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Insight Into The Impact Of Salinity Stress On Upland Rice And Plant Height Characteristics

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Abstract – The purpose of this study was to examine the impact of salinity stress on upland rice and plant height characteristics. This research was conducted on farmer's land in Medan Selayang, Medan City. This study used a randomized block design with 2 factors in 3 replications. The first factor was the upland rice variety (P1= Sigambiri Merah; P2= Inpago-8; P3= Sigambiri Putih; P4= Ramos) and the second factor was the dose of salinity (0, 4, 8, 12 dS/m). Parameters were analyzed using ANOVA and the mean was further tested with 5% DMRT. The results show thatupland rice varieties inpago-8, white sigambiri, and ramos had plant height growth that was significantly different from the red sigambiri variety at the end of the observation (12 WAP). The highest growth was found in the white sigambiri variety of 148.48 cm. Other results also show that giving a salinity dose of 4-12 dS/m caninhibited the height growth of upland rice plants at the age of 8 WAP.

Keywords – Salinity, Rice, Plant, Characteristic

I. Introduction

Agricultural development has a very important role in economic growth in Indonesia. The large number of workers working in the agricultural sector and the large potential for this sector requires special attention from the government, just like the industrial and service sectors. The agricultural sector is not easily affected by the world economic crisis, therefore agricultural development needs to be increased to obtain more optimal production results. Especially Indonesia which is an agricultural country and rich in natural resources. Rice plants can grow and produce both in wet or flooded soil conditions (lowland rice) or dry soil conditions (upland rice/field rice) (Bhargava, 2013). The availability of water in paddy fields is more secure, so lowland rice yields are generally higher than upland rice yields. Besides that, Upland rice areas are generally dominated by podzolic soils which react acidicly and are poor in nutrients. Given the magnitude of the challenges of lowland rice cultivation, intensification of upland rice needs to be implemented to ensure national rice availability (Bohn, 1985). Upland rice cultivation developed slowly from 1969 to 1989, upland rice production grew by a third of the rate of lowland rice. Upland rice or also known as field rice or land rice is one of the rice producers besides paddy rice. In Indonesia there are approximately 1.2 million ha of upland rice plantations and constitutes 14% of the total rice plantations. Upland rice cultivation developed slowly from 1969 to 1989, upland rice production grew by a third of the rate of lowland rice. Upland rice or also known as field rice or land rice is one of the rice producers besides paddy rice. In Indonesia there are approximately 1.2 million ha of upland rice plantations and constitutes 14% of the total rice plantations (Cha-Um, 2007). Upland rice cultivation developed slowly from 1969 to 1989, upland rice production grew by a third of the rate of lowland rice. Upland rice or also known as field rice or land rice is one of the rice producers besides paddy rice. In Indonesia there are approximately 1.2 million ha of upland rice plantations and constitutes 14% of the total rice plantations.

One of the efforts to increase rice productivity in tidal land containing salinity stress (NaCl) is by using tolerant varietal characters (Clermont-Dauphin, 2010). The main obstacles in upland rice cultivation include low productivity, pest and disease disturbances, drought, and the lack of superior varieties that have the potential for stable high yields on marginal land.Productivity of upland rice nationally only reached 1.95-2.17 tons ha. This happens because the land for planting is less fertile, namely the type of red yellow podzolic acid mineral soil. A serious problem in cultivating plants on acid soils is aluminum (Al) poisoning and low phosphorus which causes root growth to be stunted, thereby interfering with nutrient and water absorption (Chunthaburee, 2016).

The lack of varieties tolerant to environmental and biotic stress, especially Al stress and the lack of a package of upland rice cultivation technology makes it difficult to cultivate crops in acid soils.Rice production growth in Indonesia in 2020 has reached 31.33 million tons with a consumption rate of 94.02 kg/capita/year (Agricultural Data and Information System Center, 2021). This rice production needs to be increased in line with the increasing population in Indonesia (Cramer, 1988). Efforts that can be made to maintain the stability of rice through increased production of rice plants on marginal land. Upland rice plants on marginal land such as landsaline (high salt content) can be used as an alternative in the optimization program to increase national rice production.For most farmers, rice is the main choice to cultivate in an effort to meet their basic food needs. In addition, the government has increased the cost of harvested grain and rice which can be sold at any time because the consumers are always there.

Compared to lowland rice, upland rice productivity is still very low, namely only 1.3 tonnes per ha with low yield stability. Farmers generally still use cultivars (local varieties) which have low yield potential with cultivation techniques that are not yet optimal. The low level of productivity of upland rice and the slow rate of development of upland rice production is caused by the problems faced by upland rice which are far more difficult than those of paddy rice. Besides that, the government's attention as outlined in various policies to increase rice production is more directed to lowland rice than upland rice. This is reasonable considering the potential for increasing lowland rice production is far greater than that of upland rice, while the constraints on increasing lowland rice production are far less severe than the constraints on increasing upland rice.

II. RESEARCH METHODS

This study used a randomized block design with 2 factors (variety and salinity dose) in 3 replications. The use of salinity doses is based on NaCl levels in soil solution, namely > 2 dS/m (Strawn et al., 2015).

Factor 1. Upland rice variety P1 = Sigambiri Merah

P2 = Inpago-8

P3 = Sigambiri Putih P4 = Ramos

Factor 2. Salinity Dose (dS/m) S0= 0 dS/m (0 g/l water)

S1 = 4 dS/m (2560 mg/kg= 2.56 g/l water)

S2 = 8 dS/m (5120 mg/kg= 5.12 g/l water)

S3 = 12 dS/m (7680 mg/kg= 7.68 g/l water)

Parameters of upland rice were analyzed using ANOVA and the mean was further tested with DMRT at a level of 5% using IBM SPSS statistics 20. Pearson correlation analysis was performed for each parameter of upland rice. Salt (NaCl) was given when the upland rice plants were 2 MSP by dissolving NaCl in 20 liters of water then splashed onto the growing media according to the treatment. Calculation of salinity content is converted using the formula, namely 1 dS/m = 640 mg/kg (density of water 1 kg/l), then converted with the density of mineral soil 1.4 g/cm3, and multiplied by the mass of topsoil 20 kg.

S1= 4 dS/m= 4 x 640= 2560 mg/kg= 2.56 g/l x 1.4 g/cm3 x 20= 71.68 g/polybag

S2= 8 dS/m= 8 x 640= 5120 mg/kg= 5.12 g/l x 1.4 g/cm3 x 20= 143.36 g/polybag

S3= 12 dS/m= 12 x 640= 7680 mg/kg= 7.68 g/l x 1.4 g/cm3 x 20= 220.08 g/polybag.

Parameters of upland rice were analyzed using ANOVA and the mean was further tested with DMRT at a level of 5% using IBM SPSS statistics 20. Pearson correlation analysis was performed for each parameter of upland rice.

III. RESULTS AND DISCUSSION

Agronomy of Upland Rice Plants

Upland rice is a type of rice grown on dry land areas or commonly known as dry rice. Upland rice cultivation does not require irrigation at all and can be applied in areas with low rainfall.The characteristics of saline soils cause delays in the agronomic characteristics of upland rice plants. It has been reported by Grattan et al., (2002); Shereen et al., (2005) stated that rice plants are very sensitive to salinity stress at the germination stage compared to the tiller formation stage. Shereen et al., (2015) added that there was an inhibition of root and shoot wet weight in 9 varieties of rice plants due to administration of 100 ppm NaCl. Joseph & Mohanan, (2013) concluded that the early flowering stage of rice is influenced by the level of salinity. Saeedipour, (2014) found a decrease in 1000 grain weight and grain yield of rice plants due to salinity stress (Fageria, 1985).

Salinity stress can affect the physiological characteristics of upland rice plants. Salinity stress during germination can delay sprout growth and reduce germination rate (Janmohammadi et al., 2008). Salinity stress can inhibit water uptake by seeds, cause sodium and/or chloride toxicity in embryos, and alter protein synthesis.Hyper-osmotic stress and the toxic effects of sodium and chloride ions on seeds germinating under salinity stress can delay or inhibit germination (Khajeh-Hosseini et al., 2003).

Plant roots are the first organs to be affected by salinity stress, but plant shoots are more sensitive to salinity stress than roots (Munns & Sharp, 1993). Salinity increases the suberization of the hypodermis andendodermis, and the casparia strip develops closer to the root tip (Muns & Termaat, 1986). Salinity reduces crown growth by suppressing leaf initiation and expansion, as well as internodes growth, and accelerating leaf abscission (Qu et al., 2012). Salinity stress rapidly reduces the leaf growth rate due to a reduction in the number of elongated cells and/or the rate of cell elongation (Wakeel et al., 2011). Science stress can also displace calcium from the binding site of the plasma membrane, thereby causing membrane leakage as the main response of plant cells to saline stress (Cramer et al., 1988).

In soils stressed by salinity, there is an excessive accumulation of sodium and chloride ions in the rhizosphere and causes nutrient imbalances. This is because the interference of sodium and chloride ions is relatively strong with other important nutrients such as potassium, calcium, nitrogen, phosphorus, magnesium, iron, manganese, copper, and zinc (Turan et al., 2010). Generally, salinity stress can reduce the uptake of nitrogen, potassium, calcium, magnesium, and iron (Yasmeen et al., 2013). In addition, saline stress can also interfere with the translocation of potassium from the roots to the canopy tissue, causing the potassium content in the shoots to be lower than in the roots (Hu et al., 2007). The accumulation of higher concentrations of sodium and chloride in various plant tissues as the main causenutrient imbalance. High accumulation of sodium and chloride ions in the rhizosphere reduces the uptake of nitrogen, potassium, calcium, magnesium and iron (Gadalla et al., 2007). The impact of salinity stress on the physiological growth and development of plants can be empirically shown in Figure 1.

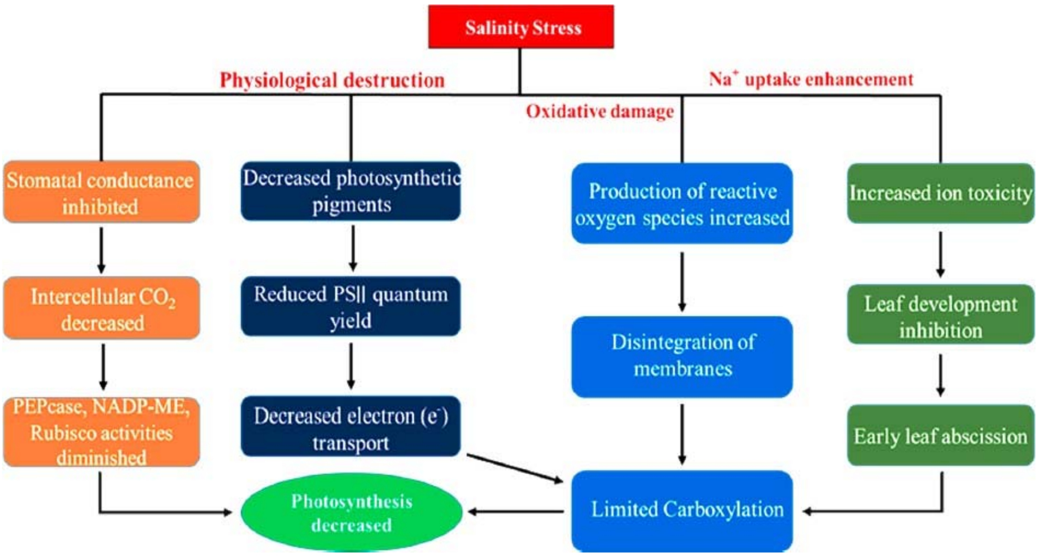

Figure 1. Schematic diagram of the impact of soil salinity stress on plants.

Source: Farooq et al., (2015).

Figure 1 explains that salinity stress on plant physiology can affect Na+ uptake (increase ion poisoning, inhibit leaf development, accelerate leaf abscission), oxidative damage(increases ROS production, membrane damage, limited carboxylation enzymes), and physiological disorders (decreases photosynthetic pigments, reduces PS-II yield, decreases electron transport, inhibits stomatal conductance, decreases intracellular CO2, inhibits PEP-ase, NADP-ME enzymes, and rubisco). Decreased stomatal conductance, impaired carbon fixation enzyme activity, reduced photosynthetic pigments, and photosynthetic damage lead to carbon fixation capacity under conditions of salinity stress (Gong et al., 2011).

The total photosynthetic content decreases due to inhibition of leaf development and expansion and early leaf abscission, and the long-term influence of salinity stress can cause ion toxicity, membrane disruption, and stomata closing, thereby inhibiting the process of photosynthesis. Salinity stress can affect stomatal conductance due to disruption of water availability and local synthesis of abscisic acid. Analysis of gas exchange showed that the decrease in the net photosynthetic rate was related to the limited availability of carbon dioxide between cells and caused a decrease in the rate of transpiration and stomatal conductance in saline stressed corn plants. Salinity stress during the reproductive phase of maize can reduce grain weight and quantity, as well as decrease seed production (Schubert et al., 2009). Decreased activityphotosynthesis and sink restriction are the main causes of reduced grain number (Hiyane et al., 2010). This reduction is due to the inhibition of assimilation translocation to the developing seeds so that seed filling is hampered and ultimately low seed production (Lohaus et al., 2000).

Salinity stress can affect the bikomic character of upland rice plants. During the last decades, a number of plant secondary metabolites such as terpenoids and steroids, phenolics and flavonoids and alkaloids have been produced and involved in cellular stress as a response of plants resistant to salinity stress.(Sytar et al., 2018). Production of aromatic compounds (alkaloids, isoprenoids and phenols) and phenylpropanoid derivatives (tannins, flavonoids and hydroxycinnamic esters) at higher levels is found in salinity stress (Sytar et al., 2018; Selmar, 2008). Important physiological changes and metabolite production under conditions of salinity stress in vitro or in vivo involve the production and accumulation of cellular osmolytes (polyols, proline, sugar alcohols, pinitol, glucosinolate and glycine betaine) and soluble sugars (glutamate, sorbitol, mannitol, oligosaccharides, fructans). and sucrose) (Parihar et al., 2015; Bhargava & Sawant, 2013). The impact of salinity stress on primary and secondary metabolite content in plants can be summarized in Figure 2.

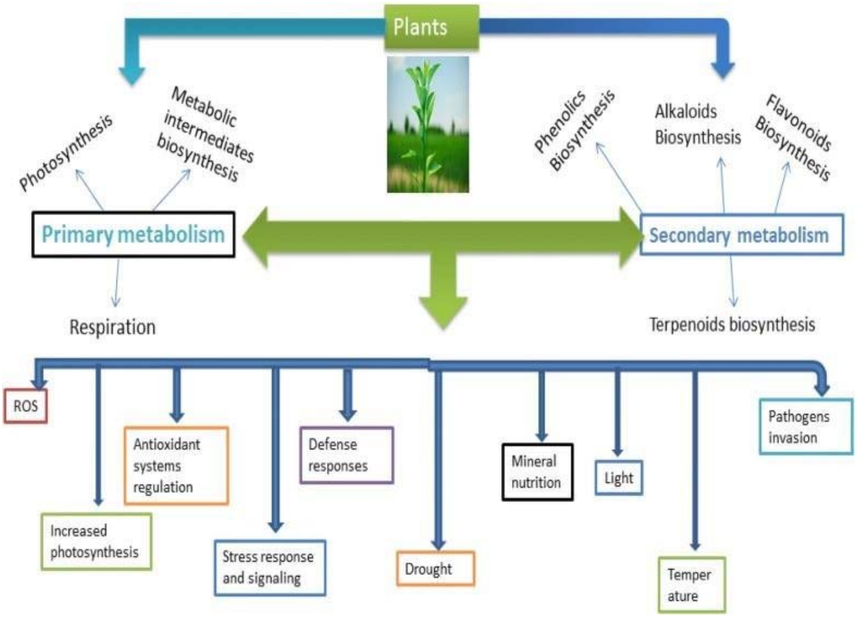

Figure 2. Schematic diagram of the impact of salinity stress on the content of primary and secondary metabolites of plants. Source: Isah, (2019).

Figure 2 explains that the physiological processes that are disrupted as a resultSalinity stress causes the production of primary and secondary metabolites (phenolics, alkaloids, flavonoids, and triterpenoids) to increase as plant resistance to salinity stress. Biochemical markers for tolerance to salinity stress such as the accumulation of cellular osmolytes (polyamines, proline, soluble sugars and glycine betaine) play a role in maintaining the stability of membranes and other cellular structures (Parihar et al., 2015). The effects of salinity cause changes in carbon and oxidative metabolism, nutrition and ion accumulation and interfere with physiological processes related to the production of plant secondary metabolites (Parihar et al., 2015). Like polyols which include sorbitol and mannitol, glycinebetaine, fructans and trehalose and proline sugars act as osmolytes in cells by reducing stress caused by excessive salt exposure (Shulaev et al., 2008).

In general, the upland rice variety with medium plant height is Sunggal which is in the height range of 50–70 cm and has a fairly high number of leaves, number of tillers, leaf area, and total root length which respectively are >90, >29, >1100 cm2, and >2000 cm. The results of the analysis of variance showed that the upland rice variety was significant for plant height at 4, 8, and 12 weeks after treatment (MSP). Likewise, the dose of salinity significantly affected the plant height of upland rice at the age of 4 and 8 WAP (Farooq, 2015)

Table 1. Plant height of upland rice due to differences in varieties, salinity doses, and their interactions at the age of 4, 8, and 12 MSP.

variety	Salinity Dosage (dS/m)				Average
	0	4	8	12	
4 MSPs					
Red Sigambi	102.48	101.57	93.97	93.05	97.77b
Inpago-8	108.95	99.32	99.83	95.48	100.90b
White Sigambiri	105.97	101,22	94.67	95,20	99.26b
Ramos	109,33	103,72	103.73	102,82	104.90a
Average	106.68 a	101.45 b	98.05 bc	96.64c	
8 MSP					
Red Sigambi	113,47	105,15	102,22	103.53	106.09b
Inpago-8	133,48	110.30	108,68	109.55	115.50a

White Sigambiri	126.75	106,17	106,60	107,38	111.73 a
Ramos	126,18	111,20	110.83	113.30	115.38a
Average	124.97a	108.20b	107.08b	108.44b	
12 MSP					
Red Sigambi	129.00	137,10	132.93	129.08	132.03b
Inpago-8	150.93	144.97	138,18	147,38	145.37a
White Sigambiri	148.83	148.45	149.75	146.88	148.48 a
Ramos	144,67	143.08	144.83	145.30	144.47 a
Average	143,36	143,40	141.43	142,16	

Note: numbers followed by different letters in the same column and row show a significant effect on the 5% DMRT test.

Table 1 shows that the upland rice varieties inpago-8, white sigambiri, and ramos had significantly different plant height growth from the red sigambiri varieties at the end of the observation (12 WAP). The highest growth was found in the white sigambiri variety of 148.48 cm. Other results also show that giving a salinity dose of 4-12 dS/m caninhibited the height growth of upland rice plants at the age of 8 WAP. The highest inhibition was found at a dose of 8 dS/m of 14.32% compared to the control. Visually, the height growth of upland rice plants can be seen in Figure 3.

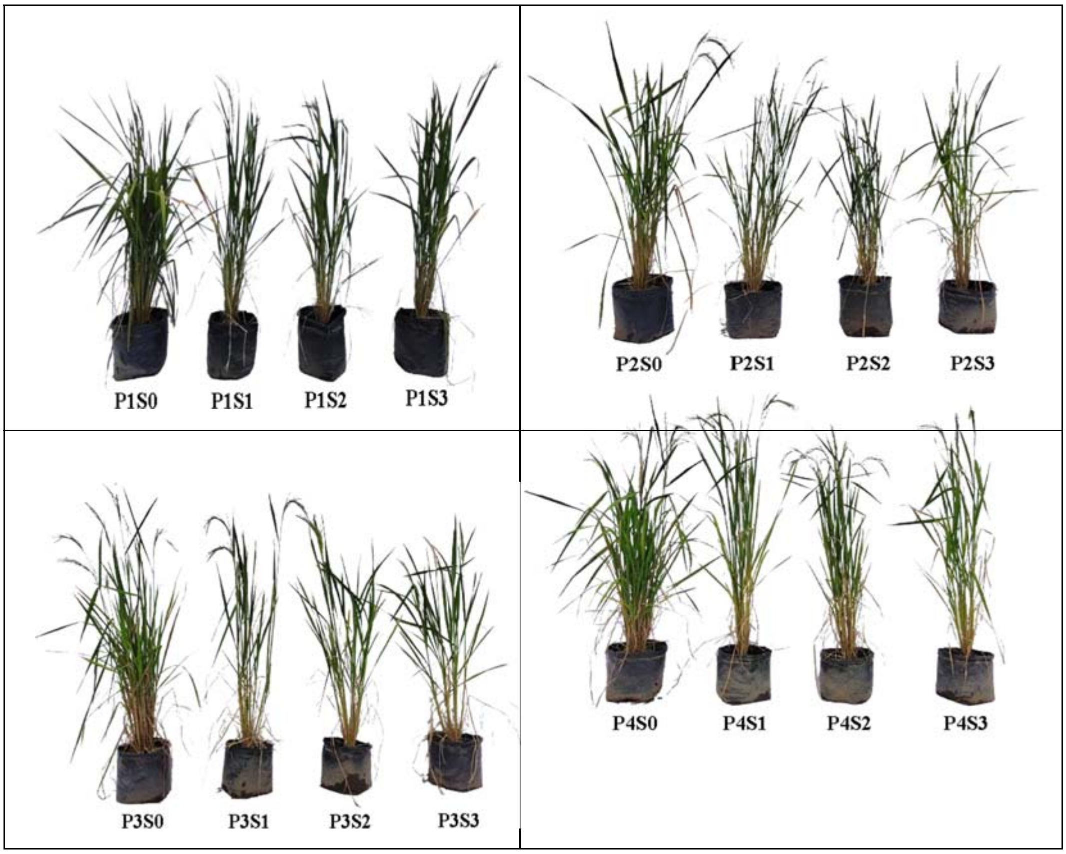

Figure 3. Differences in upland rice plant height at 8 MSP. Upland rice varieties (P1= Red Sigambiri; P2= Inpago-8; P3= White Sigambiri; P4= Ramos). Salinity dose (S0= 0; S1= 4; S2= 8; S3= 12 dS/m).

These results indicate that plant varieties of upland rice significantly affect plant height characteristics.

IV. Conclusion

Salinity stress can affect the bikomic character of upland rice plants. During the last decades, a number of plant secondary metabolites such as terpenoids and steroids, phenolics and flavonoids and alkaloids have been produced and involved in cellular stress as a response of plants resistant to salinity stress. In general, the upland rice variety with medium plant height is Sunggal which is in the height range of 50–70 cm and has a fairly high number of leaves, number of tillers, leaf area, and total root length which respectively are >90, >29, >1100 cm2, and >2000 cm. The results of the analysis of variance showed that the upland rice variety was significant for plant height at 4, 8, and 12 weeks after treatment (MSP). Likewise, the dose of salinity significantly affected the plant height of upland rice at the age of 4 and 8 WAP. upland rice varieties inpago-8, white sigambiri, and ramos had plant height growth that was significantly different from the red sigambiri variety at the end of the observation (12 WAP). The highest growth was found in the white sigambiri variety of 148.48 cm. Other results also showed that giving a dose of 4-12 dS/m salinity could inhibit the height growth of upland rice plants at the age of 8 MSP.

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