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Cite as: AIP Conference Proceedings **2583**, 020042 (2023); https://doi.org/10.1063/5.0117338
Published Online: 13 January 2023

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Tolerance Level of Rice (*Oryza sativa* L.) to Aluminum Stress in Ultisol Soil

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Abstract. Aluminum can have harmful effects on plant growth both directly and indirectly. This study aims to examine the tolerance level of lines of rice plants to aluminum stress in ultisol soil. This research was conducted from February 2020 to May 2020 in the Experimental and Research Field of Faculty of Agriculture, Fisheries and Biology, Universitas Bangka Belitung. The experimental design used a Factorial Complete Randomized Design (FCRD) consisting of 2 factors. Factor 1 was 10 F_6 rice lines and 2 check varieties. Factor 2 were P_0 as control (0 ppm) and P_1 as stress Al 200 ppm. The results showed that plant varieties had very significant effects on plant height, leaves number, productive tillers number, root length, panicle length, flowering age, harvest age, the weight of pithy seeds, and the number of pithy seeds, but no significant effect on the root volume. The application of 200 ppm aluminum does have not a significant difference with the control treatment (0 ppm aluminum) for all observed characters. Based on the results showed that all f_6 rice lines tested had a score of 1 (tolerant) of aluminum stress in ultisol soil.

INTRODUCTION

Rice is a staple food of Indonesian society. Rice has a variety of shapes and colors. In Indonesia, there are three colors of rice, namely white rice, brown rice, and black rice. Brown rice has better nutritional content than white rice, such as fiber content, essential fatty acids, and some vitamins are higher than white rice [1]. Brown rice is broken skin rice (without rubbing), whose outer skin layer or window is still attached to the endosperm. This outer skin layer contains high anthocyanins, rich in vitamins B and E, and its nutritional value and fiber are higher compared to white rice [2].

Food needs, especially rice, continue to increase along with the growing population and high consumption levels (84.88 kg /cap/ yr) [3]. Rice production in Indonesia in 2015 amounted to 75.40 million tons of milled dry grain (GKG), while rice production for the Bangka Belitung Islands province in 2015 amounted to 27,068 tons (0.03% of Indonesia's rice production) [4]. The rice production figures of Bangka Belitung Islands province are only able to meet 14% of the rice needs of its people [5]. Local rice Bengkalis shows tolerance (Genotype Yamin and Sadani) and moderate (rice genotype Amat Candu and Solok) to Al stress [6]. However, tolerant resistance to rice production is still low, this is occurring because the land for the land is less fertile, namely the type of dry land with the type of ultisol soil.

Rice planting land is still widely available is on sub-optimal land such as dry land with ultisol soil type. Increased rice crop production can be done with an extensive program, namely through the expansion of the land area to dry land [7]. The potential for dry land for rice cultivation is conlinesed by low soil fertility rates where low pH can reduce the availability of nutrients for plants [8]. In addition, the limiting factor of food crop cultivation in dry land is the saturation of High Al [9]. The toxicity of Al^{3+} causes root growth to be inhibited, causing water and nutrients absorbed by plants to be reduced. This as a whole can decrease crop productivity [10]. Increased productivity of plants in sour soil depends on the level of tolerance limited by Al and the ability to absorb nutrients by roots [11].

Aluminum can have detrimental effects on plant growth either directly or indirectly. The influence of Aluminum is not the same on all plants, even in the same species. Roots are the part of the plant most sensitive to Al poisoning

The 5th International Conference on Agriculture and Life Science 2021 (ICALS 2021)
AIP Conf. Proc. 2583, 020042-1–020042-6; https://doi.org/10.1063/5.0117338
Published by AIP Publishing. 978-0-7354-4216-0/$30.00

[12]. The first symptom of Aluminum stress is disturbed root growth. This is due to the inhibition of cell division in the roots [13].

Proper and rapid methods of testing varieties/lines against Al poisoning are still difficult to come by. This is because the tolerance of rice plants to Al poisoning is influenced by plant nutrient conditions, climate, and growth phase [14]. This method should be able to reflect the condition of Al poisoning widely in Indonesia. Research on screening in the field is a good method and much done to find out the tolerance of lines/varieties of rice to Al poisoning. Al's toleration test on rice plants using a screening method correlated with Al's poisoning score in the field with nutrient culture or polybag [13].

The development of Al-tolerant red rice needs to continue by utilizing various sources of genetic diversity. The origin of red rice seeds is a cross result of PBM UBB1 x Inpago 8, PBM UBB1 x Banyuasin, Inpago 8 x Beam, Inpago 8 x Banyuasin, Inpago 8 x PBM UBB1, Beam x Banyuasin, Beam x Inpago 8, Banyuasin x Beam, Banyuasin x PBM UBB1, and Banyuasin x Inpago 8 [15]. The lines used are F6 lines resulting from the mutant crossing PBM UBB1, Beam, Inpago 8, and Banyuasin. The lines of red rice used are generation F6 lines, but it is not yet known the tolerance level to Aluminum. The research aims are to determine the tolerance level of F6 lines of rice to aluminum in ultisol soil and find out that F6 lines are tolerant to aluminum in ultisol soil.

MATERIALS AND METHOD

The research was conducted from February 2020 to May 2020 in the Experimental and Research Garden of the Faculty of Agriculture, Fisheries and Biology, at Universitas Bangka Belitung. The design used Factorial Complete Randomized Design (CRD) consisting of 2 factors. The first factor is 10 lines of F6 rice and 2 comparator varieties (12 treatments). The second factor is P0 is control and P1 is al-200 ppm. The combination of control treatment and Aluminum (Al) consists of 24 combinations. 24 combinations and 3 repeats on each experiment. Each treatment is repeated 3 times so that 72 experimental units are obtained, and in 1 experimental unit, there are 5 polybags so the total polybag is 360 polybags.

Preparation of tools and materials is one of the first steps that must be done before doing research. Materials used such as rice seeds and $Al_2(SO_4)_3$. Land preparation is done by cleaning the land that will be used by manual means that is cleaning with a hoe to weed the disturbing grass. The rice seeds used are selected F6 lines seeds and 2 good quality comparison varieties such as not broken or damaged. Planting media in the form of topsoil soil taken from a depth of 0 to 20 cm from the ground level around the campus of Bangka Belitung University. The soil that has been dug up is then weighed as much as 10 kg and then filled into a polybag. The filled polybags are arranged with a distance between polybags of 25 cm x 25 cm between treatments. Screen houses are made using wood with para net and using clear plastic roofs. The shadow house used measures 10.5 m long and 7.5 m wide. The area of land used is (10.5 m x 7.5 m) 78.75m^2, and the area of the plot used is 1 m. The preparation of the polybag must pay attention to the design used. The design used in this study is a factorial complete random design (CRD) where the preparation of polybags to be treated is determined randomly or drawn. Embroidery is done to replace dead seedlings and abnormal seed growth with surviving reserve plants. Embroidery is done when the plant is about 14 days old after planting.

The application of aluminum treatment in planting media is first done by determining the field capacity. Three polybags are filled with dry soil media and then weighed. Water saturation is carried out on three polybags. Three saturated polybags were weighed. The difference in the average weight of saturated soil is reduced by the weight of dry soil which is the volume of aluminum solution used as a treatment [7]. The application of Al is then done once watering which is 21 days after planting. Plant maintenance activities include fertilization, water administration, weed control, and plant-disrupting organisms. Rice that is ready to be harvested must-have criteria of 85% of rice grains have yellowed and grains feel hard when pressed and do not secrete milky white liquid.

The parameters observed in this research were plant height, leaf number, productive tillers number, root length, root volume, panicle length, flowering age, weight of pithy seeds, number of pithy seeds, leaf color, and Al poisoning score. Data analysis was conducted with Analysis of Variance (5% standard F test) if the data give a significant effect it will continue by using Duncan's Multiple Range Test (DMRT) at the level of 5%. Observational data is also analyzed using correlations.

RESULT AND DISCUSSION

Soil analysis results that have been tested at the Environmental Biotechnology Laboratory (ICBB) show that the parameters analyzed include PH, N Total, P2O$_5$ Available, P_2O_5 Potential, K_2O Potential, KTK, Aluminum, Ca^{2+}, and

Mg^{2+}. The soil pH on ultisol soil has a PH of 5.06 with a rather wry criterion. N-total rate of 0.09% with very low criteria (Table 1). This is because the pH of the rhizosphere at a pH below 4 reduces tolerance ability, while the pH of the soil ultisol is 5.6. The higher the KTK of the land, the tolerance to toxic Al is increasingly difficult. *Mucilage-mucigel* (a high molecular weight material in the apical root zone containing *polysaccharides* and *polyglacti*n acid) [16].

TABLE 1. Analysis of The Chemical Properties of Ultisol Soil

Parameters	Chemical properties
PH	5,06
N Total (%)	0,09
P2O5 Tersedia (mg/kg)	22,51
P2O5 Potensial (mg/100g)	12,42
K2O Potensial (mg/100g)	6,03
KTK (cmol (+) kg)	5,06
Aluminium (mg/kg)	41809,60
K+ (cmol (+) kg)	0,08
Na+ (cmol (+) kg)	<0,06
Ca2+ (cmol (+) kg)	0,31
Mg2+ (cmol (+) kg)	0,18

The F6 rice shows a difference in character to the aluminum treatment. The Analysis of Variance showed that plant varieties had a highly significant effect on plant height character, leaves number, productive tillers number, root length, panicle length, flowering age, harvest age, the weight of pithy seeds, and the number of pithy seeds. This suggests that the average characters observed from across the genotypes tested had differences from each other. Two important factors affect the growth of a plant, namely genetic factors, and environmental factors, genetic actors of each line and comparison varieties have special genetic traits and traits that are one of the causes of the diversity of plant appearance as well as the consequences of the adaptation of varieties to the environment [17]. Varieties have no significant effect on the volume of roots. The 200 ppm aluminum check provides no noticeable difference with the control treatment (without aluminum administration) for all observed characters. The results of the analysis variance showed no interaction between aluminum and the type of variety against all observed characters (Table 2). Al tolerant rice plants can suppress the effects of damage caused by Al's cheques, so that tolerant varieties can grow better than other rice varieties/genotypes [6]. Plants that are tolerant to Al poisoning can suppress the adverse effects of Al poisoning.

TABLE 2. Analysis Variance of Several Genotype Characters of Rice plants on Aluminum Treatment.

Parameters	Varieties		Al treatment		Interactions		CV (%)
	F Value	P>f	F Value	P>f	F Value	P>f	
Height plant	90,01	<,0001**	0,23	0,6361 ns	1,49	0,1668 ns	3,24
Leaves Number	21,10	<,0001**	0,60	0,4423 ns	1,49	0,3696 ns	12,22
Productive tillers number	27,13	<,0001**	0,09	0,7653 ns	0,83	0,6129 ns	10,80
Root length	3,37	0,0017**	2,94	0,0930 ns	0,91	0,5348 ns	16,30
Root volume	2,59	0,0113ns	1,58	0,2154 ns	0,71	0,7246 ns	22,18
Panicle length	25,38	<,0001**	3,96	0,0523 ns	3,23	0,0023 ns	4,67
Flowering age	19,75	<,0001**	0,33	0,5656 ns	1,82	0,0756 ns	2,15
Weight of Pithy seeds (t)	18,69	<,0001**	0,00	0,9817 ns	0,37	0,9601 ns	16,83
Number of Pithy seeds (t)	19,57	<,0001**	0,01	0,9245 ns	0,31	0,9796 ns	31,05

Description: **: Significant at level 1%; *:Significant at level 5%; ns: Not Significant ; CV (%): Coefficient of Variance; F Value; Pr > F: Probability Value; T: 'Square Root' Data Transformation= Sqrt (original data + 0.5).

DMRT's follow-up test results with a 95% confidence level in the genotype character of red rice plants against aluminum (Al) yield showed that all plant genotype characters differed markedly except for root volume. The lines 23A-56-24-22-12 have character number of leaves, number of productive tillers, and root length highest compared to others lines. The root length of each line's F6 and 2 comparison varieties is controlled by genes that interact with the soil environment. his is also because in gripped conditions the roots still have better adaptation and grow. The ability of the root to remove organic exudates that can protect the root feathers from the negative influence of aluminum that can kill the roots, to be able to process metabolism and growth [18]. The character of production is the weight of pithy seeds and the highest number of pitiful seeds is lines 23A-56-30-25-12 but is not different from other lines. The number of tillers formed will increase the amount of grain formed in the panicle, thus causing an increase in the number of pithy grains [19]. The production of pithy grain can increase when the assimilate formed in the process of photosynthesis is translocated to the grain [20].

TABLE 3. Average Genotive Character of Red Rice Plants on Aluminum Stress

Lines	Plant Height (cm)	Leaves Number	Productive Tillers Number	Root Length (cm)	Panicle Length (cm)	Flowering Age (day)	Harvest Age (day)	Weight of Pithy Seeds	Number of Pithy Seeds
19I-06-30-17-17	81,55 fg	132,20 ab	24,73 bc	23,52 d	20,16 cd	74,46 b	105,53 def	382,07 b	12,99 b
19I-06-09-23-3	82,58 f	100,86 ed	22,96 c	34,21 abc	19,61 d	70,76 ef	106,73 ef	142,95cd	5,27 de
21B-57-21-21-1	91,05 e	145,13 a	26,10 ab	31,94 abc	20,16 cd	78,43 a	109,33 cde	38,25 d	1,61 ef
21B-57-21-21-2	96,46 d	133,66 ab	25,16 cb	32,71 abc	18,43 e	77,13 ab	112,83 ab	5,17 d	0,25 f
19I-06-30-17-27	81, 01 fg	126,43 cb	23,76 cb	26,76 cd	19,80 d	75,46 bc	106,73 cde	243,22 bc	7,66 cd
23A-56-30-25-1	107,56 bc	94,26 e	19 d	28,87 bcd	21,21 bc	69,33 f	101,23 g	381,66 b	9,34 bcd
19I-06-09-23-27	77,88 gh	125,33 cb	24,66 cb	27,36 cd	18,97 de	72,40 de	109,90 ace	42,15 d	1,70 ef
23A-56-30-25-13	110, 58 b	75,16 fg	14,66 e	34,22 ab	22,39 b	70,43 f	96,80 h	349,20 b	10,49 bc
23A-56-30-25-12	97,70 d	112,86 cd	23,06 cb	27,99 bcd	21,91 b	72,73 d	102,70 fg	548, 83 a	18,03 a
23A-56-24-22-12	74,86 h	141,13 ab	28,76 a	34,56 ab	16,43 f	72,96 d	108,70 cd	292,50 b	9,97 bc
Inpago 12 Agritan	105,28 c	90,86 ef	15,56 e	30,69 abc	22,14 b	75,93 bc	113,53 a	4,22 d	0,22 f
Rindang 1 Agritan	114,83 a	69,23 g	13,06 e	35,15 a	23,50 a	74,16 cd	104,03 efg	276,42 bc	8,77 bcd

Description: The numbers followed by the same letter in the same column show no distinct apparent on the Duncan Multiple Range Test (DMRT) level of 95%.

Qualitative character is observed when the rice plant enters the tillers phase of production until the generative phase. The qualitative character observed is the color of the leaves. Qualitative character is observed of each rice plant generation F6. The characters observed almost as a whole have a uniform physical appearance (Table 4). This is due to the color of the leaves tested showing no symptoms of bronzing-like leaf discoloration.

TABLE 4. Qualitative Parameters of Leaf Color

Lines	Leaf Color
19I-06- 30-17-17	Strong Yellow Green A
19I-06-09-23-3	Strong Yellow Green A
21B-57-21-21-1	Moderate Olive Green B
21B-57-21-21-2	Moderate Yellow Green C
19I-06-30-17-27	Moderate Yellow Green C
23A-56-30-25-1	Moderate Yellow Green C
19I-06-09-23-27	Moderate Olive Green B
23A-56-30-25-13	Moderate Olive Green B
23A-56-30-25-12	Moderate Yellow Green C
23A-56-24-22-12	Strong Yellow Green A
Inpago 12 Agritan	Moderate Yellow Green C
Rindang 1 Agritan	Moderate Yellow Green C

Description: The Character of The Leaf Color is Strong Yellow Green A; Moderate Olive Green B; Moderate Yellow Green C*(RHS Color chart).*

The results of the correlation test showed some characters had a real correlation related to the weight of pithy seeds, namely root volume, flowering age, harvest age, and the number of pithy seeds. Root volume, flowering age, and harvest age correlated markedly and very noticeably to the weight of pithy grains, but the correlations were worth negative. This is the higher the value of the three characters, the lower the weight value of pithy seeds. The number of pitiful seeds is perfectly correlated (r=0.98) with the weight of pithy seeds at 1% (Table 5). The character of flowering age is positively and noticeably correlated with the character of the age of harvest, meaning that plants that flower quickly will show a faster harvest age [21]. The results showed a noticeable positive correlation between the number of pithy seeds to the weight of pithy seeds [22]. The appearance of agronomy and its correlation leads to the growth and production of crops. Lines F6 and 2 comparison varieties that adapt well to the growing environment will grow optimally and provide the best results. The adaptation mechanism is indicated by the good agronomic appearance of all characters as well as the correlation between those characters. The appearance of agronomy and its correlation leads to the growth and production of crops. Strains F6 and 2 comparison varieties that adapt well to the growing environment will grow optimally and provide the best results. The adaptation mechanism is indicated by the good agronomic appearance of all characters as well as the correlation between those characters.

TABLE 5. Correlation between The Genotype Characters of Red Rice Plants

Parameters	Parameters								
	Plant Height (cm)	Leaves Number	Productive Tillers Number	Root Length (cm)	Root Volume	Panicle Length (cm)	Flowering Age (day)	Harvest Age (day)	Number of Pithy Seeds
Plant Height (cm)	X								
Leaves Number	-0,78**	X							
Productive Tillers Number	-0,84**	0,92**	X						
Root Length (cm)	0,30^{ns}	-0,29^{ns}	-0,22^{ns}	X					
Root Volume	0,001^{ns}	0,13^{ns}	0,06^{ns}	0,45*	X				
Panicle Length	0,79**	-0,77**	-0,81**	0.01^{ns}	-0,08^{ns}	X			
Flowering Age (day)	-0,16^{ns}	0.48*	0,26^{ns}	-0,19^{ns}	0,37^{ns}	-0,10^{ns}	X		
Harvest Age (day)	-0,39^{ns}	0,50*	0,37^{ns}	-0,10^{ns}	0,35^{ns}	-0,45*	0,64**	X	
Number of Pithy Seeds	0,12^{ns}	-0,27^{ns}	-0,14^{ns}	-0,18^{ns}	-0,53**	0,27^{ns}	-0,49*	-0,80**	X
Weight of Pithy Seeds	0,06^{ns}	-0,20^{ns}	-0,07^{ns}	-0,20^{ns}	-0,53**	0,23^{ns}	-0,42*	-0,74**	0,98**

Description:

1. The number followed by the symbol "*" in the column shows a real correlate at the level of 5%.
2. The number followed by the symbol "**" in the column shows a real correlate at the level of 1%.
3. Correlation value 0.00-0.20 (no correlation); 0.21-0.40 (weak correlation); 0.41-0.60 (medium correlation); 0.61 0.80 (strong correlation); 0.81 - 1.00 (perfect correlation).

CONCLUSION

Based on the research conducted it can be concluded that all lines of F6 rice tested to have a score of 1 (tolerant) to aluminum (Al) in the soil ultisol. The most tolerant lines of aluminum on the ultisol land judging by its growth and production are lines 23A-56-24-22-12 and 23A-56-30-25-12.

REFERENCES

[1] M. Asmarani, skripsi, Universitas Bandar Lampung, Lampung, 2017.
[2] Mawaddah, B. Purwoko, I. Dewi, and D. Wirnas, J Agron Indonesia. **46**, 126–132, (2018).
[3] Mira, U. Widyastuti, E.D. Mustikarini. Enviagro, J Pertan dan Lingkung. **3**, 1–43 (2011).
[4] BPS. (2016), available at: http://www.bps.go.id.
[5] Ahmadi, D. Rusmawan, *Prosiding Seminar Nasional Agroinovasi*, Bangka Belitung, 2016.
[6] E. Lestari, D. Roslim, and Herman, Junal Din Pertan. **29**, 139–44 (2014).
[7] H. Sitorus, skripsi, Universitas Bengkulu, Bengkulu, 2014.
[8] A. Kasno, J Sumberd Lahan,**13**, 27–40 (2019).

[9] A. Kasno, A. Trustinah, and Rahmiana, Penelit Pertan Tanam Pangan. **32**, 16–24 (2013).
[10] J. Awasthi, B. Saha, P. Regon, S. Sahoo, U. Chowra, A. Pradhan, et al, PLoS One. **12**, e0176357 (2017).
[11] X.Q. Zhao, R. Shen, Front Plant Sci. **9**, (2018).
[12] E. Mulyaningsih, A. Perdani, S. Indrayani, Suwarno, J Penelit Pertan Tanam Pangan. **35, (**2016).
[13] Indrayani S, Anggraheni Y, Wibowo H, Mulyaningsih E, Artik Ilm Pus Penelit Bioteknol LIPI, (2018)
[14] Sitaresmi T, Rina H, Wening, T. Ami, Rakhmi, N. Yunani, et al. Iptek Tanam Pangan. **8**, (2013).
[15] E.D. Mustikarini, G.I. Prayoga, R. Santi, H. Saragi, The3rdICSAFS. **334**, :1–8 (2019).
[16] R. Dwiningrum, Zulkifli, T. Handayani, J Penelit Pertan Terap. **16**, 139–46 (2016).
[17] D. Yuliani, Agric. **29**, (2017).
[18] Haryanto, T. Suwarno, D. Susanti, Agronomika, **11**, 136–44 (2011).
[19] T. Zulchi T, A. Husni, T. Hadiarto, Suparjo. *Prosiding Seminar Nasional Agroinovasi Spesifik Lokasi Untuk Ketahanan Pangan Pada Era Masyarakat Ekonomi ASEAN*, 2016.
[20] I. Nainggolan, I. Wijana, Santosa, Agroteknologi Trop, **6**, 319–28 (2017).
[21] A. Riyanto, T. Widiatmoko, B. Hartanto B. *Prossiding SemNas Pengembangan Sumber Daya Pedesaan dan Kearifan Lokal Berkelanjutan II*, p. 8–12, 2012.
[22] W. Rohaeni, K. Permadi, Agrotop. **2**, 185–90 (2012).
[23] X. Zhang, Y. Long, J. Huang, J Xia, Int. J. Mol. Sci. 20, 1551, 1-16 (2019).

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