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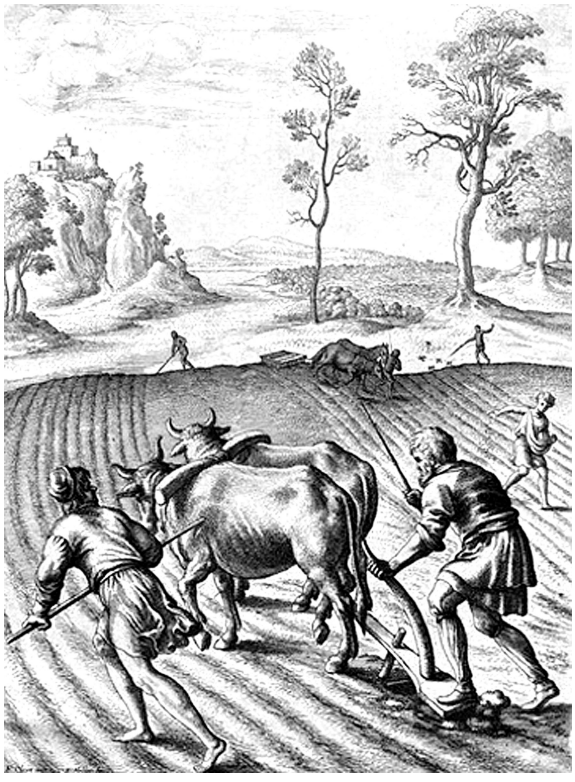

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Research Article
Effect of Vesicular Arbuscular Mycorrhiza on the Growth and the Characteristics of Rice Varieties in Rainfed Lowland Rice Cultivation

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Abstract

Background and Objective: Growth response of various rice varieties showed a different result to the application of Vesicular Arbuscular Mycorrhiza (VAM) in rainfed lowland rice field. The purpose of this study was to determine the leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate of rice varieties applied with the treatment of VAM in rainfed lowland rice field. **Materials and Methods:** The research design was Randomized Completely Block Design with 2 factors and 3 replications. The first factor was rice varieties (IR64, Mentikwangi, Pepe, Mekongga, Way Apo Buru, Inpari, Situbagendit and Mamberamo). The second factor was the application of VAM (without VAM and with VAM). The research was conducted in the rice field in Demangan, Sambi, Boyolali, Central Java, Indonesia with 113 m above sea level. **Results:** The results indicated that the VAM applications can increase the leaf area index of IR64, Mentikwangi, Pepe, Way apoburu, Inpari and Mamberamo variety; leaf area duration of IR64, Pepe, way Apoburu and Inpari variety; crop growth rate of all varieties except mekongga and mamberamo; net assimilation rate of IR64, Pepe and Inpari variety and relative growth rate of Mekongga variety. A significantly positive correlation was obtained between the leaf area index to the leaf area duration, crop growth rate, net assimilation rate and relative growth rate. **Conclusion:** The application of VAM to various of rice varieties in rainfed lowland rice field can increase the leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate. There was a significance and positive correlation between the leaf area index to the leaf area duration, crop growth rate, net assimilation rate and relative growth rate.

Key words: Growth analysis, rice, rainfed lowland, rice varieties, vesicular arbuscular mycorrhiza

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important main food crop for more than half of the world's population[1] and is a major source of calories for around 60% of the world's population[2].

The area of rice cultivation in irrigated rice field experienced a lot of deterioration due to the conversion of agricultural land so that expansion was needed in sub-optimal lands including rainfed land.

Rainfed land has a potential to be used as an area to increase rice production[3]. However, due to the low rice productivity resulted in rainfed lowland rice field which is around[4] 3.5-4.5 t ha^{-1}, so that the effort to increase the productivity is needed even there are some obstacles such as water stress (drought).

One of the efforts to overcome the problem of water shortage is the use of microbial-based technologies, such as VAM. Mycorrhiza can increase the nutrient absorption especially P and other nutrients such as N, K, Ca, Mg, Cu, Mn and Zn; the production of hormones and growth regulating substances and the resistance to drought[5]. The VAM fungi also function to improve the nutrient status of the plants; increase growth and development and confer the plant's resistance to drought[6]. The VAM has a positive effect on lowland rice by increasing root dry weight[7] 122.8% and grain weight 27.7% compared to the control[8]. Mycorrhiza has a very positive effect on plants that experience water stress as it has more potential of root xylem as a water transporter so that it accelerates the recovery of the root cortex; the ability of hyphae to absorb water when the plants are no longer able and the ability to change the potential of plant water[9]. Drought resistance due to water can flow directly through hyphae, increases phosphorus absorption and changes into hormonal balance[10]. According to Panneerselvam *et al.*[11] and Sowarnalisha *et al.*[12], fungi hypha increases the surface area for P absorption through the mycelium to the root of the host plant so that it will increase the availability of P and other nutrients.

This study aimed to determine the effect of VAM to the leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate rice varieties in rainfed lowland rice field.

MATERIALS AND METHODS

This research was carried out in rainfed lowland rice field in Demangan, Sambi, Boyolali, Central Java, Indonesia and the Laboratory of Plant Science, Faculty of Agriculture, Universitas Gadjah Mada, Indonesia (March-July, 2018). The materials used were seeds of IR64, Mentikwangi, Pepe, Mekongga, Way Apo Buru, Inpari, Situbagendit, Mamberamo. Rice seeds were obtianed from the Paddy Seed Center in Tegalgondo, Klaten, Central Java, Indonesia. While other materials were straw, cow manure, urea, SP36 and KCl.

This study used a complete randomized block design with 2 factors and repeated 3 times. Factor I was rice varieties (IR64, Mentikwangi, Pepe, Mekongga, Way Apo Buru, Inpari, Situbagendit, Mamberamo). Factor II was the application of VAM (without mycorrhizae and with mycorrhizae). The planting was done using 3 seeds then removed into 2 seedlings, at age of 14 days was selected and left into 1 plant. Urea-SP36-KCl fertilizer at a dose of 200, 83.3 and 50 kg ha^{-1}.

The parameters observed were leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) which was analyzed at 3 up to 6 weeks after planting. The LAI, LAD, CGR, NAR and RGR were calculated using following equation[13-16]:

$$\text{Leaf area index (LAI)} = \frac{LA}{P}$$

$$\text{Leaf area duration (LAD)} = \frac{LAI1 + LAI2}{t2 - t1} \times 2 \text{ dm}^2 \text{ week}^{-1}$$

$$\text{Crop growth rate (CGR)} = \frac{1}{A} \times \frac{W2 - W1}{T2 - T1} \text{ g m}^{-2} \text{ day}^{-1}$$

$$\text{Net assimilation rate (NAR)} = \frac{W2 - W1}{T2 - T1} \times \frac{\text{Ln LA2} - \text{Ln LA1}}{LA2 - LA1} \text{g m}^{-2} \text{ day}^{-1}$$

$$\text{Relative growth rate (RGR)} = \frac{\text{In W2} - \text{In W1}}{t2 - t1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where:

LA = Leaf area
P = Ground area
LAI = Leaf area index
In = Natural log
W1 = Dry weight of plant/m^2 recorded at time t1
W2 = Dry weight of plant/m^2 analyzed at time t2, t1 and t2 were the interval of time, respectively

The statistical analysis was done using standard two-way ANOVA SAS 9.0 program[17]. If there was a significance differences among the treatment then followed by Duncan Multiple Range Test (DMRT) at 5% level of probability[18].

RESULTS AND DISCUSSION

Leaf area index (LAI): Leaf area index (LAI) is the ratio between leaf surface area and land surface area over grown in the plants[19]. The leaf area index is closely related to the plant's ability to keep the light from solar radiation which is coming. The LAI value needed to hold 95% of the light comes in the rice canopy for photosynthesis was around[19] 4-8, also Rajput *et al.*[20] stated that LAI is a photosynthetic area of the plant.

The results of data analysis (Table 1) showed that LAI was influenced by the interaction between varieties and VAM. The VAM increased LAI of IR64, Mentikwangi, Pepe, Way Apo Buru, Inpari and Mamberamo variety. The highest LAI resulted from the application of without VAM and with VAM was obtained by Mekongga and Inpari variety, respectively, but there was not significantly different compared to other varieties.

Leaf area duration (LAD): The results of data analysis (Table 2) showed that LAD was affected by the interaction between varieties and VAM. The VAM increased the LAD of IR64, Pepe, Way Apo Buru and Inpari variety. The highest LAD resulted from the application of VAM and without VAM was obtained by Inpari and Mekongga variety respectively, but there was not significantly different from other varieties.

Crop growth rate (CGR): Crop growth rate is the increase of plant weight per unit area of land occupied by the plants in a certain time[21]. The results of data analysis in Table 3 showed that mycorrhizae can increase the growth rate of IR64, Mentikwangi, Way Apo Buru, Inpari and Situbagendit variety. The highest growth rate from the treatment with VAM and without VAM was resulted by the CGR IR64 variety and the Mekongga variety respectively, but there was not significantly different with other varieties.

Net assimilation rate (NAR): Net assimilation rate is the production of dry matter per unit of leaf area per unit time. This gives an understanding that leaves and light are the determining factors in the formation of assimilation result. The wider the leaf and the more light that can be absorbed, the higher assimilation will be produced. The NAR will increase when all leaves intercept the light and are not shaded by other leaves.

The results of data analysis (Table 4) showed that mycorrhizae can increase the NAR of IR64, Pepe and Inpari variety. The highest NAR resulted from the treatment without mycorrhizal and with mycorrhizae was obtained by Situbagendit and IR64 variety, respectively.

Relative growth rate (RGR): The relative growth rate showed an increase of dry weight in a time interval in relation to the fresh weight of the plant[21].

The results of data analysis (Table 5) showed that VAM can increase the RGR of Mekongga variety. The highest RGR resulted from the treatment without VAM and with VAM was obtained by IR64 and Mekongga variety, respectively.

Table 1: Leaf area index of rice varieties to the application of VAM in rainfed lowland rice field

	Vesicular arbuscular mycorrhiza (VAM)		
Varieties	Without VAM	With VAM	Mean
IR64	4.45^{d-f}	7.43^{ab}	5.942^{a-f}
Mentikwangi	4.28^{d-f}	7.54^{ab}	5.910^{a-f}
Pepe	3.36^{d-f}	7.58^{ab}	5.472^{a-f}
Mekongga	5.34^{b-d}	7.12^{a-c}	6.228^{a-f}
Way Apo Buru	3.51^{d-f}	7.05^{a-c}	5.280^{a-f}
Inpari	4.67^{cd}	8.59^{a-f}	6.632^{a-f}
Situbagendit	5.13^{b-d}	7.42^{ab}	6.277^{a-f}
Mamberamo	4.39^{d-f}	7.65^{ab}	6.020^{a}
Mean	4.39^{b}	7.55^{a-f}	(+)

Numbers in the same column followed by the same letter are not significantly different according to DMRT 5%

Table 2: Leaf area duration of rice varieties to the application of VAM in rainfed lowland rice field (dm^2 $week^{-1}$)

	Vesicular arbuscular mycorrhiza (VAM)		
Varieties	Without VAM	With VAM	Mean
IR64	35.00^{cd}	53.41^{ab}	44.20^{a-f}
Mentikwangi	37.12^{b-d}	54.97^{ab}	46.04^{a-f}
Pepe	32.69^{d-f}	54.70^{ab}	43.70^{a-f}
Mekongga	43.62^{a-f-d}	50.59^{a-c}	47.11^{a-f}
Way Apo Buru	32.09^{d-f}	51.51^{a-c}	41.80^{a-f}
Inpari	38.14^{b-d}	60.58^{a-f}	49.35^{a-f}
Situbagendit	39.05^{b-d}	54.84^{ab}	46.94^{a-f}
Mamberamo	39.01^{b-d}	55.11^{ab}	47.06^{a-f}
Mean	37.09^{b-f}	54.46^{a-f}	(+)

Numbers in the same column followed by the same letter are not significantly different according to DMRT 5%

Table 3: Crop growth rate of rice varieties to the application of VAM in rainfed lowland rice field (mg cm^{-2} $week^{-1}$)

	Vesicular arbuscular mycorrhiza (VAM)		
Varieties	Without VAM	With VAM	Mean
IR64	13.22^{c-f}	22.09^{a-f}	17.658^{a-f}
Mentikwangi	10.78^{d-f}	19.48^{ab}	15.132^{a-c}
Pepe	10.13^{ef}	18.66^{a-c}	14.398^{a-c}
Mekongga	13.36^{c-f}	15.78^{b-e}	14.570^{a-c}
Way Apo Buru	9.79^{f}	16.26^{b-d}	13.025^{bc}
Inpari	10.34^{ef}	19.05^{ab}	14.693^{a-c}
Situbagendit	12.99^{c-f}	19.39^{ab}	16.190^{ab}
Mamberamo	9.83^{f}	13.94^{b-f}	11.883^{c}
Mean	11.31^{b-f}	18.08^{a-f}	(+)

Numbers in the same column followed by the same letter are not significantly different according to DMRT 5%

DISCUSSION

The application of VAM will increase the LAI as the water uptake and nutrients will increase and improve the photosynthesis process which will result in increasing the leaf area. This result is supported by Sowarnalisha *et al.*[12], who stated that the presence of VAM will increase the availability of phosphorus uptake which will be useful for photosynthesis. The higher LAI in all periods of growth, the more yield will be obtained as it leads to higher production and yield of biomass[22]. The Situbagendit variety which is a rainfed rice variety with high yield potential results the highest LAI compared to other samples (with VAM or without VAM).

Leaf area index at initial growth will increase as the plant growth rises. But the further increases of LAI value (>1), the photosynthetic rate will decrease as some leaves will be covered by other leaves and the spread of sunlight will not be evenly distributed throughout the leaf surface.

The application of VAM will increase the LAD as it was able to contribute P-available to the plants then it will increase the absorption and translocation of nutrients and change in hormonal balance[9]. Base on the correlation analysis, the LAD had a positive correlation with LAI (r = 0.98**). This result was also supported by Irshad and Cheema[22].

Crop growth rate had a positive correlation with LAI (r = 0.85 **) and LAD (r = 0.82) (Table 6). Similar results were reported by Irshad and Cheema[22] and Ozalkan *et al.*[23], who stated that a positive correlation was found in LAI and crop growth rate, also Gardner *et al.*[24] stated that with the increasing LAI, the CGR will increase as well.

Net assimilation rate had a positive correlation with LAI (r = 0.80**), LAD (r = 0.53**) and CGR (r = 0.79**), Sridevi and Chellamuthu[25] stated that the NAR and CGR during the growth of rice plants generally showed a phenomenon of increase (high) at the beginning of the growth phase, but further will decline rapidly as the age of the plant increased. NAR had a positive correlation with the LAI (r = 0.80**) (Table 6) which was the higher the LAI, the more NAR will be produced.

The RGR has a positive correlation with LAI (r = 0.54**), LAD (r = 0.49*), CGR (r = 0.52**), NAR (0.33*) (Table 6). The NAR determined the relative growth rate (RGR)[15].

To increase the efficiency of water use which is very limited in rainfed lowland, especially in the dry season, it is better to use VAM as it helps in water uptake and nutrients. With the increasing of water uptake and nutrients, it will improve the rice growth characteristics. The higher rice growth obtained, the more results will be produced. The Situbagendit variety should be used in rainfed lowland as it responds positively to the use of VAM.

Table 4: Net assimilation rate of various rice to the application of VAM in the rainfed lowland rice field (mg cm^{-2} $week^{-1}$)

	Vesicular arbuscular mycorrhiza (VAM)		
Varieties	Without VAM	With VAM	Mean
IR64	4.73^{b-e}	8.36^{a-f}	6.558^{a-f}
Mentikwangi	4.18^{c-e}	6.38^{a-f-e}	5.282^{ab}
Pepe	3.85^{de}	7.59^{ab}	5.718^{ab}
Mekongga	4.23^{c-e}	5.28^{a-f-e}	4.727^{ab}
Way Apo Buru	4.02^{c-e}	6.20^{a-e}	5.112^{ab}
Inpari	3.86^{de}	7.23^{a-c}	5.542^{ab}
Situbagendit	5.54^{a-e}	7.04^{a-d}	6.290^{ab}
Mamberamo	3.16^{e}	5.43^{a-e}	4.295^{b-f}
Mean	4.19^{b-f}	6.68^{a-f}	(+)

Numbers in the same column followed by the same letter are not significantly different according to DMRT 5%

Table 5: Relative growth rate of various rice varieties to the application of VAM in the rainfed lowland rice field (g $week^{-1}$)

	Vesicular arbuscular mycorrhiza (VAM)		
Varieties	Without VAM	With VAM	Mean
IR64	1020^{b-f}	1716^{b-f}	1085.0^{ab}
Mentikwangi	820^{b-f}	1093^{b-f}	956.7^{b-f}
Pepe	763^{b-f}	1120^{b-f}	941.7^{b-f}
Mekongga	920^{b-f}	1716^{a-f}	1318.3^{a-f}
Way Apo Buru	776^{b-f}	963^{b-f}	870.0^{b-f}
Inpari	756^{b-f}	1086^{b-f}	921.7^{b-f}
Situbagendit	873^{b-f}	1040^{b-f}	956.7^{b-f}
Mamberamo	676^{b-f}	880^{b-f}	778.3^{b-f}
Mean	826^{b-f}	1131^{a-f}	(+)

Numbers in the same column followed by the same letter are not significantly different according to DMRT 5%

Table 6: Correlation analysis among leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate

Growth analysis	Leaf area index (LAI)	Leaf area duration (LAD)	Crop growth rate (CGR)	Net assimilation rate (NAR)	Relative growth rate (RGR)
LAI	0				
LAD	0.98**	0			
CGR	0.85**	0.82**	0		
NAR	0.80**	0.53**	0.79**	0	
RGR	0.54**	0.49**	0.52**	0.33*	0

CONCLUSION

It can be concluded that the application of VAM to the rice cultivated in the rainfed lowland rice field can increase the LAI, LAD, CGR, NAR and CGR. There was a positive and real correlation between the LAI and LAD, CGR, NAR and RGR.

SIGNIFICANCE STATEMENTS

This study aims to determine the growth analysis i.e., leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate of rice varieties to the application of Vesicular Arbuscular Mycorrhiza in the rainfed lowland rice field. The research need to be done as an anticipation of drought stress on rainfed lowland rice field. This research is to help the researchers and or local farmers to use the VAM and select the suitable rice variety in rainfed lowland rice field that often face drought stress problem to increase the productivity.

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