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Amelioration Technology to Overcome of Water Stress in Sub-Optimal Paddy Fields and its Relationship with Growth and Yield of New Types of Local Rice (Oryza Sativa L.)

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Abstract.

Rice (Oryza sativa L.) is a staple food for most Indonesian people, but its availability is inadequate. Intensive rice cultivation also cannot solve the problem so the expansion of new paddy fields is usually not optimal. The purpose of this study is to obtain technology for rice cultivation in suboptimal paddy fields by integrating innovative, dynamic and compatible technology components for increased and sustainable production. This research has been carried out with experimental methods on sub-optimal soils in greenhouses and using new types of local rice varieties. Ameliorant compost straw 10 t ha-1 can be used as a type of rice cultivation technology to overcome water stress in sub optimal rice fields. Increasing the water stress period from 60 days to 80 days after planting, the ameliorant in the new rice fields cannot store and supply water to support the growth and yield of new types of local rice.

Keywords. New Type of Local Rice, Sub Optimal Rice Fields, Amelioran.

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INTRODUCTION

A serious problem for all nations in the world in the future is the food crisis. The report of the UN agency, United Nations food agency (FAO), International Fund for Agricultural Development (IFAD) and the World Food Program (WFP), for the past decade shows that the world community experiencing malnutrition has decreased by more than 100 million people. However, by 2013 one in eight people in the world (12%) had been hungry or seriously malnourished (Muyassir, 2014).

Hunger and malnutrition have threatened the community and are increasing every year due to population growth, stagnation in food production, limited land for food production, the phenomenon of land conversion to non-agriculture, changes in community eating patterns, and climate change that will continue in various parts of the world (Gödeckea et al., 2018; Nainggolan, 2011).

As a result of this phenomenon the government has made a policy of national food security and sovereignty through intensification and extensification programs. Increased rice production through extensification by building new fields that are generally suboptimal with low fertility and water limitations. In 2018 in Aceh Province new rice fields had been built to reach 21,000 Ha (Aceh Agriculture and Plantation Office, 2017). While intensive rice cultivation also continued to be developed, but in 1999 its production was leveling off especially for national varieties. The Central Statistics Agency (BPS) has recorded that throughout 2018 the Indonesian government has imported 2.25 million tons of rice with a value of US $ 1.03 billion throughout 2018 (BPS Indonesia, 2018).

The application of innovative low input technology is an option in managing suboptimal rice fields, one of which is the use of amelioration materials. Ameliorant ingredients that are easily obtained include; (a) biochar and (b) rice straw compost. The use of biochar can significantly increase the availability of water and plant nutrients. Whereas 20 tons of rice straw per compost per hectare had a very significant effect on the chemical properties of the soil, growth and yield of national varieties of rice (Salbiyah, et al. 2012; Jamilah et al., 2012; Waty et al. 2012). Therefore this amelioration technology study is very important to be able to increase sub-optimal land productivity, reduce the practice of agricultural land use change, and save the country's foreign exchange

Aceh's local rice cultivars that are commonly planted are cultivars that have been selected naturally so that they have good adaptability to various environmental stresses (suboptimal). However, local rice varieties have negative traits that cause them to be unable to compete with modern rice varieties (Sobrizal, 2016). To improve the negative characteristics of Aceh's local rice such as longevity, low production and plant stems that are too high, breeding efforts have been made to preserve the positive traits and at the same time add to its economic value. Research at the laboratory scale shows the growth and yield potential of this new type of local rice exceeds the results obtained by national superior varieties (Efendi et al., 2012).

The superior genetic characteristics of Aceh's local rice have been tested under various optimal environmental conditions (Bakhtiar et al., 2011; Efendi et al., 2016; Chairunnisak et al., 2018). However, information about the results obtained in sub-optimal environmental conditions due to responses to soil improvement materials such as drought stress resistance and other agronomic characteristics is still very limited. Likewise, the characteristics of optimal rice fields as a result of the response to soil ameliorants are given.

As a result, efforts to develop new types of local rice cultivation in sub-optimal rice fields are constrained. This research is new and very important to be carried out to obtain technology formulation of lowland rice cultivation on sub-optimal land to be able to improve soil quality and sustainable food production.

METHOD

This research was conducted at the Greenhouse of the Faculty of Agriculture, Syiah Kuala University. This study lasted for 10 (ten) months from March to December 2018. The soil material as a planting medium was taken from new paddy fields in the village of Teuruebeh, Kota Jantho Subdistrict, Aceh Province Indonesia.

Amelioration material consists of biochar from Aceh BPTP, and compost of rice straw made by the researcher. The rice seed used is a new type of local variety from the Seed Laboratory of the Faculty of Agriculture, Syiah Kuala University. Fertilizers used are Urea 150 kg ha-1, SP-36 and KCl each of 100 kg ha-1. Chemicals for analysis of samples in the laboratory, nursery containers used in the form of trays that have a length of 40 cm and a width of 30 cm and a trial pot measuring 20 kg of soils.

To answer the problem of this study using an experimental method with a field design in the form of a factorial randomized block design. The treatment consists of amelioration type, and water stress with the following details:

(a) The first factor is amelioration material consisting of 4 (four) levels, namely control, biochar 10 t ha-1, Pim-organic 10 t ha-1, and 10 t ha-1 rice straw compost; (b) The second factor is the water stress condition which consists of three levels, namely: (i) normal condition, which is a process without drying for 3 months, carried out by maintaining the condition of rice growing media in normal condition (shredding); (ii) Water stress 1, namely drying carried out at 41-60 days of planting age and re-watering at 61 days of planting until harvesting); (iii) Water stress 2, which is drying carried out from the age of planting 41-80 days and watering again at the age of 81 days to harvest). In total there were 12 treatment combinations with each treatment combination repeated 3 (three) times so that this study had 36 experimental unit units.

Plant responses due to the treatment given were observed and measured in the field and in the laboratory from samples taken in each experimental pot. The variables are: rice growth (plant height (cm), maximum number of tillers (stems), (b) crop yield (percentage of productive tillers (%), empty grain percentage (%), percentage of filled grain (%), and yield potential per ha. The data obtained were analyzed by the F test and if there was a significant effect followed by the Duncan test.

RESULTS

Characteristics of Suboptimal Paddy Fields

The results of laboratory analysis showed that sub optimal rice fields were partly dominated by sand especially fine sand. Land with particle domination like this has the ability to hold water, low plasticity. The sand fraction has a small specific surface area so that it is less reactive and means less to soil chemical reactions. However, it plays a significant role in soil physical properties such as porosity and weight of contents and soil structure (Table 1).

Table 1. Results of analysis of the chemical properties of sub optimal paddy fields

No	Aspect of Analysis	Results	Criteria
1	Soil Texture:		
	a. Sand	42%	-
	b. Silt	29%	-
	c. Clay	29%	-
	Texture Classification	Clay Loam	-
2	pH (H_2O)	5,35	Low
3	C-Organic	0,66%	Very low
4	N-Total	0,24%	Medium
5	C/N Ratio	2,75	Very low
6	P-available	2,85 mg kg^{-1}	Very low
7	Cation Exchange Capacity	15,60 Cmol kg^{-1}	Low
8	Base Saturation	47,82%	Medium
9	Al-dd	1,00 Cmol kg^{-1}	Very low

The sub optimal soil pH before treatment is 5.35 (acid), this illustrates the availability of macro nutrients and micro nutrients in the soil is problematic. The organic C content of the soil in the paddy field is very low and the total N of the soil is classified as medium, the P-available is very low and the C / N ratio is very low as a result of the low vegetation and land clearing. While the status of N soil is highly dependent on the state of the environment such as climate and vegetation as organic sources and soil texture. Munawar (2013) stated that soil organic matter is all the carbon in the soil that comes from the remnants of dead plants and animals.

Rice Plant Height

The results showed that the ameliorant of 10 t ha^{-1} in sub-optimal paddy fields was not significant to the new type of local rice height at each stage of observation. Whereas water stress at the age of 15 to 30 days after planting (DAP) has shown a significant effect on the height of the rice, but respond significantly at 45 DAP (P

0.011) to 60 DAP (P 0.003). The average height of new types of local rice in sub-optimal paddy fields due to ameliorant treatment and water stress are shown in Table 2.

The Water stress in sub optimal paddy fields has suppressed the height of new types of local rice and the growth is not normal, where the height of rice plants decreases with increasing water stress. The height of the rice at 15 DAP due to water stress in the sub optimal paddy fields ranged from 79.34 cm to 82.97 cm and at the age of 60 HST ranged from 80.75 to 87.25 cm.

The longest rice plant height at 45 DAP is in the control (normal water content) that is 82.97 cm, significantly different from the height of plants in drought stress conditions 1 (without water at 40 to 60 DAP) and water stress 2 (without water supply 40 -80 DAP). The same phenomenon is also seen in observations of age 60 DAP.

Table 2. The average height of new types of local rice plants aged 15, 30, 45, and 60 days after planting due to ameliorant and water stress

Treatments	New type of local rice plant height			
	15 DAP	30 DAP	45 DAP	60 DAP
Ameliorant (10 t/ha)	.... cm			
Control	27.70 ±3.54	60.57 ±8.65	81.10 ±2.90	83.44 ±2.65
Biochar	26.79 ±3.87	59.39 ±4.01	79.54 ±3.71	83.89 ±6.48
PIM Organik	28.07 ±3.11	61.57 ±2.75	81.26 ±4.54	83.33 ±5.29
Straw Compost	27.18 ±2.52	60.06 ±4.63	80.61 ±4.15	83.11 ±4.91
$P_{\alpha\ 0.05}$	-	-	-	-
Water Stress				
Control	27.38 ±3.64	60.08 ±4.61	82.97 ±3.44 b	87.25 ±4.14 b
WS 40-60 days	27.78 ±2.85	61.17 ±7.65	79.34 ±3.66 a	82.33 ±3.98 a
WS 40-80 days	27.13 ±3.28	59.93 ±3.56	79.58 ±3.31 a	80.75 ±3.98 a
$P_{\alpha\ 0.05}$	-	-	0.011	0.003

Info. The numbers followed by the same letters in the same column are not significantly different (Duncan Test α 0,05; ± Standard Deviation; WS = Water Stress

Number of Rice Tiller

The number of tillers was observed at the ages of 30, 45 and 60 DAP, this last observation was also used as the variable of the maximum number of tillers. The results showed that ameliorant given to the soil was 10 t ha^{-1} significantly toward the number of tillers at 30 DAP (P 0.047), then until the last observation at 60 DAP showed no significant effect. While the effect of water stress has a significant effect on the number of tillers at the age of

45 DAP (P 0.01) to the last observation (60 DAP) (P 0.05). The average number of local rice tillers in sub-optimal paddy fields due to ameliorant treatment and water stress are showed in Table 3.

Table 3. Average number of tillers aged 30, 45 and 60 DAP due to the influence of ameliorant and water stress

Treatment	Number of tillers		
	30 DAP	45 DAP	60 DAP
Amelioran (10 t/ha)	.... Stems per clump............................		
Control	8.67 ±1.871 ab	18.67 ±2.236	21.22 ±5.495
Biochar	7.78±2.224 a	18.33 ±6.285	18.89 ±7.114
PIM organic	8.44 ±1.667 ab	18.11 ±3.790	18.11 ±5.011
Straw compost	10.11 ±2.028 b	21.11 ±4.485	19.89 ±3.480
$P_{\alpha\ 0.05}$	0.047	-	-
Water Stress			
Control	9.33 ±1.670	22.58 ±4.122 b	21.25 ±1.60 b
WS 40-60 days	8.92 ±2.193	18.33 ±2.839 a	18.67 ±2.02 a
WS 40-80 days	8.00 ±2.216	16.25 ±3.793 a	16.08 ±1.97 a
$P_{\alpha\ 0.05}$	-	0.001	0.05

Info. The numbers followed by the same letters in the same column are not significantly different (Duncan Test α 0,05; ± Standard Deviation; WS = Water Stress

The number of new types of local rice tillers at the age of 30 HST was significantly different due to different ameliorant material which ranged from 7.78 to 10.11 stems per clump. Straw compost showed the best effect on the growth of new types of local rice in sub-optimal paddy fields, was not significantly different in PIM organic or control and was significantly different from biochar.

The stress of the water in the new paddy field began to have a significant effect on the number of tillers at the age of 45 to 60 DAP. The number of tillers planted in the paddy fields decreases with increasing of water stress. As a result, at the age of 45 DAP the number of rice tillers reached 22.58 stems per clump in the control and decreased to 16.25 stems per clump due to water stress that occurred from the 40th to 60^{th} day of DAP. Along with the increase in water stress at the age of 40 to 80 DAP, the number of paddy tillers decreased by 16.08 stems per clump.

Rice Production

One component of the new type of local rice yield observed was the number of productive tillers. The results showed that 10 t ha^{-1} ameliorant material in sub-optimal paddy fields accompanied by interactive water stress conditions significantly affected the number of new types of local rice tillers (P 0.005). The average number of productive tillers in sub-optimal paddy fields due to the interaction between ameliorant and water stress is shown in Table 4.

Table 4. Number of productive tillers due to the influence of ameliorant interactions with water stress

Treatment	Amelioran (10 t/ha)			
Water Stress	Control	Biochar	PIM Organik	Kompos Jerami
Control	12.67 ± 2.52 a B	14.67 ± 1.15a B	13 ± 2.00 a B	15.67 ± 1.53 b B
WS 40-60 days	12 ± 1.73 a B	16.00 ± 2.65 b C	11.33 ± 2.11 a A	17.67 ± 2.52 c C
WS 40-80 days	10.67 ± 0.58 b A	9.33 ± 3.06 a A	14.33 ± 2.52 c C	14.33 ± 0.58 c A

Info. Numbers followed by the same letters in the same column and row are not significantly different (Duncan Test α 0.05), lowercase letters are read horizontally and capital letters are read vertically; ± standard deviation; WS = Water Stress

The results showed that the average productive tillers of new type of rice planted in new paddy fields ranged from 11.33 to 17.67 stems per clump. Compost of 10 t ha^{-1} rice straw has increased the maximum productive tillers of rice in water stress conditions 40 to 60 HST. Increased water stress to more than 60 DAM, straw compost at the dose is no longer able to increase the productive tillers of the rice.

Ameliorant material in sub-optimal paddy soils has not significantly affected the percentage of filled grain, empty grain and the potential yield of new types of local rice. Whereas water stress significantly affected the percentage of filled grains (P 0.007), the percentage of empty grains (P 0.033) and the potential yield of rice (0, 044). The average values above due to water stress conditions are shown in Table 5.

The condition of water stress in the sub optimal paddy field significantly decreases the percentage of fill grain, potential yield and increases the percentage of empty grain. The average percentage of filled grain in the condition without water stress was higher and significantly different from the filled grain in water stress conditions both in the period 40-60 DAP or 40-80 DAP.

As a result, the potential of rice yields in the sub optimal paddy fields also experienced the same, reaching 3,691.75 kg ha^{-1} in normal water conditions (control), decreasing dramatically due to continued water stress so that the potential obtained was only 2,915.25 kg ha^{-1}. On the other hand, the percentage of empty grain, where the conditions without water stress (control) are lower and increase with increasing water stress in the rice.

Table 5. Average percentage of filled grain, empty grain and potential yield of rice due to the influence of water stress

Water Stress	Filled Grain	Empty Grains	Potential Yield
	....................%		.... kg ha^{-1} ....
Control	78.08 ± 6.30 b	7.36 ± 1.44 a	3691.75 ± 934.87 b
WS 40-60 day	72.37 ± 5.97 a	8.58 ± 1.34 b	3124.17 ± 838.27 ab
WS 40-80 days	71.05 ± 5.39 a	8.63 ± 1.23 b	2915.25 ± 683.30 a
P $_{\alpha\ 0.05}$	0,007	0.033	0,044

Info. The numbers followed by the same letters in the same column are not significantly different (Duncan Test α 0,05; ± Standard Deviation; WS = Water Stress

DISCUSSION

Ameliorant in the form of Biochar, Organic PIM and straw compost is able to influence environmental conditions and affect the growth of new types of local rice. In the first planting season, the ameliorant material was more dominant effect on increasing of water holding capacity so that water stress in sub optimal land became a significant on the growth of new types of local rice at the age of 45 to 65 DAP. At the beginning of planting the availability of water was still sufficient so that at the age of 45 to 65 DAP rice seedlings decreased with increasing of the water stress.

During these periods the water supply is reduced and causes nutrient solubility to decrease, water and nutrient uptake through plant roots is disturbed. Water is needed in the process of photosynthesis, water limitations inhibit the rate of photosynthesis and have an impact on each phase of plant growth and development (Akram, Ali, Sattar, Rehman, & Bibi, 2013). The water stress significantly affects plant height, because plants need enough water for their growth and development (Supriyanto, 2013), stunted plants, dry weight and low productivity (Violita, 2007).

Seedlings that are planted initially experience vegetative growth in the form of primary, secondary, and tertiary tiller. The results showed that the average number of new type of local rice seedlings at the beginning of growth (15 DAP) was significantly different due to the ameliorant given. Ameliorant material given is estimated to have started supplying nutrients in the soil even though in limited quantities, especially those sourced from organic PIM.

Due to the slow mineralization of ameliorant material and increased competition between plants and microorganisms, the response was not significantly different at the age of 45 dan 65 DAP. Initial soil analysis results show that N and P content in new paddy soils are classified as low to very low, while the growth of paddy tillers is strongly influenced by the availability of nutrients, water, light and other environmental conditions. The function of N elements for plants as a constituent of proteins, chlorophyll, nucleic acids and produce thin cell walls so that it can stimulate more maximum plant production (Purwadi, 2011).

Ameliorant material with interaction water stress conditions significantly affected the productive of new type of rice grown in sub optimal rice fields so that the highest productive tillers were obtained 17.67 stems per clump. Water stress conditions from the age of 40 to 60 days cause the ground water content to decrease dramatically, but the presence of ameliorant material 10 t ha^{-1} is thought to have increased the capacity and to extend the storage capacity of water in the soil or the field capacity that can be utilized by rice plants. Ameliorant material contributes to soil organic matter, can increase soil C-organic content and affects the physical, chemical and biological properties of the soil for the better (Utami and Handayani (2003).

Organic materials play a role in increasing water holding capacity, improving structure the soil becomes loose, prevents hardening of the soil, and supports the reaction of the soil from acidity, alkalinity and salinity, and it is also suspected that in conditions of drought stress 40 to 60 HST plants in sub optimal rice fields are protected from iron and H2S gas poisoning and rhizofir conditions become oxidative so that gives oxygen an opportunity to enter the soil as occurs in the intermittent irrigation system, interrupted irrigation system provides an opportunity for oxygen penetration into the soil, rhizosphere in aerobic conditions can stimulate the growth and activity of microorganisms that play a role in the decomposition of organic matter, which means it will increase nutrients available to plants (Regazzoni et al., 2013),

The results showed that the components of the new type of rice yield were observed to be significantly different due to water stress. The percentage of filled grain and the potential for new type of rice yield decreased with increasing of water stress and the opposite with the percentage of empty rice that is increasing with increasing of water stress. The same results were obtained from the study of Supriyanto (2013) that the treatment of drought stress significantly affected the age of flowering, harvest age, number of grain, percentage of filled grain, weight of 100 grains and weight of grain per clump.

Water deficiency during growth periods can cause stress to the plant. Water limitations cause disruption of plant metabolic processes such as inhibition of nutrient absorption, cell division and enlargement, decreased enzyme activity and stomata closure. These physiological disorders cause plant growth and development to be inhibited (Asmara, 2011). Finally, the genetic performance of plants seen from the percentage of rice grain and the potential yield of new lowland rice decreases linearly with increasing water deficiency in the plant environment.

CONCLUSIONS

Ameliorant material in the form of 10 t ha^{-1} rice straw compost can be used as a new type of rice cultivation technology to overcome water stress in sub optimal paddy fields. The addition of a dry period from 60 days to 80 days after planting, ameliorant materials in sub optimal paddy fields are no longer able to bind and provide sufficient amounts of water to support the growth and yield of new types of local rice.

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