, G12 and G13 (Figure 3). In addition to the effect of watering levels, P fertilizer doses of the previous rice also affected the percentage of unfilled grain number (Figure 4), in which most genotypes show the highest percentage of unfilled grain number on the P200 treatment or some on the P0 treatment residues, and percentage of unfilled grains had a negative correlation with grain yield (Table 3).

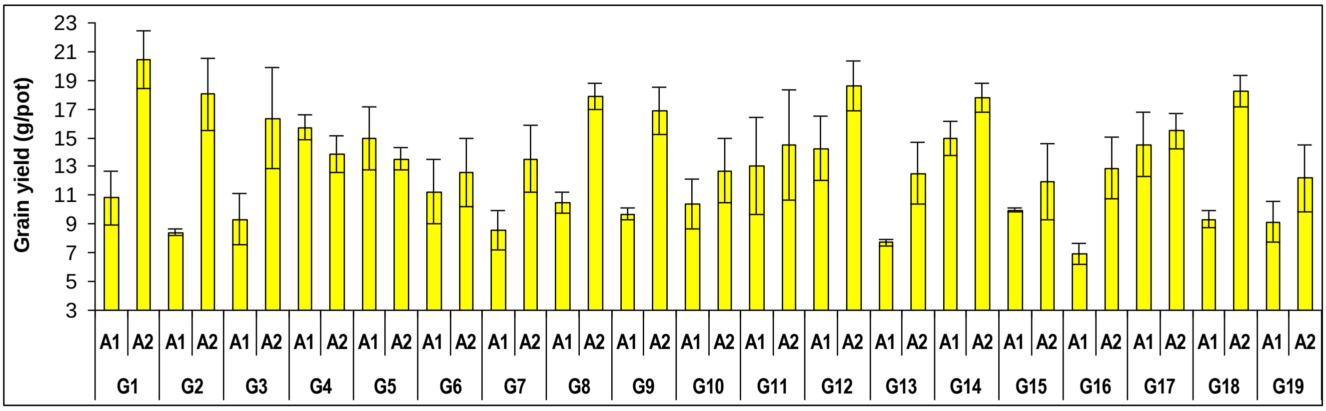

Fig.1: Average dry grain yield (Mean ± SE) of each red rice genotype between the two levels of watering

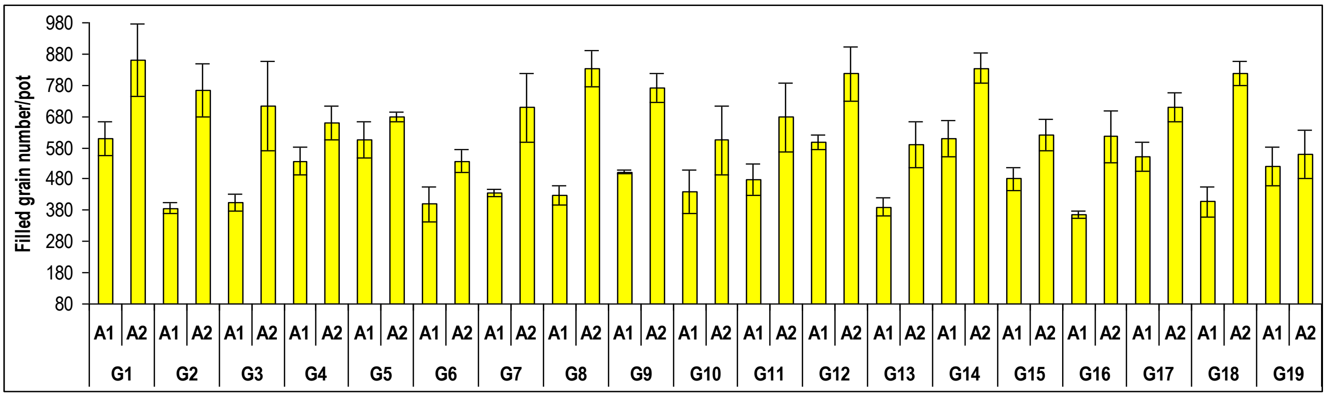

Fig.2: Average filled grain number per pot (Mean ± SE) of each red rice genotype between the two levels of watering

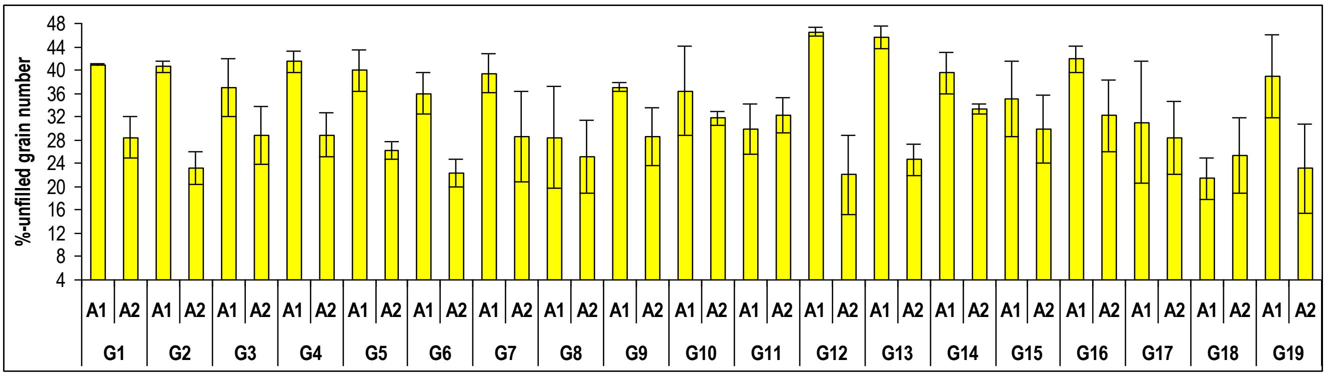

Fig.3: Average percentage of unfilled grain number (Mean ± SE) of each red rice genotype between the two levels of watering

The negative relationship between percentage of unfilled grain number and grain yield might be the strongest variable causing variability in grain yield because the correlation is highly significant. Therefore, high percentages of unfilled grain number in Figure 4 are mostly in accordance with lowest grain yields in Figure 5.

It is possible that the percentages of unfilled grain number are related to the doses of P fertilizers applied to the preceding rice plant in relation to the doses of N fertilizer applied in this experiment. The N fertilizer applied was Urea (45% N) at 300 kg/ha, which means 135 kg N per ha. With an assumption of 20 cm x 20 cm planting space, then N dose was 540 mg/pot of 4.44 kg soil, so the dose was 121.6 mg N per kg soil in the pot. This N application dose is much lower than the high level N dose of 400 mg/kg soil applied to 19 upland rice genotypes by Fageria et al. [10], in which the difference in average yield between the low and high level of N was highly significant, i.e. between 12.1 g/pot in low N and 54.9 g/pot in the high level of N fertilization. This could mean that an increase in P application dose from 75 - 150 kg/ha P_2O_5 with the same N dose, i.e. 121.6 mg N per kg soil might have imbalanced the nutrients to lower N level. According to Sinclair and de Wit [11], sufficient nitrogen is required by seed plants especially during the seed-filling stage. Therefore, it is possible that higher P dose (i.e. 200 kg/ha P_2O_5) have imbalanced the nutrients to lower N, which possibly caused higher percentages of unfilled grain number in the higher than in the lower P dose on most genotypes (Figure 4).

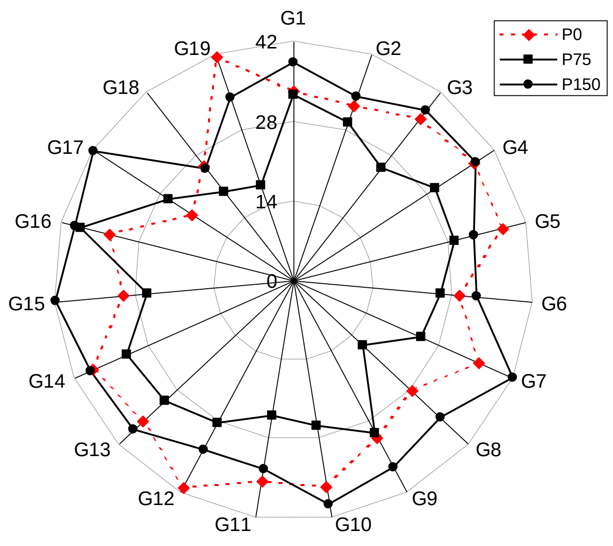

Fig.4: Averages of percentage of unfilled grain number on each red rice line in relation to levels of P fertilization

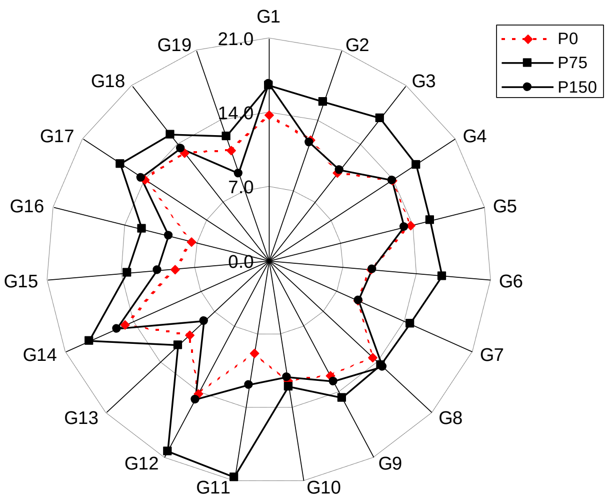

Fig.5: Averages of grain yield of each red rice line in relation to levels of P fertilization

However, increasing N application doses without increasing P doses have also been proven to reduce grain yield increase on some varieties of upland rice such as in the results reported by Onaga et al. [12] on the upland rice var. Masindi under various N doses (0, 40, 80, and 120 kg/ha N) and single P dose (20 kg/ha P_2O_5). In other research, Islam et al. [13] showed that increasing P application from 100 to 200 kg P_2O_5 per ha under 120 kg N per ha reduced P content in the shoot from 0.70 to 0.58 and in the grain from 2.80 to 2.76 mg/g on the “Nipponbare” rice variety. Therefore, it is possible that an increase in P doses from 100 to 200 kg/ha SP36 in the preceding rice plants without increasing N dose of 135 kg/ha N resulted in higher percentage of unfilled grain number (Figure 4).

IV. CONCLUSION

The P fertilizer doses applied to the preceding rice plants also affected grain yield of red rice, and reduction in levels of watering significantly reduced grain yields, most possibly due to significant increase in the percentage of unfilled grains, which had the most significant negative relationship with grain yield. The genotypes showing the highest yield potential under sufficient watering, such as G1, G2, G8, G9, and G18, appeared to be most adversely affected by reduction in levels of watering, but there were three genotypes having relatively high grain yield showing non-significant effect of reduction in watering level, i.e. G4, G5 and G17. Levels of P fertilization to the preceding rice plants also significantly affected grain yield of the following rice plants, most probably due to their effects on the percentage of unfilled grain number.

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