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Effect of soil tillage and mycorrhiza application on growth and yields of upland rice in drought condition

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Abstract

Dry land management technology for food crop agriculture with soil conservation, organic matter management, and water management. This study aims to determine the effect of soil treatment and mycorrhiza on growth and yield of upland rice in drought stress conditions. This experiment uses the Split Split Plot design consists of 3 factors: The first factor as the main plot of mycorrhizas consisting of no mycorrhizal and mycorrhizal administration. The second factor as a plot is the soil cultivation consisting of no soil preparation) and treatment. The third factor as Multiplication Children is Varieties consisting of three groups of varieties namely Toleran group (Ciapus Varieties, Inpago Varieties 4 and Varieties inpago 8) moderate varieties group include (Inpago Varieties 5, Varietas situ bagendit, Inpago Varieties 7 and Varietas towuti) and the susceptible varieties are (In jari 6 varieties, Inpari 33 varieties and synthetic varieties). Treatment without tillage and without mycorrhiza decreased leaf area, root canopy ratio, leaf proline content, degree of root infection and dry grain production. Soil sampling and mycorrhizal fertilization of Inpago 4 tolerant varieties showed a mechanism of avoidance against drought stress by increasing leaf area, root canopy ratio, leaf proline content and root infection. The highest dry grain production was found in the tolerant (Inpago 4) varieties group of 7.5 tons per ha and can be planted in drought stress conditions at rainfall ± 3.2 mm / day.

Keywords: Upland, Rice, Land Preparation, Mycorrhiza, Soil treatment

Introduction

Potential of upland rice production in Indonesia has reached up to 2.69 t/ha (BPTP, 2012) or about 5.2% of the total national rice production. Although the proportion is low, yet it has a high value. This is due to the harvest time of upland rice generally falls during the dearth rice periods. Upland rice is generally harvested time comes earlier than rainfed lowland rice and limited irrigated rice fields (Toha, 2010).

Farming on dry land comes with a certain situation such as lack of water, high acidity, but low nutrients (Gunawan, 1993). One effort which had been taken to overcome the problems is the utilization of arbuscular mycorrhizal fungi. Mycorrhiza is a fungus that lives in symbiosis with the root system of plants (Grant et al., 2011). Utilization of mycorrhiza not only increase the absorption zone and the availability of nutrients but also water stress resistance and pest resistance (Setiadi, 1999).

Mycorrhiza has a potential for alternative technology to increase plant growth and productivity, especially on the less fertile soil. Inoculation of mycorrhizal fungi in food crops can increase water uptake and provide sufficient water requirements for the plant's physical needs, especially in dry conditions (Thangadurai et al., 2010).

Crop treatment by always covering the land surface by vegetation and/or plant or litter remains also plays a certain role in soil conservation. Intensive soil cultivation is the cause of production decrease of dry land. The results show that excessive soil tillage can damage soil structure (Larson and Osborne 1982) and lead to soil organic matter crudeness (Rachman et al., 2004). Land conservation practice (LCP) is an alternative to land preparation to heighten land productivity (Brown et al., 1991) LCP is characterized by reduced discharge or reversal of the soil, intensifying the use of crop residues or other ingredients as mulch, sometimes (but not recommended) with the use of herbicides to suppress the growth of weeds or other nuisance plants. This study aims to determine the effect of soil tillage and mycorrhiza application on the growth and yield of upland rice in drought stress conditions.

Material and Methods

The study was conducted in Alue Mudem Lhoksukon village, North Aceh District, Nanggoe Aceh Darussalam Province, Indonesia from January 2015 to May 2015. The experiment in the field using split split plot design consists of three factors: The first factor as the main plot is mycorrhizas and no mycorrhizas. The second factor as a subplot is land cultivation consisting of no tillage and tillage (one round cultivation). The third factor as sub-subplot is rice varieties consisting of three groups of varieties, namely tolerant varieties (Ciapus, Inpago 4 and Inpago 8), moderate varieties (Inpago-5, Situbagendit, Inpago-7 and towuti) and sensitive (Inpari-6 jete , inpari-33 and Sintanur).

On soil tillage treatment, the soil was cultivated one week before planting whereas for no soil tillage the land was conducted by scrapping soil surface using small hoe. There were 120 plots with the size of 1 m x 2.5 m. Manure at 10 ton $ha^{-1}$was applied two weeks before rice planted. Fertilizer of Phonska at the dose of 300 $kg.ha^{-1}$and urea 200 $kg.ha^{-1}$were applied at the day of rice planted. Arbuscular mycorrhizal fungi, 10 g. planting $hole^{-1}$wasinoculated before the rice seeds were planted. Prevention of pests and diseases is done intensively from seed treatment to harvest. Fungicides in use are Oksiklorida 50 % and insecticides used are BPMC 480, MIPC Carbaryl 85% and Diazinon.

Measurement of leaf area was carried out using leaf area meter at 6, 8, 10 WAP weeks after planting (WAP). Shoot-root ratio was determined by measuring the ratio of dry weight of shoot compared to the dry weight of roots. Leaf proline content was **a**nalyzed at 10 and 13 WAP.

Degree of root infection caused by micorrhizas was assessed at 10WAP by staining according to Kormanik and Graw (1982). Grain production was determined at a moisture content of 14%.

Data Analysis

Data were analyzed using Windows SAS statistical program (Version 9) for analysis of variance at α test = 0.05 and continued with Duncan's Multiple Range Test (DMRT) test for significant difference.

Results and Discussion

Results

Groundwater level of the soil during the study was ranging from 33.55% to 36% of field capacity. The development of leaf area increased from age 6 and 10 WAP and at harvest. Leaf area of Inpago 4 (tolerant) variety is the highest while the lowest is of Inpari 33 (susceptible) variety (Figure 1).

Leaf area of upland rice treated with mycorrhizal fertilizer at 10 WAP showed more leaf area with no mycorrhizal fertilizer (Table 1).While the effect of soil tillage on leaf area is presented in Tabel 2. Leaf area of rice is much higher if soil is cultivated before planting (Table 2).

Root-Shoot Ratio

Root bearing ratios were significantly influenced by the interaction of upland rice and mycorrhizal varieties at age 6 WAP and 8 WAP Inpari 33 varieties (susceptible varieties) with no tillage and no mycorrhizal fertilizer showed the highest ratios while the inpago 4 varieties (tolerant varieties groups) on no soil treatment with no mycorrhizal fertilizers showed the lowest root canopy ratios as listed in Table 3.

The interaction of soil preparation and mycorrhizal fertilizer gave a significant effect on the root-shoot ratio. The highest root-shoot ratio was observed at no mycorrhiza and no soil tillage (Table 4).

Proline content

Inpago 4 varieties (tolerant varieties group) have the highest proline content available without tillage with no mycorrhizal biochemical fertilizer whereas the lowest proline content ratio was found in inpari 33 varieties (sensitized) without soil treatment without mycorrhizal fertilizers, as shown in Table 5.

Figure 2 shows the mechanism difference of 10 varieties in accumulating proline. Increased proline is a crop mechanism for dealing with drought stress conditions. In varieties of inpago 4 (tolerant varieties group) shows the highest prolina accumulation in the band with other varietal groups.

Degree of root infection

The degree of root infestation by mycorrhiza was measured based on the proportion of the mycorrhizal infected field. Infected category was based on Rajapakse and Miller (1992) in Prafithriasari (2010) as follows: <5% infected is categorized very low (Class 1), 6 - 25% is categorized low (Class 2), 26 - 50% is categorized moderate (Class 3) 51 - 75%is categorized high (Class 4), and> 75% is categorized very high (Class 5). Roots of Inpago 4 variety (tolerant group) were 46.33 percent infected whereas the number of uninfected roots was found in untreated with mycorrhiza.

The content of proline is significantly influenced by the interaction of soybean and mycorrhizal biofertilizer varieties at age 10 MST and 12 MST.

Rice grain production

The production of dried un hulled rice harvested from different land preparation and different mycorrhiza treatment is shown in Table 7. The production is significantly influenced by the interaction of soil tillage and mycorrhizal treatment. Inpago 4 variety (tolerant variey group) gave the highest dry grain production in soil tillage plus mycorrhiza treatment whereas the lowest grain production was found in sintanur varieties (sensitive variety group) grown on no tillage and mycorrhiza (Table 7).

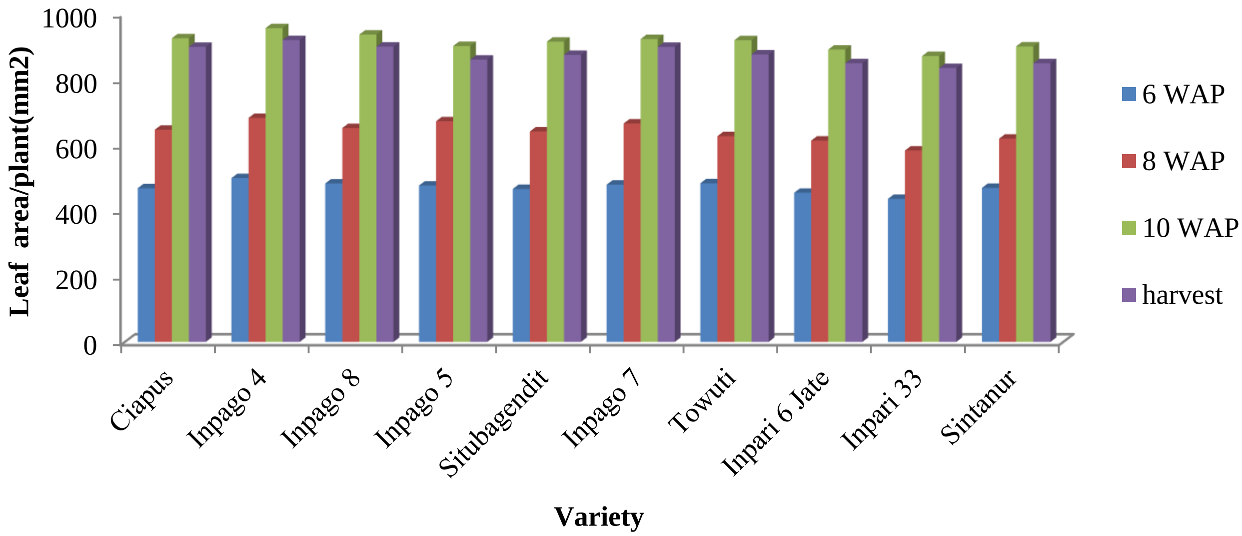

Figure 1. Leaf area of 10 upland rice varieties at 6, 8, 10 WAP and harvest time

Table 1. The average of leaf area of rice plant treated with mycorrhiza 10 WAP

Leaf Area 1)	
Treatment	10 WAP (mm^2)
Control (no mycorrhiza)	995.35 a
Mycorrhiza	833.03 b

1) Numbers followed by the same letters in the same column are not significantly different based on DMRT atα 0.05

Table 2. Leaf area of upland rice grown on soil tillage and no tillage 6 WAP

Treatment	Leaf area[1)]
	--------------------- mm^2----------------------
No tillage	851.53 b
Soil tillage (plowed)	976.85 a

1) Numbers followed by the same letters in the same column are not significantly different based on DMRT atα 0.05

Table 3. Root-shoot ratio of 10 upland rice varieties on different land preparation and mycorrhizal fertilizer at the age of 6 and 8 WAP

Land Preparation	Upland rice variety	Root-shoot ratio†			
		6 WAP		8 WAP	
		No mycorrhiza	With mycorrhiza	No mycorrhiza	With mycorrhiza
No tillage	Ciapus	2.77 b-d	1.87 e-j	1.82 e-j	2.18 c-i
	Inpago 4	1.09 n-p	1.36 j	1.53 g-j	1.48 h-j
	Inpago 8	1.88 g-k	1.68 f-j	1.98 e-j	1.32 j
	Inpago 5	1.73 h-l	1.90 e-j	1.80 e-j	1.99 e-j
	Situbagendit	2.07 f-i	1.77 e-j	2.07 c-j	2.77 a-d
	Inpago 7	1.70 h-l	1.92 e-j	2.28 c-g	2.26 d-h
	Towuti	1.26 l-o	1.90 e-j	2.06 c-i	2.01 d-j
	Inpari 6 Jate	2.35 d-g	2.03 d-j	1.46 ij	1.55 g-j
	Inpari 33	2.26 d-h	2.15 c-i	2.82 a-c	1.58 g-j
	Sintanur	2.24 d-h	1.96 f-j	2.15 c-i	1.68 f-j
Tillage	Ciapus	1.06 n-p	2.77 b-d	1.87 e-j	1.82 e-j
	Inpago 4	0.58 p	1.09 n-p	1.36 j	1.53 g-j
	Inpago 8	0.59 p	1.88 g-k	1.68 f-j	1.98 e-j
	Inpago 5	1.47 j-n	1.73 h-l	1.90 e-j	1.80 e-j
	Situbagendit	1.37 k-o	2.07 f-i	1.77 e-j	2.07 c-j
	Inpago 7	1.42 k-n	1.70 h-l	1.92 e-j	2.28 c-g
	Towuti	1.30 k-o	1.26 l-o	1.90 e-j	2.06 c-i
	Inpari 6 Jate	2.11 f-i	2.35 d-g	2.03 d-j	1.46 ij
	Inpari 33	1.25 l-o	2.26 d-h	2.15 c-i	2.82 a-c
	Sintanur	1.58 i-n	2.24 d-h	1.96 f-j	2.15 c-i

†Numbers followed by similar letter in the same column are not significantly different based on DMRT test at α 0.05

Table 4. The impact of the interaction of land preparation (soil tillage) and mycorrhizal fertilizer on root-canopy ratio 10 WAP and at harvest time

Land preparation (tillage)	Root canopy ratio†			
	10 WAP		Harvest	
	No mycorrhiza	Mycorrhiza	No mycorrhiza	Mycorrhiza
No tillage	2.96 a	2.24 b	2.81 a	2.19 b
Soil tillage	2.33 b	2.24 b	2.42 b	2.30 b

†Numbers followed by similar letter on the age with no significant effect based on DMRT test atα 0.05

Table 5. Proline content in 10 varieties on different soil tillage and mycorrhiza

Land Preparation	Upland rice variety	Mycorrhiza			
		10 WAP		13WAP	
		No mycorrhiza	With mycorrhiza	No mycorrhiza	With mycorrhiza
No tillage	Ciapus	38.84 hi	40.34 gh	16.68 j-l	24.65 g-i
	Inpago 4	62.23 a	79.01 a	44.55 b	51.33 a
	Inpago 8	57.27 c	50.82 d	37.88 c	43.21 b
	Inpago 5	28.45 l	25.19 m	17.43 jk	15.99 kl
	Situbagendit	24.16 mn	38.59 h-i	18.70 j	23.18 i
	Inpago 7	27.46 l	22.11 op	13.29 m-o	13.58 mn
	Towuti	45.14 e	42.81 f	26.10 f-h	24.29 h-i
	Inpari 6 Jate	16.23 q	24.20 mn	9.43 rs	17.84 jk
	Inpari 33	11.87 r	17.16 q	7.62 s	9.58 q-s
	Sintanur	22.99 no	23.46 m-o	12.07 n-q	18.32 jk
Tillage	Ciapus	30.39 k	37.77 i	16.68 j-l	22.66 i
	Inpago 4	62.00 b	51.43 d	31.33 d	36.66 c
	Inpago 8	46.66 e	42.88 f	30.35 de	28.14 ef
	Inpago 5	28.15 l	27.36 l	12.80 m-p	11.81 n-q
	Situbagendit	27.57 l	24.35 nm	11.62 n-r	14.63 lm
	Inpago 7	22.24 op	33.17 j	10.28 p-r	27.84 f
	Towuti	42.55 f	41.50 fg	26.85 fg	28.48 ef
	Inpari 6 Jate	34.01 j	33.93 j	18.21 jk	23.67 i
	Inpari 33	24.21 mn	20.75 p	10.02 rq	10.94 o-r
	Sintanur	20.39 p	28.87 kl	10.65 p-r	18.32 jk

†Numbers followed by similar letter on the age with no significant effect based on DMRT test atα 0.05

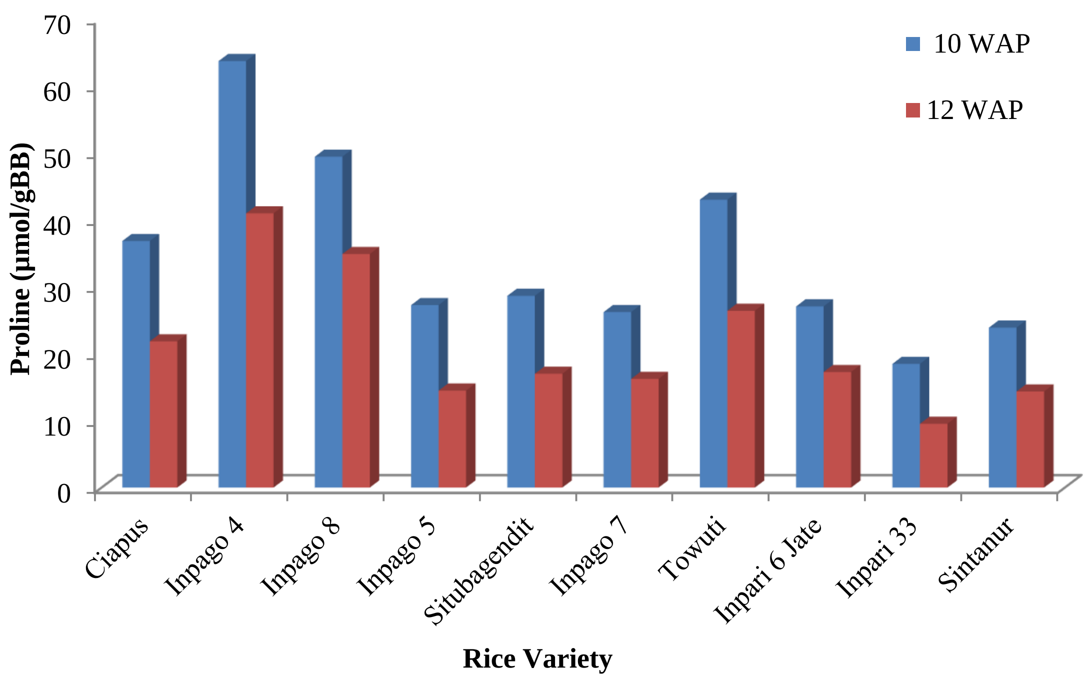

Figure 2. Proline content found in each rice variety 10 WAP and 12 WAP

Table 6. Root infection by mycorrhiza in 10 upland rice varieties on mycorrhizal treated soil

Rice Variety	Land preparation	Root infected (%) in soil treated with mycorrhiza	Category
Ciapus	No tillage	22.25 j	level 2(low)
Inpago 4		36.00 a-d	level 3 (low)
Inpago 8		33.33 b-c	level 3 (medium)
Inpago 5		22.75 e- j	level 2 (low)
Situbagendit		21.83 f-j	level 2 (low)
Inpago 7		28.66 c-g	level 3 (medium)
Towuti		30.66 c-d	level 3 (medium)
Inpari 6 Jate		19.50 g- j	level 2 (low)
Inpari 33		13.00 j	level 2 (low)
Sintanur		27.83 c-d	level 3 (medium)
Ciapus	Soil tillage	41.83ab	level 3 (medium)
Inpago 4		46.33 a	level 3(medium)
Inpago 8		35.33 b-c	level 3(medium)
Inpago 5		36.16 a-d	level 3(medium)
Situbagendit		37.33 a-c	level 3 (medium)
Inpago 7		25.33 d-i	level 2 (low)
Towuti		26.16 d-h	level 2 (low)
Inpari 6 Jate		16.50 h-j	level 2 (low)
Inpari 33		14.83 ij	level 2 (low)
Sintanur		13.66 j	level 2 (low)

†Numbers followed by similar letter on the age with no significant effect based on DMRT test atα 0.05

Table 7. Rice grain production of 10 upland rice varieties growing on soil tillage and treated with mycorrhiza

Rice variety	No tillage and no mycorrhiza (Control)	No tillage-mycorrhiza	Soil tillage (ploughed) and no mycorrhiza	Soil tillage (ploughed) and mycorrhiza
ciapus	3.41 o-r	4.18 ef	3.78 j-m	4.31 de
Inpago 4	3.80 i-m	5.37 d	4.53 fg	7.55 a
Inpago 8	3.32 o-p	4.21 d	3.79 g-l	4.73 d
Inpago 5	2.91 op	3.68 k-m	3.86 h-m	6.84 h-m
Situ Bangendit	3.55 l-m	3.92 fg	3.61 fg	4.63 k-m
Inpago 7	2.45 p-q	3.83 h-m	4.37 f-h	6.32 f-h
Towuti	3.52 lm	4.21 de	3.84 g	4.60 bc
Inpari 6 Jate	2.23 rq	4.33 f-i	3.44 mn	3.65 lm
Inpari 33	2.91 s	3.51 no	3.19 r-q	3.65 mn
Sintanur	2.07 rs	3.69 k-m	2.75 o-q	4.34 f-i

Discussion

The results showed that the difference among the 10 varieties tested showed that Inpago 4 variety seemed to be more adaptive to unfavorable environments, where the water shortage did not interfere the growth (Table 3, 5 7). Inpago 4 variety representing new superior varieties (VUB) is tolerant to environmental stress, including to drought. Soil treatment arrangements and mycorrhizal applications of varieties may be reflected in leaf area characteristics, root-shoot ratios, degree of root infection, leaf proline content and grain production that can be used in determining drought tolerant varieties. The tolerant variety (Inpago 4 variety) showed that the character of leaf area, root-shoot ratio, degree of root infection, leaf proline content and highest production in soil tillage and mycorrhizal treatment. This indicated that inpago 4 upland rice variety is more adaptable to these conditions and did not indicate any significant inhibition of long root growth. This variety could grow better than other varieties due to its ability to absorb water from deeper depth in the soil. Root–shoot ratio is an important indicator for plant ability to take water from deeper soil (Abdallah et al., 2016). Fukai Lilley (1995) reported that the depth of root achievement and root diameter is an important indicator in determining tolerance to drought stress in upland rice

Root establishment in the tolerant variety group is better than that of moderate varieties and susceptible varieties which therefore increase the ability to reach water level. Serraj et al. (2004) reported that root response to drought stress will increase the depth of root achievement and wider root development

Asch (2005) stated that relatively tolerant varieties increase root growth greater in drought stress conditions. The mechanisms of tolerance in plants as a response to drought stress include (i) the ability of plants to continue to grow in the condition of water shortage is to decrease the leaf area and shorten the growth cycle (ii) the ability of the root to absorb water in the deepest layer of soil. (iii) the ability to protect the root meristem from drought by increasing the accumulation of certain compounds such as glycine, betaine, alcohol sugar and proline for adjustment and (iv) optimizing the role of stomata to prevent leaf water loss (Nguyen et al., 1997) in the presence of such osmotic adjustment allowing growth to continue and stomata remains open.

Inpago 4 tolerant varieties showed higher physiological agronomic characteristics, root-shoot ratios, compared to other varieties in soil tillage and mycorrhizalization (Tables 3 and 4). Growth ratio of root-shoot in drought conditions will result in different responses for each variety. Root length will increase when faced with drought associated with mechanism of resistance of plant genotype to drought not by influence of moisture content. Sitompul and Guritno (1995) stated that, plants that grow in a state of water shortage will form longer and more root quantities with lower yields than plants grow in water adequacy. Root shoot character is important to keep the potential of leaf water root remains high and to maintain evapotranspiration in water deprivation (Peng and Ismail 2004).

Drought stress caused increased accumulation of proline in ten varieties of upland rice and mycorrhizal biofertilizer treatment showed different response of varieties to drought stress conditions (Table 2). Drought stress associated with drought tolerance is an increase in prolina accumulation. According to Yue et al (2006) the mechanism of tolerance through osmotic adjustment is increased proline accumulation but under normal circumstances, proline would be reoxidized into glutamic acid (Widyasari and Sugiyarta, 1997). In this study proline content was higher in …variety at 10 to 13 WAP (Fig. 2).

The occurrence of mycorrhizal infection with rooting is also the beginning of symbiosis between the mycorrhiza arbuscular fungus (CMA) and the roots of upland rice plants. In this study, a higher rate of root infections was found in the treatment of mycorrhiza and soil application on inpago 4 tolerant varieties of about 46.3%, while inpari 33 varieties (sensitive varieties) in mycorrhizal and no till fertilizer applications showed the lowest root infection 13% (table 6). Mycorrhiza is a symbiosis between fungi and plant roots. Mycorrhizas are beneficial for plants that increase nutrient uptake especially of phosphorus and increase plant resistance to drought stress. Upland rice is a plant that has a positive response to the development of mycorrhiza and has the ability as a mass of mycorrhizal mass propagation. This is in line with Sastrahidayat (2010) which stated that the ability of spores adapting to the environment greatly determine the effectiveness of inoculation in host plants. The absence of good root infections in no mycorrhizal condition

Soil cultivation and mycorrhizal application of Inpago 4 showed the ability to adapt drought conditions by avoiding drought stress which is shown in the ratio of root-shoot, leaf proline content, root infection and increased grain production of 7.5 tons per hectare.

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