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Growth Analysis of Situ Bagendit Variety in Rainfed Lowland Rice Applied Mycorrhizae with Nitrogen and Phosphorus in Entisol

Achmad Fatchul Aziez[1], Soelistijono[1], Sapto Priyadi[1], Haryuni[1]

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ABSTRACT

Background: Water is one of the factors limiting rice cultivation on raindrop land. The provision of mycorrhizae can help the absorption of water in the soil solum deeper. Besides, it can also save the use of nitrogen and phosphor fertilizers in water-choked conditions. This research aimed to optimize dosage of nitrogen and phosphorus fertilizers on growth in rainfed lowland rice applied mycorrhizae.

Methods: This research was carried out from April to July 2019 in rainfed lowland rice with entisol in Demangan, Sambi, Boyolali, Center Java, Indonesia The research method was a randomized complete block design (RCBD) with three replications. The first factor was the dosage of nitrogen fertilizer, which consisted of four levels, *i.e.*, 0, 45, 90, and 135 kg ha^{-1}. The second factor was the dosage of phosphorus fertilizer, which consisted of four levels, *i.e.*, 0, 25, 50, and 75 kg ha^{-1}.

Result: The results showed that fertilizer dosage of nitrogen of 90 kg ha^{-1} and phosphorus of 50 kg ha^{-1} increased the leaf area index (LAI), leaf area duration (LAD), net assimilation rate (NAR), and crop growth rate (CGR). The application of nitrogen and phosphorus fertilizer can improve the Situ Bagendit variety's physiological character better than without fertilizer. Rice cultivation in rainfed lowland rice applied mycorrhizae should use nitrogen of 90 kg ha^{-1} and phosphorus of 50 kg ha^{-1}.

Key words: Drought stress, Growth analysis, Mycorrhizae, Nitrogen, Rainfed lowland rice.

INTRODUCTION

Rainfed lowland is paddy field whose water depends on rainfall so water is a major problem. Besides water problems, the response of plants to fertilization is also low. (Kasno *et al*., 2020) stated that in rainfed lowland, apart from water problems, the status of soil nutrients is generally low but the response to fertilization sometimes varies. Meanwhile, entisol soil has the ability to hold low water so that water easily escapes. Besides that, the entisol soil is dominated by the sand fraction so that the level of nutrient availability is quite low, especially nitrogen. Mycorrhizae are fungi that have a hipha that can connect water in the deeper layers of the soil to the roots of a plant. Mycorrhizae can increase the absorption of water and plant nutrients, so that plant growth increases (Djazuli 2011).

Plant growth is an event where an increase in cell number or an increase in plant dry weight. Ayuningtyas *et al*. (2016) define growth is as a process of cell division or an increase in the number of irreversible cells, while Moraes *et al*. (2014) are increasing biomass.

Internal and external factors influence the process of plant growth. Leaves are an internal factor that acts as a photosynthetic organ. The shape and size of the leaves are crucial in catching the sunlight as the main energy source. External factors that affect plant growth include nitrogen and phosphorus fertilizer. The application of balanced fertilizers can stimulate vegetative growth. The need for nitrogen and phosphorus nutrients must be met to support plant growth. The optimal vegetative growth phase will provide maximum generative results.

[1]Department of Agrotechnology, Jalan Balekambang Lor no. 1, Surakarta, Central Java, Indonesia.

Corresponding Author: Achmad Fatchul Aziez, Department of Agrotechnology, Jalan Balekambang Lor no. 1, Surakarta, Central Java, Indonesia. Email: achmad.aziez@lecture.utp.ac.id

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Nitrogen and phosphorus are nutrients needed by plants in large quantities in the formation of chlorophyll, protoplasm, protein, and nucleic acids. This element has an essential role in the growth and development of all living tissues (Suharja and Sutarno 2009). Phosphorus is a necessary component of energy transfer compounds, genetic information systems, cell membranes, and phosphoproteins (Ayuningtyas *et al*., 2016). (Breuninger *et al*., 2004) reported that mycorrhizae could absorb glycine and glutamic acid and transport nitrogen from these sources to the host plants. Mycorrhizae is involved in increasing nitrogen uptake and assimilation by host plants (Cavagnaro *et al*., 2012; Thakur and Shinde 2020). Dry weight is the result of overall growth, but its achievement occurs through dynamic growth over time. The hoarding of photosynthetic net or dry weight in an integrated manner with time is referred to as growth analysis

(Ayuningtyas *et al*., 2016). Two measurements are needed in a time interval to analyze the plant growth, namely the leaf area and the total dry weight.

With sufficient nitrogen and phosphorus, the photosynthesis process will run smoothly to spur plant growth. Crop growth rate (CGR) is a function of leaf area index (LAI), leaf area duration and net assimilation rate (NAR). With optimum nitrogen and phosphorus, leaf area index, leaf area duration and net assimilation rate reach the optimum, the crop growth rate is also optimum (Bianchi, Quijano, Gosparini, and Morandi, 2020). Qi *et al*. (2020), in their research using nitrogen fertilizers at doses of 200 kg ha^{-1} increased LAI, NAR, CGR, chlorophyll value and yield.

The use of phosphorus fertilizer combined with biochar (Zhu *et al*., 2019) can increase the net photosynthetic rate, chlorophyll index, leaf area duration and 23% yield on soybean plants, which are inefficient P. in his research using 1% biochar and P fertilizer 150 kg ha^{-1}.

The use of high yield potential rice varieties that are responsive to fertilization and resistant to drought is expected to have a positive effect on crop yields. Situ Bagendit variety is a rainfed rice variety that is resistant to drought, has a number of tillers of 12-13 $clumps^{-1}$, long and slender grains of clean white color, fluffier rice texture and is in great demand by consumers. The potential yield is 4.0 tons ha^{-1} of milled dry unhulled rice in dry land and 5.5 tons ha^{-1} in paddy fields (Anonymous, 2011).

According to Laghari *et al*. (2016), nitrogen at a level of 120 kg ha^{-1} showed promising results for rice plant height, number of tillers, dry weight, panicle length, number of filled grain $panicle^{-1}$, straw yield, biological yield, harvest index, and grain yielded 4.66 tons ha^{-1}. Meanwhile, regarding the dose of P, in Cambodia, in rainfed rice fields, a dosage of 8-10 kg of phosphorus can produce 2.5-3.0 tons of grain ha^{-1} (Seng, *et al*., 2001). Research by Pheav *et al*. (2005) concluded that the use of phosphorus of 8-10 kg ha^{-1} could produce 2.5-3.0 tons ha^{-1}. Kokou *et al*. (2012) added that N, P_2O_5 and K_2O fertilizers, respectively, 139.86, 7.2 and 120 kg ha^{-1} were the optimum dosage for IR64 varieties.This study aimed to optimize dosage of nitrogen and phosphorus to rice growth in rainfed lowland applied mycorrhizae.

MATERIALS AND METHODS

This research was carried out from April to July 2019 in rainfed lowland rice with entisol in Demangan, Sambi, Boyolali, Center Java, Indonesia with chemical composition : N total, P available, K available 0.15% (low), 8.10 (medium) and 0.79 me. 100 g^{-1} (high), respectively. A geographical position of the study area is between 110°22′-110°50′ east longitude and between 7°7′ - 7°36′ south latitude with an altitude of 184 m above sea level and the average rainfall of 139 mm $month^{-1}$.

The experimental design used in this research was a completely randomized block design with three replications.

The first factor was a dosage of nitrogen (N), which consisted of four levels, *i.e*., 0, 45, 90, 135 kg ha^{-1}. The second factor was a dosage of phosphorus (P_2O_5), which consisted of four levels, *i.e*., 0, 25, 50 and 75 kg ha^{-1}.

Soil tillage was done by plowing, then manure was dose of 10 tons ha^{-1}. The plots were made in a size of 4.0 m × 1.2 m. The need for manure $plot^{-1}$ was 1.92 kg,

Seeding was done by sowing the rice seeds on the prepared planting media. Seedlings are ready to be planted at the age of 20 days after sowing. Rice seedlings were planted at a spacing of 20 cm × 20 cm.

Urea and SP36 fertilizer were given according to the treatment, namely the first stage at 14 days and the second at 30 days after planting (DAP). KCl fertilizer at a dosage of 75 kg ha^{-1} was given simultaneously at the age of 30 DAP in all plots.

Irrigation cannot be done and only rely on rainwater. Plant maintenance carried out included transplanting at the age of 7 DAP and weed control at 14 DAP.

The parameters observed were LAI, LAD, NAR and CGR were recorded at 0 up to 12 weeks after planting and was calculated using the following formula:

The leaf area index (LAI) is the ratio of the total leaf area of one rice $clump^{-1}$ against the plant spacing or ground area shaded by the plant canopy. The LAI value was calculated using the formula in Equation 1.

$$LAI = \frac{LA}{P} \quad ....(1)$$

Where:

LA= Total of leaf area.

P= Plant spacing or ground area that shaded.

LAD is leaf area at a certain period. The LAD value was calculated using the formula in Equation 2.

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (T_2 - T_1)\ (cm^2\ week^{-1}) \quad ....(2)$$

Where:

LAI_1= LAI of plant $clump^{-1}$ recorded at time T_1.

T_1 = LAI of plant $clump^{-1}$ recorded at the time T_1.

T_1 and T_2= Interval of time, respectively.

NAR is the plants' ability to produce dry matter due to assimilation per leaf area per unit time. The NAR value was calculated using the formula in Equation 3.

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1}\ (g\ cm^{-2}\ week^{-1}) \quad ....(3)$$

Where:

W_1= Dry weight of plant $clump^{-1}$ recorded at the time T_1.

W_2= Dry weight of plant $clump^{-1}$ recorded at the time T_1.

LAI^1= Leaf area of plant $clump^{-1}$ recorded at the time T_1.

LAI_2= Leaf area of plant $clump^{-1}$ recorded at the time T_1.

ln = Logarithm natural.

CGR is the ability of plants to produce dry matter due to assimilation per unit area of land per unit of a certain time short. The CGR value was calculated using the formula in Equation 4.

$$CGR = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1} (\text{mg cm}^{-2} \text{ day}^{-1}) \quad ....(4)$$

Where:
A =Fields area or plant spacing.
W_1= Dry weight of plant recorded at the time T_1.
W_2= Dry weight of plant recorded at the time T_2.
T_1 and T_2= Interval of time, respectively.

The data of observations were analyzed using analysis of variance (ANOVA) at 5% significant levels. The treatment means were compared using Duncan. s new multiple range test (DMRT) at 5% significant levels.

RESULTS AND DISCUSSION

Leaf area index

Based on the analysis of variance on LAI, the treatment of nitrogen and phosphorus dosage at 0-3, 3-6, 6-9 and 9-12 WAP had significant effects, except for the phosphorus treatment at 0-3 WAP. There is no interaction between the two treatments. The average of LAI is presented in Table 1.

Table 1 shows that LAI increased from observations 0-3 to 9-12 WAP on all treatments. LAI on observations 0-3, 3-6, 6-9, and 9-12 WAP, the dosage of 135 kg reaches the highest number and is significantly different from without nitrogen fertilization, but the dose is 45, 90 nor did 135 kg ha^{-1} show any difference, except for observations 9-12 WAP. In 9-12 WAP observations, LAI at a dose of 135 kg ha^{-1} was different from 45 and 90 ha^{-1}, a dose of 45 and 90 kg ha^{-1} was also different from without nitrogen fertilizer.

At 0-3 and 6-9 WAP observations in the phosphorus dose treatment, LAI was no difference at a dose of 0, 45, 90, 145 kg ha^{-1}. It means that at age, there is no need for phosphorus. It is suspected that mycorrhizae's role is very dominant at that age. One of the mycorrhizal functions is increasing phosphorus uptake, increasing phosphorus absorption and LAI will also increase. At 3-6 WAP, phosphorus doses of 25 and 50 kg ha^{-1} were not significantly different from those without phosphorus. LAI at a dosage of 25 and 50 kg ha^{-1} was also not different from the dosage of 75 kg ha^{-1}, but LAI at a phosphorus dose of 75 kg ha^{-1} was significantly different from that without phosphorus.

Leaf área index (LAI) is the ratio between leaf surface area and land surface área overgrown with plants (Ayuningtyas *et al*. 2016; Rajesh *et al*. 2011). LAI is closely related to the plant's ability to keep the light from solar radiation that is coming. LAI values needed to hold 95% of the light come in the rice canopy around 4-8 for photosynthesis (Rajesh *et al*., 2011). LAI is a photosynthetic area of the plant (Rajput *et al*., 2017; Zulkarnaini *et al*., 2019).

In the nitrogen dosage treatment, nitrogen at all observation stages increased the leaf área index of Situbagendit rice variety planted in lowland rice applied by mycorrhizae. It is because one of the functions of nitrogen is as a constituent of chlorophyll. Chlorophyll is the center of photosynthesis. The stronger the photosynthesis process will increase plant growth, including leaf size (Ayuningtyas *et al*. 2016). Thapa *et al*. (2019) reported that nitrogen fertilizer influences LAI by increasing the tiller number and leaves size. Ko *et al*. (2017) found that young seedlings, closer spacing, and urea application recorded more tillers per unit area resulting in increased LAI. LAI was highly significantly affected by fertilizer type at all growth stages.

Likewise, what happens in the treatment of phosphorus dosage. ATP is a chemical compound as energy for dark photosynthesis reaction, which will form carbohydrates that accumulate in the leaves (Ayuningtyas *et al*., 2016). The role of mycorrhizae, in this case, is less influential compared to the dosage of fertilizer applied. These are caused by the lack of mycorrhizae, which is not enough, or the application method is not right.

Leaf area duration

Based on the ANOVA on LAD, nitrogen and phosphorus dosage treatment at 0-3, 3-6, 6-9 and 9-12 WAP have

Table 1: Average of LAI at 0-3, 3-6, 6-9 and 9-12 WAP.

Treatment	Observation time (WAP)			
	0-3	3-6	6-9	9-12
Nitrogen (kgha^{-1})				
0	0.960a	1.773a	2.250a	2.281a
45	1.101ab	2.654ab	3.246ab	3.437b
90	1.637ab	3.497b	3.139ab	3.815b
135	1.676b	3.607b	3.842b	4.830c
Phosphorus (kg ha^{-1})				
0	1.215p	2.273p	2.523p	2.733p
25	1.284p	2.591pq	3.258p	3.776q
50	1.438p	3.094pq	3.126p	3.832q
75	1.437p	3.575q	3.570p	4.022q
Interaction	(-)	(-)	(-)	(-)

Note: The numbers was followed by the same characters in the same column indicate no significantly different based on DMRT at 5% significant levels. (-) = No significant interaction.

significant effects, except phosphorus treatment at 0-3 WAP. There is no interaction between the two treatments. The average of LAD was presented in Table 2.

Based on Table 2, LAD growth increased from observations 0-3 to 9-12 WAP on all treatments.The nitrogen dosage of 135 kg ha^{-1} in observations 0-3, 3-6, 6-9 and 9-12 WAP shows the highest LAD. The LAD at 0-3 WAP, the dosage of 135 kg ha^{-1} did not differ from the dosages of 45 and 90 kg ha^{-1}. However, 45 and 90 kg ha^{-1} did not differ from without nitrogen. It means that there is no increase in LAD at 0-3 WAP with the nitrogen of 45 and 90 kg ha^{-1}. It is suspected that at the age of 0-3 WAP, soybean plants need less N fertilizer because of mycorrhizae role, which helps nutrient uptake. However, 45 and 90 kg ha^{-1} did not differ without nitrogen. This means that there is no increase in LAD at 0-3 WAP with nitrogen of 45 and 90 kg ha^{-1}. It is suspected that at the age of 0-3 WAP, soybean plants need less N fertilizer because of the role of mycorrhizae which helps nutrient absorption.

At 3-6 and 6-9 WAP, LAD at a 45 kg ha^{-1} was no different from without nitrogen fertilizer, whereas at 9-12 WAP the dosage was 45 and 90 kg ha^{-1}nitrogen is no different without nitrogen fertilization. Seeing a pattern like this shows that nitrogen on land given mycorrhizae needs a high dosage so that the LAD is different compared to without nitrogen. It is presumably because the hyphae of mycorrhizal fungi are already long to absorb more water and nutrients. LAD shows the same pattern as LAI, namely the increasing nitrogen dosage, the LAD also increases.

Likewise, the increased phosphorus is given, the LAD will increase except 0-3 WAP because there is a role for nitrogen and phosphorus fertilizer. It is similar in his research (Kabir, *et al*., 2013) that phosphate fertilizer with a dosage of 50 kg ha^{-1} is better than 25 kg ha^{-1} on plant height, branches number plants^{-1}, crop growth rate, and leaf area index of groundnut.

Net assimilation rate

Based on the ANOVA, nitrogen dosage treatment significantly affected 9-12 WAP and phosphorus dosage treatment significantly impacted 0-3 WAP. There was no interaction between the two treatments. The DMRT result at 5% level was presented in Table 3.

In Table 3, the highest NAR growth occurred in 0-3 WA and decreased in observations of 3-6 to 9-12 WAP in all treatments. It can be seen that the nitrogen treatment, NAR at 0-3, 3-6 and 6-9 WAP at dosages of 45, 90 and 135 kg ha^{-1} did not differ from without nitrogen, whereas 9-12 WAP at different nitrogen dosages had different NAR effects. The highest NAR was at nitrogen dosages of 90 kg ha^{-1} and significantly different from those without nitrogen fertilization, but did not differ from the dosage of 45 or 135 kg ha^{-1}.

In the treatment of phosphorus dosages (Table 3), NAR at 3-6, 6-9 and 9-12 WAP, at dosages of 45, 90 and 135 kg ha^{-1} did not differ from without phosphorus fertilization (0 kg ha^{-1}). On the 0-3 WAP observation, it looks different. The highest NAR was at a phosphorus dosage of 75 kg ha^{-1} and was different from a dosage of 25 kg ha^{-1}, but did not differ from 50 kg ha^{-1} and without phosphorus fertilization. NAR determines the RGR (Shipley, 2006).

The NAR measures the average photosynthetic efficiency of leaves in a community of cultivated plants (Ayuningtyas *et al*. 2016). NAR is the production of dry matter per unit of leaf area per unit time. It gives an understanding that leaves and light are the determining factors in the formation of assimilation results. The wider the leaf and the more light that can be absorbed, the higher assimilation will be produced. NAR will increase when all leaves intercept the light and are not shaded by other leaves.

Crop growth rate

CGR increases plant weight per unit area of land occupied by plants at a certain time (Harish *et al*., 2017). Based on

Table 2: Average of LAD (cm^2 week^{-1}) at 0-3, 3-6, 6-9 and 9-12 WAP

Treatment	Observation time (WAP)			
	0-3	3-6	6-9	9-12
Nitrogen (kg ha^{-1})				
0	575a	1.639a	2,464a	2,768a
45	660ab	2.253ab	3,540ab	4,009ab
90	982ab	3.081bc	3,982b	4,088ab
135	1,005b	3.169c	4,368b	5,022b
Phosphorus (kg ha^{-1})				
0	727p	2.091p	2,877p	2,987p
25	770p	2.325pq	3,509pq	4,220pq
50	863p	2.719pq	3,732pq	4,175pq
75	862p	3.007q	4,236q	4,505q
Interaction	(-)	(-)	(-)	(-)

Note: The numbers followed by the same characters in the same column indicacate no significantly different based on DMRT at 5% significant levels. (-) = No significant interaction.

the analysis variance on CGR, nitrogen dosage treatment significantly affected 0-3, 3-6 and 9-12 WAP and the treatment of phosphorus dosage significantly affected 0-3 and 9-12 WAP. There was no interaction between the two treatments. The average of CGRR at 0-3, 3-6, 6-9, and 9-12 WAP could be seen in Table 4.

Table 4 showed that CGR growth stable trend from observations 0-3 to 9-12 WAP on all treatments, except in without nitrogen or phosphorus fertilizer. The CGR at 0-3 WAP, the nitrogen dosage of 90 kg ha^{-1} does not differ from 45 kg ha^{-1}. Without nitrogen fertilization and dosages of 90 kg ha^{-1} also does not differ from a dosage of 135 kg ha^{-1}. CGR at a dosage of 135 kg ha^{-1} is different from that without nitrogen fertilization. The highest CGR was found at the dosage of 90 kg ha^{-1} but did not differ from 135 kg ha^{-1}. The CGR at 3-6 WAP and 9-12 WAP at nitrogen dosage treatment have the same pattern. CGR at nitrogen dosages of 45, 90 and 135 kg ha^{-1} did not differ. CGR at the dosage of 45, 90 and 0 kg ha^{-1} was also no different. At 3-6 and 9-12 WAP this CGR was highest at a nitrogen dosage of 135 kg ha^{-1}.

At 0-3 WAP observation, the CGR dosage of 25 kg ha^{-1} was not different from the dosage of 50 kg ha^{-1} or without phosphorus fertilization in the phosphorus dosage treatment. However, the dosage of 50 kg ha^{-1} is also no different from 75 kg ha^{-1}. The highest was at a dosage of phosphorus 75 kg ha^{-1}. In 9-12 WAP observations, CGR at dosages of 25, 50 and 75 kg ha^{-1} did not differ. Likewise, the dosage of 25 kg ha^{-1} did not differ from those without phosphorus fertilization.

The CGR has the same pattern as LAI, meaning that the more LAI increases, the CGR will increase. According to Ko *et al*. (2017), increased LAI and total dry matter production using younger seedlings have higher CGR. Permanasari *et al*. (2016) stated that during the initial growth stage. The CGR and NAR values increased due to more numbers of tillers and leaves per unit area.

Table 3: Average of NAR (g cm^{-2} week^{-1}) at 0-3, 3-6, 6-9, and 9-12 WAP.

Treatment	Observation time (WAP)			
	0-3	3-6	6-9	9-12
Nitrogen (kg ha^{-1})				
0	126.26a	21.56a	15.55a	3.83a
45	122.57a	31.47a	22.60a	9.65ab
90	133.33a	24.17a	23.76a	20.70b
135	158.25a	27.78a	12.44a	12.34ab
Phosphorus (kg ha^{-1})				
0	115.24pq	25.79p	22.74p	10.71p
25	102.22p	29.15p	17.46p	11.33p
50	144.38pq	25.57p	18.53p	11.82p
75	178.57p	24.47p	15.62p	12.66p
Interaction	(-)	(-)	(-)	(-)

Note: The numbers followed by the same characters in the same column indicacate no significantly different based on DMRT at 5% significant levels. (-) = No significant interaction.

Table 4: Average of CGR (mg cm^{-2} day^{-1}) at 0-3, 3-6, 6-9, and 9-12 WAP.

Treatment	Observation time (WAP)			
	0-3	3-6	6-9	9-12
Nitrogen (kg ha^{-1})				
0	22.12a	21.33a	73.11a	7.95a
45	21.25a	48.17ab	60.43a	27.38ab
90	37.42ab	54.26ab	55.34a	48.37ab
135	36.52b	71.17b	42.75a	59.16b
Phosphorus (kg ha^{-1})				
0	30.52p	40.17p	66.37p	19.16p
25	22.41p	57.26p	56.72p	35.37pq
50	20.12pq	50.19p	44.43p	42.96q
75	44.26q	47.31p	64.11p	45.37q
Interaction	(-)	(-)	(-)	(-)

Note: The numbers followed by the same characters in the same column indicacate no significantly different based on DMRT at 5% significant levels. (-) = No significant interaction.

CONCLUSION

The research results and the discussion above could be taken as follows. The fertilizer dosage of nitrogen of 90 kg ha^{-1} and phosphorus of 50 kg ha^{-1} increased the leaf area index (LAI), leaf area duration (LAD), net assimilation rate (NAR) and crop growth rate (CGR). The application of nitrogen and phosphorus fertilizer can improve the Situ Bagendit variety's physiological character better than without fertilizer. Rice cultivation in rainfed lowland rice given mycorrhizae should use nitrogen of 90 kg ha^{-1} and phosphorus of 50 kg ha^{-1}.

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