Available on line at:
https://ppjp.ulm.ac.id/journal/index.php/jwem

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Rice Production in Tidal Lands: The Role of Several Soil Properties

HAIRIL IFANSYAH , ABDUL HADI, AND AGUS MAULANA

Department of Soil Science, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, Indonesia

Abstract

Tidal swamp land is an alternative land that has great potential for agricultural development in the future. At present time, the rice productivity in tidal areas vary from relatively high to low. This diversity is caused by obstacles and problems, including low soil fertility, acidic soil reactions, the presence of pyrite, high levels of Al, Fe, Mn and organic acids, deficiency of P, poor base cations such as Ca, K, Mg, and suppressed microbial activity. This research aimed at determining the role of several soil properties (pH, soluble Fe, available P, organic C, soil CEC, presence of pyrite and groundwater level) on rice production in tidal areas. This research is field research using survey methods. Sampling in the field was carried out using *purposive sampling* technique, namely referring to differences in rice production of the Karang Dukuh variety in Barito Kuala Regency. Soil samples were taken at a depth of 0-20 cm from the ground surface three points at each location with different rice production level. The research results showed that only three variables had a partially significant effect on rice production, namely soil pH, soluble Fe and available P. Together these three variables play a major role in rice production in tidal areas which best (coefficient of determination of 0.919) approached with aquation $Y_{(\text{rice production})}$ = 1,501 − 0.011 Fe-soluble + 0.269 P-available + 0.561 Soil pH. C-organic content, soil CEC, pyrite depth and water level play a very small role (≤ 8.1%) in rice production in tidal areas (coefficient of determination ≤ 0.081).

Key words: Rice production, soil pH, available P, soluble Fe, organic C, soil CEC, pyrite depth and water level.

INTRODUCTION

The area of tidal swamp land in Indonesia is estimated to be around 20.13 million ha, and 9.53 million ha of potential for agriculture, while only around 2.27 million hectares have been newly reclaimed (BBSDLP, 2011). According to (Nugroho *et al.* , 1993), the area of tidal land that can be used as agricultural land is around 9.45 million ha, but only 4.2 million ha has been utilized by local farmers, for transmigration placement programs and other migrant farmers.

The tidal land in South Kalimantan covers an area of 167,057 ha, of which 118,898 ha is in the Barito Kuala Regency area, 35,512 ha in Banjar Regency, 1,737 ha in Banjarmasin City and 10,910 ha in Tanah Laut Regency. Of this amount, 98,411 ha have been cultivated (BPS and South Kalimantan Provincial Agriculture Service, 2012). Tidal swamp land is an alternative land that has great potential for agricultural development in the future.

Barito Kuala is one of the districts in South Kalimantan which is a rice production center, especially local rice. This district is able to contribute the largest rice production, namely 17.28% of the total rice production in South Kalimantan (Lesmayati and Hasbullah, 2013). Ar-Riza (2000) reported that the problems faced

**Correspondence Author*: Department of Soil Science, Faculty of Agriculture, Lambung Mangkurat University; Jl. A. Yani Km 36 Banjarbaru (70714), Indonesia E-mail: hifansyah@ulm.ac.id

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

by farmers in tidal swamp land include the fact that local rice yields in tidal swamp land in Barito Kuala Regency are very diverse, ranging from 1-1.5 t ha $^{-1}$ mill dry grain. Hikmah and Saderi (2005) also reported that rice yields in the tidal swamplands of South Kalimantan were still low, namely 3.52 t ha $^{-1}$ mill dry grain. This diversity is caused by obstacles and problems, including low soil fertility, acidic soil reactions, the presence of pyrite, high levels of Al, Fe, Mn and organic acids, deficiency of P, poor base cations such as Ca, K, Mg, and suppressed microbial activity (Arsyad, 2015).

Data regarding the role of soil properties on the diversity of rice production in the tidal fields of Barito Kuala Regency is still not widely available. Therefore, this research was conducted to determine the relationship between rice production in tidal areas and several soil properties

METHODS

This research was carried out from June to August 2021. The research location was Barito Kuala Regency, South Kalimantan. Soil analysis was carried out at the Soil Department Laboratory, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru.

This research was a field research using survey methods. Sampling in the field was carried out using *purposive sampling* technique, namely referring to differences in rice production of the Karang Dukuh variety in Barito Kuala Regency. Soil samples were taken at each observation point at a depth of 0-20 cm from the ground surface. When taking soil samples, the presence of pyrite was also observed and the groundwater level was measured. Observation of the presence of pyrite was carried out using H_2O_2 solution while ground water level measurements were carried out using a tape meter. Soil sampling, measuring water levels and identifying the presence of pyrite were carried out three times at each location with different rice production level. Observations made on soil samples included parameters: soil pH (electro glass water extract 1: 2.5), Fe-soluble (ammonium acetate extract pH 4.8), P-available (Bray-I extract), C-organic (Walkley and Black), and soil CEC (ammonium acetate extract pH 7). The observed data were analyzed using multiple regression and correlation tests . Data processing for multiple regression and correlation tests was carried out using the SPSS version 25 computer application program.

RESULTS

The Role of Several Soil Properties on Rice Production on Tidal Lands

Data on rice production in tidal fields and data from observations of several soil properties, namely pH (water extract 1: 2.5) , Fe-soluble (ammonium acetate extract pH 4.8) , P-available (Bray-I extract), C-organic (Walkley and Black), soil CEC (ammonium acetate extract pH 7), the presence of pyrite (H_2O_2 test) and the ground water level can be seen in Table 1.

Based on analysis using SPSS, the coefficient value and significance of each variable (partial) on rice production can be seen in Table 2.

Table 1. Rice production, soil chemical properties, and field data at study site.

Journal of Wetlands Environmental Management
Vol 11 No 2 (2023) 126– 132
http://dx.doi.org/10.20527/jwem.v11. i2.20091

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Site code	Product-ivity (ton ha^{-1})	Soil pH	Soluble Fe (ppm)	Available P (ppm)	Organic-C	CEC (me 100g $soil^{-1}$)	Pyrite depth (cm)	Water table/flood (cm)
A1	2.42	4.20	131.74	1.24	4.72	21.48	60	27
A2	2.42	4.55	125.08	0.92	2.37	19.48	41	27
A3	2.42	4.21	156.07	0.85	2.28	20.88	75	40
B1	2.08	3.96	153.05	0.60	4.96	21.11	20	36
B2	2.08	3.88	185.82	0.29	5.20	31.49	40	36
B3	2.08	4.09	146.04	1.01	4.08	29.22	10	36
C1	3.46	3.86	51.63	1.00	1.16	25.85	90	33
C2	3.46	3.83	43.52	1.92	3.28	35.20	93	30
C3	3.46	4.39	74.84	1.53	2.12	32.22	89	33
D1	4.50	4.48	28.76	3.64	1.33	36.60	100	10
D2	4.50	4.83	60.27	4.11	3.01	33.77	77	10
D3	4.50	4.56	20.78	2.54	0.78	25.36	79	10
E1	2.77	4.21	76.85	1.23	2.76	26.23	57	20
E2	2.77	3.98	100.30	1.17	3.24	32.86	96	20
E3	2.77	3.88	86.52	0.59	2.47	24.46	76	20
F1	4.15	4.35	68.68	0.86	2.22	19.54	50	28
F2	4.15	4.61	70.55	3.49	2.55	21.90	90	28
F3	4.15	4.31	74.43	3.55	1.75	27.48	70	28
G1	3.11	4.33	103.27	1.35	1.73	23.23	60	21
G2	3.11	4.12	94.11	1.18	4.58	26.63	55	21
G3	3.11	4.68	119.19	1.21	3.53	19.53	55	21
H1	1.73	3.74	209.92	0.96	5.30	25.20	20	29
H2	1.73	4.36	215.08	1.14	6.16	27.29	20	29
H3	1.73	3.39	141.71	0.75	3.92	23.43	30	29

Table 2. Coefficient value and significance of variable X (partial) on variable Y (rice production)

Variable	*Unstandardized Coeff.*		*Standardized Coeff.*	t	*Sign*
	B	Std. Error	Beta		
(Constant)	1,374	1,302		1,055	0.307
Soil pH	0.561	0.254	0.206	2,204	0.043
Fe-soluble	-0.011	0.003	-0.645	-3.86	0.001
P-available	0.269	0.093	0.31	2,883	0.011
C-organic	-0.006	0.096	-0.009	-0.061	0.952
Land CEC	-0.005	0.017	-0.029	-0.328	0.747
Pyrite depth	0.001	0.004	0.024	0.197	0.846
Flood height	0.007	0.011	0.06	0.632	0.537

Description: <0.05 there is a relationship, >0.05 there is no relationship

Based on the results of the t test in regression and correlation analysis, it shows that soluble Fe, available P and soil pH individually have a significant effect on rice production, this can be

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025---

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

seen from the t-sig value of soluble Fe <0.05, namely 0.001, the t value -sig P-available is 0.011 and the t-sig value of soil pH is 0.043. This condition indicates that only three variables have a partially significant effect on rice production, namely soil pH, soluble Fe and available P (Table 2) . Together (multiple regression) these three variables produce the regression equation:

Y (rice production) = 1,501 − 0.011 Fe-soluble + 0.269 P-available + 0.561 Soil pH , with a coefficient of determination (R^2) of 0.919 or 91.9% and the correlation coefficient (r) is 0.959 or 95.9%.

Based on this equation, it can be seen that soluble Fe has a negative coefficient, meaning that every additional unit of soluble Fe value will reduce the value of rice production by 0.011 tons/ha. P-available has a positive coefficient meaning that every addition of one unit of the P-available value will increase the production value by 0.269 tonnes/ha, and soil pH has a positive coefficient meaning that every addition of one unit of the soil pH value will increase the production value by 0.561 tonnes/ha . The coefficient of determination (R^2) is 0.919 or 91.9% indicates that the variables Fe-soluble, P-available and soil pH have a contribution or role in the value of rice production produced is 91.9% and the remaining 8.1% is the contribution or role of other independent variables. The correlation coefficient (r) value is known to be 0.959 This means that soluble Fe, available P and soil pH have a very strong correlation with rice production variables.

DISCUSSION

The reaction (soil pH) plays a role in rice production in tidal areas (Table 2), this is because soil pH is related to the availability of essential nutrients for plants (Shanti, 2018). High levels of soil acidity cause an increase in the solubility of Fe^{2+}, Al^{3+}, and Mn^{2+} ions in the soil which can be toxic to plants (Irsal Las *et al*., 2007). According to Hasibuan (2008), high soil acidity also causes the availability of the P element to decrease because it is bound by Fe or Al, resulting in a lack of nutrients in the soil and causing a decrease in rice production. According to Hardjowigeno (2007) the neutral pH value will affect the speed of nutrient absorption by plant roots, because at neutral pH most of the nutrients are easily dissolved and available in the soil solution. This results suggest that increasing the soil pH value can increase the yield of rice production.

Soluble Fe content plays a role in rice production in tidal areas (Table 2). Iron has an important role in determining soil fertility in tidal areas. According to Sahrawat and Narteh (2001) the presence of iron, both in terms of type and solubility, plays an important role in the dynamics of soil pH, nutrient availability and the decomposition of organic matter in tidal fields. Iron can be a source of soil acidity through hydrolysis reactions, or oxidation reactions of iron sulfide pyrite minerals (Dent 1986; Fanning 2002; Ahern *et al* (2004). Iron is an essential element needed by plants, iron has many important roles in metabolic processes plants (Mehraban *et al.* , 2008). This metabolism includes photosynthesis, respiration, the main constituent of cell proteins (Connolly and Guerinot, 2002) and is also responsible for the quality and quantity of plant results (Celik *et al.*, 2010). Therefore The growth and yield of rice in tidal areas is influenced by the solubility of iron. High iron solubility causes iron poisoning in plants (Tadano *et al.* , 1978). According to Audebert (2006), the high amount of ferrous iron (Fe^{2+}) in the soil solution also can result in an imbalance of mineral nutrients that affects plant growth.

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025---

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

The available P nutrient content plays a role in rice production in tidal areas (Table 2), this is because P (phosphorus) is an essential element for plants and cannot be replaced in the plant by other elements (Khan *et al* . 2010), so that plant P needs must be available and fulfilled by the soil as a growing medium . Phosphorus is an element that is required in large quantities (macro nutrient) and is absorbed by plants in the form of primary orthophosphate ions (H_2PO^{4-}) and secondary orthophosphate ions (HPO_4^{2-}) (Hakim *et al*., 1986). According to Havlin *et al*. (1999), phosphorus is needed by plants for the formation of Adenosine Triphosphate and Adenosine Diphosphate (ADP and ATP) which are energy sources for photosynthesis, respiration, energy transfer and storage, cell division and enlargement, as well as plant growth and development processes.

C-organic content plays less of a role in rice production on tidal land (Table 2), this is thought to be because based on observations made on the level of maturity of organic matter contained in each land with different rice production (Table 1) it is generally not very different , namely with a level of maturity that is not yet perfect.

Soil CEC plays less of a role in rice production on tidal land (Table 2), this refers to the observation data in Table 1 where The CEC value of land on this land is generally relatively the same, not much different. Rice production at location point D has a production value of 4.5 tons/ha and location point H has a production value of 1.73 tons ha^{-1}. From the differences in production at these locations, the CEC values for the land are both relatively high.

The depth of pyrite (FeS_2) plays less of a role in rice production in tidal land (Table 2), this is thought to be because the land is in a flooded or reduced condition, causing the pyrite layer not to oxidize. This statement is in accordance with Zuraida (2013) that soil flooding can affecting the sulfate concentration in the soil, the cause of the pyrite layer undergoing an oxidation process is the decrease in the ground water level so that oxygen enters the soil pores and will oxidize the pyrite to form sulfuric acid, hydrogen ions and Fe^{3+}.

Groundwater levels play less of a role in rice production in tidal areas (Table 2). This is thought to be because in the vegetative phase the plant's water requirements are sufficient. Water availability to plants so that roots develop well and allows for the development of seedlings. In accordance with the opinion of Abbas and Abdurachman (1985) that water-saving settings for lowland rice cultivation with aerobic soil conditions produce rice seedlings that are no different from land flooded by 5 cm.

CONCLUSIONS

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. Soil reaction (pH), soluble Fe and available P play a major role in rice production in tidal areas.
2. The relationship between soil pH, soluble Fe and available P on rice production in tidal areas is: Y = 1,501 − 0.011 Fe-soluble + 0.269 P - available + 0.561 Soil pH , with a coefficient of determination of 0.919 and a correlation coefficient of 0.959
3. C-organic content, soil CEC , pyrite depth and water level play less role on rice production in tidal areas.

REFFERENCES

Abbas, AI & A., Abdurachman. 1985. The Effect of Water Management and Land Cultivation on the Water Use Efficiency of Rice Fields in Cihea, West Java. Pembrit. Penel. *Soil and Fertilizer*, **4**: 1-6.

Ahern, CR, AE McElnea, & LA Sullivan. 2004. *Acid Sulfate Soils Laboratory Methods*

http://dx.doi.org/10.20527/jwem.v11. i2.20091

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025---

Guidelines . Queensland Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland, Australia.

Arsyad, DM 2015. Development of agricultural innovation in tidal swamp land supports food sovereignty. *Agricultural Innovation Development*, **7**, 169-176.

Ar-Riza, I. 2000. *Prospects for developing lowland swamp land in South Kalimantan to support increased rice production* . Journal of Agricultural Research and Development 19 (3): 92-97.

Audebert, A. 2006. *Iron partitioning as a mechanism for iron toxicity tolerance in lowland rice* . In : Audebert, A. (ed.), Narteh, LT (ed.), Millar D. (ed.), Beks, B. (ed.). Iron toxicity in rice-based systems in West Africa. Cotonou: WARDA (Africa Rice Center), 34-46

Central Bureau of Statistics and Agricultural Service 2012. *Agricultural Statistics – Land (Land Use Report)*. South Kalimantan Provincial Agriculture Service. Banjarbaru.

BBSDLP. 2011. *State of the art and grand design overview*. Bogor: Balai Besar Litbang Sumbereast Lahan Pertanian. Bogor.

Celik , H. , Asik , BB , Gurel , S. & Katkat , AV 2010. Effect of potassium and iron on macro element uptake of maize. *Rural Agriculture,* 97, 11-22.

Connolly, EL & Guerinot, ML 2002. *Iron stress in plants* . Genome Biology 3(8), 1021–1024.

Dent, DL 1986. *Acid Sulphate Soils; A baseline for research and development*. ILRI. Wakeningen. Publ. When. 39 The Netherlands. 204 p.

Fanning, DS 2002. *Acid sulfate soils* . In : R. Lal (Ed.), Encyclopedia of Soil Science, vol. 1. Marcel Dekker, New York, p. 11–13.

Hakim, N., MY Nyakpa, AM Lubis, SG Nugroho & M. Amin Diha. Gobang Hong, HH Bailey. 1986. *Basics of Soil Science* . Lampung University. Lampung.

Hardjowigeno, S. 2007. *Geology* . Pusaka Utama Publisher, Jakarta.

Hasibuan, BE 2008. *Soil and Water Management on Marginal Lands* . USU. Medan.

Havlin, JL & JD Beaton, SM Tisdale, and WL Nelson. 1999. *Soil Fertility and Fertilizers* . An introduction to Nutrient Management. Prentice Hall, Upper Saddle River, New Jersey. P. 154-194.

Hikmah, ZH & DI Saderi. 2005. *Opportunities for post-harvest technological innovation to improve the quality of local tidal rice in Barito Kuala* . Proceedings of the National Seminar on Integrated Land Management, Banjarbaru, 28-29 July 2005. Swamp Land Research Institute, Banjarbaru. p. 357-360.

Irsal L, Sukarman, Kasdi Subagyono, DASuriadikarta, M. Noor, & Achmadi Jumberi. 2007. *Grand design of swamp land* . Proceedings of the National Seminar on Swamp Agriculture. Agricultural Research and Development Agency. Central Kalimantan.

Khan, MS, A. Zaidi, M. Ahemad, & M. Oves. 2010. Plant growth promotion by phosphate solubilizing fungi-current perspective. *Arch Agron Soil Sci*. 56:73-98.

Lesmayati, S., & Hasbullah, R. 2013. the effect of delay time and threshing method on the yield and quality of local rice grain of the karang dukuh variety in South Kalimantan. *Journal of Agricultural Technology Assessment and Development*, **16**: 3.

Mehraban P., Zadeh, AA & Sideghipour, HR 2008. Iron toxicity in rice (Oryza sativa L.), under different potassium nutrition. *Asian Journal of Plant Science*, **7**, 251-259.

Nugroho, K. Alkusuma, Paidi, Wahyu Wahdini, Abdulrachman, H. Suhardjo & IPG. Widjaja Adhi. 1993. *Map of potential areas for agricultural development of tidal swamps, swamps and beaches* . Lagan Resources Research Project , Center for Soil and Agroclimate Research, Agricultural Research and Development Agency. Agriculture Department.

Sahrawat, KL & LT Narteh. 2001. Organic matter and reducible iron control of ammonium production in submerged soils.

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025---

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Commun. *Soil Sci. Plant Anal*., **32**; 1543–1550.

Shanti, R. 2018. *Soil Fertility and Fertilization* . Mulawarman University Press.

Tadano, T., & Yoshida, S. 1978. Chemical changes in submerged soils and their effect on rice growth. *Soils and Rice*, 399-420.

Zuraida, TM. 2013. *Hydrological Management of Tidal Lands in South Kalimantan: Study of Changes in Soil Acidity Due to Flooding and Drainage* . Report to Faculty of Agriculture. Banjarbaru.

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025---