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Distribution Pattern of Na^+ and Cl^- Concentrations in Mycorrhizal Plant Grown on Saline Soil

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***Abstract*— Saline soil has a high salt content with pH between 7,3 – 8,5. These conditions contribute decreased of plant growth, yield quality and metabolic disorders related to salt (Na^+ and/or Cl^-) toxicity. Although the saline soil is potential to be used due to the huge area in Indonesia. The series of experimental studies have been conducted to describe the effect of mycorrhizae on the distribution pattern of Na^+ and Cl^- in plant grown on saline soil, including the growth parameters and phosphate uptake in two different plants (legume as a tripartite symbiotic plant and non-legume plants). The data were analyzed statistically by T-test. The results showed that mycorrhizae fungi increased significantly the growth parameters and P uptake, but decreased significantly the Na^+ concentration in the shoot. Interestingly the Na^+ concentration in the root were higher than the one in the shoot in both of the tested plants. These finding revealed that mycorrhizal plant were able to screen the toxicity amount of Na^+ that could be passed to the shoot both in tripartite symbiotic plant or non-tripartite symbiotic plant. Although the mycorrhizal plant could not decrease the Cl^- concentrations in the shoot.**

Keywords*— mycorrhizae, Na^+ and Cl^- concentrations, saline soil, tripartite symbiotic

I. Introduction

Human population is increasing every year throughout the world and by 2050 it is estimated that the increase in population reaches more than 35% [1]. In Indonesia, the population of people is 264 million with an annual population growth rate of around 1.3% [2]. Along with the increase in human population, food consumption also increases [3]. However, the increase in population was not accompanied by an increase in food production. In last decades a lot of productive land was converted into residential land, so that alternative land is needed to increase food production [4]. One of efforts to increase food production is by utilizing wetland such as coastal land as agriculture. Indonesia is the country with the second largest coastal area after Canada with the coastal length of 99,093 km [5]. With the use of coastal land as agriculture, it can become an alternative to increase food production in Indonesia. However, in the utilization of coastal land, it is found that there are obstacles in the form of coastal land characteristics that have high salinity (saline soil) due to the presence of sea water inundation where the salinity levels of sea water are increasing due to climate change [6].

Salinity is one of the abiotic stresses for plants [7,8]. Under high salinity conditions, salt accumulates in the soil and causes a decrease in plant production [9]. High salinity led to decrease of soil organic matter and other forms of soil degradation [10]. High levels of salt in saline soils have a negative effect on plant growth due to increasing soil osmotic pressure which results in decreased absorption of plant nutrients and water deficit [11]. Moreover, high salinity on saline soil decreased photosynthetic carbon assimilation, stomatal conductance and lowered photosynthetic electron transport efficiency [12]. In saline soils there is accumulation of Na^+ and Cl^- ions that cause toxicity in plants [13]. High concentration of Na^+ and Cl^- ions in plants can cause ion imbalance and cause physiological failures [14]. Other impact of high concentration of Na^+ and Cl^- ions in soil solution is decreasing of K^+ ions uptake which caused K^+ deficiency in plants [15]. Efforts are needed to minimize the effects arising from high salinity levels in the soil, one of the efforts that can be minimized by using of mycorrhizae [16].

Arbuscular Mycorrhizal Fungi (AMF) have a positive effect on plant growth under high salinity. AMF inoculation increase the gas exchange performances in plant under salt stress [17]. Moreover the symbiosis of plant with AMF improves water status which also improves plant growth and photosynthesis [18]. AMF increase plant tolerance to saline stress by improve nutrient uptake and maintenance of ionic homeostasis, superior water use efficiency and osmo-protection, enhanced photosynthetic efficiency, preservation of cell ultrastructure, and reinforced antioxidant metabolism [19]. Beside that AMF also modulate phytohormone activity to minimize salt effects on plant growth and development [20]. AMF inoculation also improve salinity tolerance in host plants by increase plant biomass [21]. Higher biomass subsequently leads to dilution of Na^+ and $Cl^–$, and manifests as better crop yield [22].

Based on the previous description, it is known that mycorrhiza has a positive role to increase plant tolerance in saline soils. However, the effect of mycorrhiza on the concentration of Na^+ and Cl^- in saline soils needs to be studied deeply. So this study was conducted which aims to record the pattern of accumulation and distribution of Na^+ and Cl^- ions in two types of test plants, namely non-legume plants and legume plants which represent tripartite symbiosis.

II. Methods

A. Soil Treatment

The composition of the planting media used was soil, sand and compost in a ratio of 2: 1: 1. The first step of the soil treatment was by sterilize the planting medium with 200 ml 2% formaldehyde each polybag, for 5 days. After that provide basic fertilizer with a combination fertilizer for each 5kg polybag with 40 mg urea, 40 mg TSP, and 40 mg KCL. Then, watering the media until the soil becomes moist (300 mL water). Watering using a concentration of NaCl 750 mg/L, is carried out every morning to prevent drought, especially if the soil conditions dry quickly in the dry season. Then mixing mycorrhizae (*Glomus agregatum*) on the growing media, which is by making the planting hole as deep as 3 cm. Then mycorrhizae were placed in the planting hole by 20 grams of inoculum each polybag. Planting tomato seeds in soil that has been given mycorrhizae (seeds placed just above mycorrhizae). Cover tomato seeds in polybags with thin soil (± 0.5 cm). Five replicate pots for each mycorrhizal and non-mycorrhizal plant were used. Plants were grown in a greenhouse (day min/max temperatures of 28/34ºC; max light intensity of approximately 900 lux).

B. *Plant Analysis*

Roots and shoots were harvested eight weeks after sowing to determine the root colonization by mycorrhizae, to measure the plant biomass, and to analyze the nutrient (P, Na, and Cl) concentrations. Percentage of root length colonized by AMF fungi was determined on roots stained in tryphan blue using the gridline-intersect method [23, 24] Spectrophotometer was used to measure P, Na, and Cl concentrations.

C. *Statistical Analysis*

T-test was applied to determine the differences of root colonization, plant biomass, P concentration in the shoot, Na^+ and Cl^- concentrations in the shoot and root due to AMF colonization ($P<0.05$).

III. Results

A. *Effect of AMF on root colonization, plant biomass, and P uptake*

In this study was obtained some of data include root colonization, plant biomass, and P uptake that shown in Table 1.

TABLE I. ROOT COLONIZATION, PLAND BIOMASS, AND P CONCENTRATION OF NON-MYCORRHIZAL (NM) AND MYCORRHIZAL (M) PLANTS GROWN ON SALINE SOIL

Plant	**Root Colonization (%)**		**Plant Biomass (g)**		**P Concentration (mg g^{-1} DW)**	
	NM	**M**	**NM**	**M**	**NM**	**M**
Tomato	18.9 ± 4.6 a	45.5 ± 7.3 b	13.9 ± 2.6 a	21.3 ± 4.1 b	2.8 ± 0.6 a	5.1 ± 0.9 b
Soybean	27.7± 7.9 a	50.3 ± 2.2 b	7.7 ± 4.8 a	22.2 ± 7.3 b	2.2 ± 0.3 a	3.0 ± 0.8 a

Different letters within one row indicate a statistically significant difference between NM and M treatment (P<0.05, T-test).

Table 1 showed that mycorrhizae fungi increased significantly the root colonization, plant growth and P uptake in tomato and soybean. However, the high root colonization by mycorrhiza did not have a significant effect on the P concentration in shoot of soybean plants which had the symbiosis of tripartite. Tripartite symbiosis is symbiosis in legume plants between AMF fungi, plants, and Rhizobium.

B. *Effect of AMF on Na^+ and Cl^- concentration*

Other data that obtained from this study was in the form of Na^+ and Cl^- concentrations in shoot and root of non-mycorrhizal (NM) and mycorrhizal (M) plants grown on saline soil.

TABLE II. Na^+ AND Cl^- CONCENTRATIONS IN SHOOT AND ROOT OF NON-MYCORRHIZAL (NM) AND MYCORRHIZAL (M) PLANTS GROWN ON SALINE SOIL

Plant	**Na^+ Concentration (mg kg^{-1} DW)**		**Cl^- Concentration (mg kg^{-1} DW)**	
	NM	**M**	**NM**	**M**
Tomato				
Shoot	592.5 ± 31.4 b	490.9 ± 52.6 a	0.058 ± 0.009 a	0.063 ± 0.01 a
Root	641.7 ± 40.1 b	541.2 ± 33.9 a	0.047 ± 0.011 a	0.070 ± 0.02 a
Soybean				
Shoot	6073.2 ± 79.3 b	4572.2 ± 83.4 a	0.047 ± 0.020 a	0.052 ± 0.018 a
Root	7418.4 ± 92.1 b	4905.9 ± 48.6 a	0.046 ± 0.017 a	0.053 ± 0.014 a

Different letters within one row indicate a statistically significant difference between NM and M treatment (P<0.05, T-test).

The results revealed that mycorrhizae fungi decreased significantly the Na^+ uptake from root to the shoot in tripartite symbiotic plant or non-tripartite symbiotic plant. This can be seen in Table 2 which showed the concentration of Na^+ in roots was higher than the concentration of Na^+ in shoots, both in tomato plants and soybean plants. Interestingly the Na^+ concentration in the root were higher than the one in the shoot in both of the tested plants. Although there was no significance difference in the Cl^- concentrations in the shoot between the mycorrhizal plant and non-mycorrhizal plant. Even there was not difference in tripartite symbiotic plant and non- tripartite symbiotic plant.

IV. Discussions

Based on the study that had been done, the results were in the form of root colonization, biomass plant, and P uptake (Table I) and concentration of Na^+ and Cl^- (Table II). Table 1 showed that mycorrhizal fungi increased significantly the root colonization, plant growth and P uptake in tomato and soybean. The results were similar to other researcher who is reported that indigenous mycorrhiza inoculum increased root colonization and significantly increased plant seedling survival, fruit yield, and P shoot concentrations that impact on plant growth [25]. Mycorrhizal fungi are mainly composed of the hyphae and form a huge hyphal network in the rhizosphere of plants that have a positive effect to promote plant growth by improving nutrient uptake in a wide range of host plants [26]. However, the study results showed that the high root colonization by mycorrhiza did not have a significant effect on the P concentration in shoot of soybean plants which had the symbiosis of tripartite. The effect of mycorrhizal on P concentration depend strongly on the P supply conditions and the fungal species involved [27]. Based on the study that was be done by Wang and his colleagues reported that only the colonization with *Rhizophagus irregularis* increased the P uptake significantly in the soybean but this effect was not significant with other mycorrhizal species such as *Glomus agregatum* [28]. Other researcher stated that the highest phosphorus uptake in shoots was found in *A. spinosa*-inoculated plants, followed by *Glomus* sp. and A. *scrobiculata* [27].

Based on Table II, the results revealed that mycorrhizae fungi decreased significantly the Na^+ uptake from root to the shoot in tripartite symbiotic plant or non-tripartite symbiotic plant. Interestingly the Na^+ concentration in the root were higher than the one in the shoot in both of the tested plants.

This result was similar to other researcher study result who is reported that rates of uptake and transport of Cl^- and Na^+ from root to shoot were markedly lower in mycorrhizal plant than in non mycorrhizal plant leading to decrease in accumulation of Cl^- and Na^+ [29]. These finding revealed that mycorrhizal plant were able to screen the toxicity amount of Na^+ that could be passed to the shoot both in tripartite symbiotic plant or non-tripartite symbiotic plant. However there was no significance difference in the Cl^- concentrations in the shoot between the mycorrhizal plant and non-mycorrhizal plant. Even there was not difference in tripartite symbiotic plant and non- tripartite symbiotic plant. Augé and his colleagues reported that mycorrhizal symbiosis had no consistent effect on shoot Cl^- concentrations [30]. This results was opposite to other finding which reported that AM colonization greatly reduced the mineral contents such as Cl in the shoot [31]. This can be influenced by the mycorrhizal species involved since each mycorrhiza has its own effect on plant under saline stress [27].

V. CONCLUSIONS

Based on results and discussions, it can be formulated some conclusions such as followed:

- AMF increased significantly the root colonization, plant growth and P uptake in tomato and soybean. However, the study results showed that the high root colonization by mycorrhiza did not have a significant effect on the P concentration in shoot of soybean plants which had the symbiosis of tripartite.

- AMF decreased significantly the Na^+ uptake from root to the shoot in tripartite symbiotic plant or non-tripartite symbiotic plant. Interestingly the Na^+ concentration in the root were higher than the one in the shoot in both of the tested plants. Although there was no significance difference in the Cl^- concentrations in the shoot between the mycorrhizal plant and non-mycorrhizal plant. Even there was not difference in tripartite symbiotic plant and non- tripartite symbiotic plant.

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