沙漠研究 **24**-1, 161-164 (2014)
Journal of Arid Land Studies － DT11 Refereed Paper －

Effects of Water and Salinity Stress on the Growth of Iceplant

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Abstract: Desertification has become one of the major environmental problems of the world in recent years. Salt damage caused by saline accumulation is reported as one of the causes of desertification. There are various methods to remediate saline soil. One of the methods, the use of halophytic ice plant (*Mesembryanthemum crystallinum*), has been developed in recent years. However, studies of *Mesembryanthemum crystallinum* are still few and report only on the effect of salinity and moisture condition on salt absorption and growth. The purpose of this study is to 1) elucidate salt absorption capacity and growth rate of iceplant under saline soil, and to 2) detect the state of salt absorption of iceplant by spectral reflectance characteristics (non-destructive measurement). According to our results, a tendency of growth reduction was found as salt stress or water stress became higher. This is presumed because the root water absorptive function is inhibited due to the decline of soil water potential. There was a trend of higher EC under lower soil water potential conditions. It is presumed that less soil water content activates more to salt absorption from the soil. A trend was also found that the iceplant physiological activity declines as salt accumulation in the leaves increases. From this result, NDVI (Normalized Difference Vegetation Index), which detects plant activity, can be a good index to show the state of saturation of absorbed salts. We propose that it is possible, by monitoring the leaf maximum salt accumulation with NDVI, to effectively desalinate soil.

Key Words: *Mesembryanthemum crystallinum*, NDVI, Saline soil, Salt stress, Water stress

1. Introduction

Desertification has become a major environmental problem of the world in recent years. Salt damage caused by salt accumulation is reported as one of the causes of desertification. There is estimated to be about 40 percent of the irrigated land that has experienced soil salinization (FAO, 1997). There are various methods to improve saline soil. One of the recently developed methods is the use of halophytic iceplant *Mesembryanthemum crystallinum*. However, studies of *Mesembryanthemum crystallinum* are still few and report only on the effect of salinity and moisture conditions on salt absorption and growth.

Hence the objectives of this study were as follows:

1) Elucidate the salt absorption capacity and growth rate of ice plant under saline soil.
2) Detect the state of salt absorption of ice plant by spectral reflectance characteristics (non-destructive measurement).

2. Materials and Methods

2.1. Experimental plants

Mesembryanthemum crystallinum, ice plant, is native to South Africa Namib Desert (**Fig. 1**). The main characteristics of ice plant are known as follows, 1) it can grow in soil

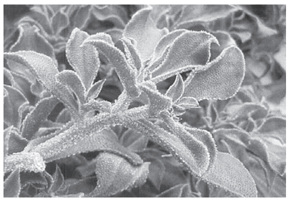

Fig. 1. Iceplant.

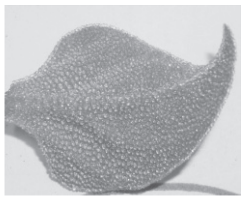

Fig. 2. Bladder cells.

containing sodium chloride (ca. 3 %); 2) it absorbs salts from the soil, and accumulates salt into leaves and stems *i.e.* ice plant generates bladder cells when absorbing salt from soil (**Fig. 2**); 3) it converts to the CAM type from C3 type photosynthesis type when it encounters stress (Agarie, 2004).

2.2. Methods

In this study, irrigation amount was set in three patterns in order to provide different soil moisture conditions. Three patterns were set as “Poor”, “Fair,” or “Good” using soil moisture states with pF. The pF represents a common

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(Received, September 25th, 2013; Accepted, January 6th, 2014)

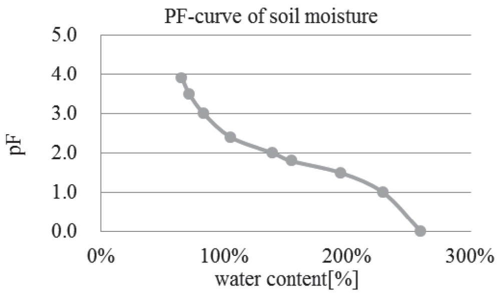

Fig. 3. pF vs. soil moisture curve of the sample soil.

logarithm of the height of water column soil moisture tension. Each pF value refers to 3.9 for Poor, 3.0 for Fair, 1.8 for Good based on irrigation amount. The irrigation amount was decided for each soil moisture condition from pF-moisture curve (**Fig. 3**). The pF was measured by centrifugation method and suction. Soil moisture characteristics were controlled according to the pF value and the moisture content in each pF was calculated. We set salinity concentration patterns of 0, 1, 2 and 3% in each condition by controlling NaCl input.

The authors measured spectral reflectance and increased amount of leaf area as indices of quality of growth until close of experiment. We calculated leaf area to create a polygon using a GIS by using the photos taken from directly above the plants every 6 days. We measured spectral reflectance on the target leaf (range is 0.26 cm in diameter) using by ASD company spectral reflectance meter (HandHeld2) every 6 days. Soil EC was measured to observe change of salinity in soil every 6 days. The soil EC was measured by using EC meter (Atago) on the collected surface soil from each sample pot. Salt concentration of the soil was estimated by measuring EC of solution of 1 : 5 in weight ratio (1: soil, 5: water), after being dipped for 1 hour. We measured EC of leaves to observe how much salt ice plant absorbed every 6 days. The leaf EC was measured using an EC meter (Atago) on minced leaves from each sample pot. Salt concentration of the leaf was estimated by measuring EC of solution of the minced leaves of 1 : 20 in weight ratio, after dipping for 25 minutes. Both young and mature leaves were measured at the experiment end date.

The number of samples was 32 in total. Poor and Fair irrigation had duplicated 3 samples for each treatment, while Good irrigation had 2 samples duplication. Fair and Poor irrigation with salinity concentration of 0, 1 and 3% treatments were started in November 2012. Fair and Poor irrigation with salinity concentration 2% treatment and Good irrigation with salinity concentration 0, 1, 2 and 3% treatments were started in December 2012. The measurements were made every 6 days and eight times in total.

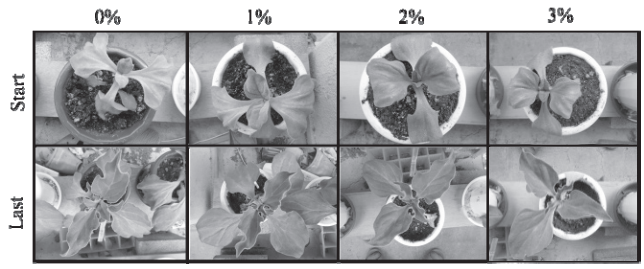

Fig. 4. Growth trend of ice plant at the beginning and the end of experiment (Good irrigation treatment).

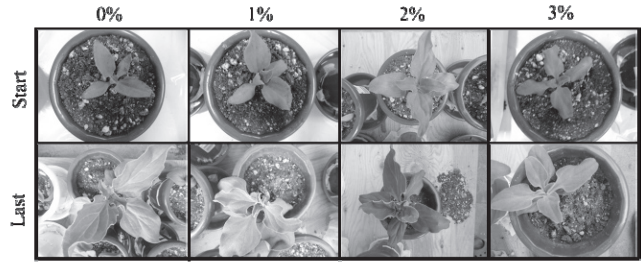

Fig. 5. Growth trend of ice plant at the beginning and the end of experiment (Fair irrigation treatment).

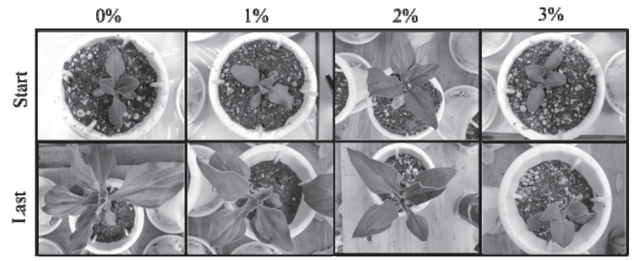

Fig. 6. Growth trend of ice plant at the beginning and the end of experiment (Poor irrigation).

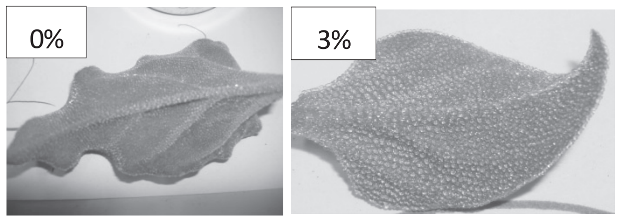

Fig. 7. Bladder cells at the end of experiment (Good irrigation treatment).

3. Results and Discussion

3.1. Growth trends

Figures 4, 5 and **6** show growth trend of ice plant samples. No growth on was visually observed in the poor irrigated condition and 3% salinity concentration treatment. Bladder cells could be observed in all conditions (**Fig. 7**). As result, irrigation high salinity concentration treatment created many bladder cells in all irrigation patterns. These results confirm the absorbance of salts from soil into the iceplant leaves.

3.2. Soil EC transition

Figure 8 shows soil EC transition in all irrigation conditions of salinity concentration patterns. The soil EC

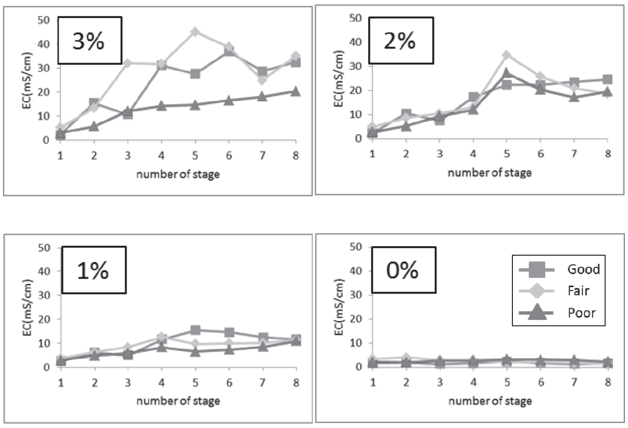

Fig. 8. Soil EC transition (One stage indicates 6 days).

Table. 1. Leaf area growth (from the first day to the last day).

	0%	2%	3%
Good	186.1(±31.7)	208.6(±85.5)	61.5(±31.7)
Fair	161.6(±35.2)	5.8(±28.5)	7.5(±12.8)
Poor	157.6(±29.6)	46.7(±46.7)	6.8(±1.0)

High soil water potential Low

High soil water potential Low

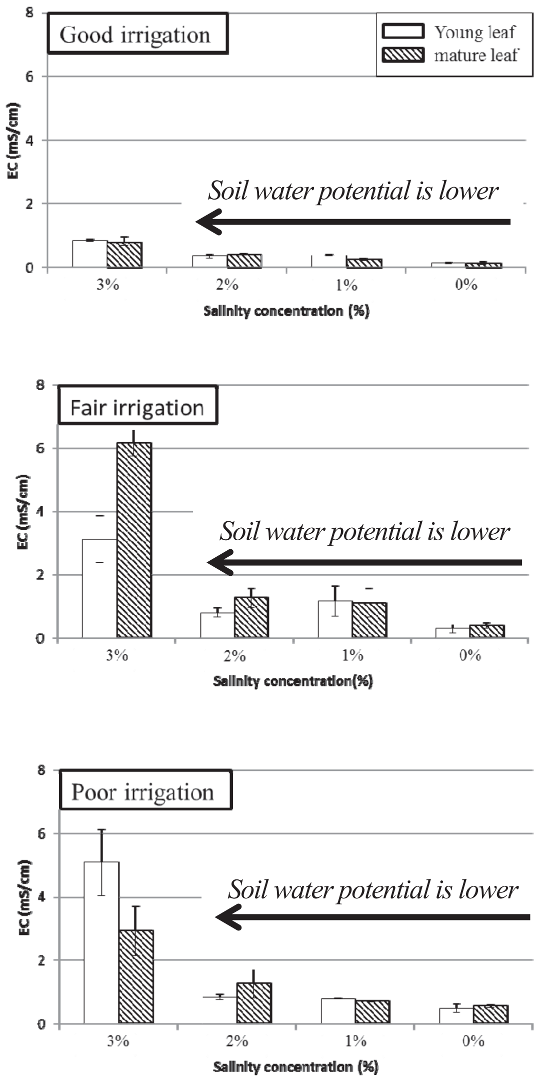

Fig. 9. Leaf EC of both young and mature in each treated sample.

values in poor irrigation condition were relatively low in all salt concentration treatments. Fair irrigation condition showed the highest EC on average in all saline treatments.

3.3. Leaf area growth

Table 1 shows measured leaf area in each irrigation condition and saline treatment. From these results, a tendency of growth reduction was found as salt stress or water stress become higher. The salt concentration treatments higher than 2% with less irrigation (Fair and Poor) showed no growth. From these, it can be observed that growth was inhibited as soil water potential became lower and at the same time soil osmotic potential became higher. Sodium chloride in the soil increased the osmotic potential in the soil. This is supposedly the cause of the growth inhibition. Furthermore, plants are presumed to suppress their transpirationsby closing the stomata of leaves in this dry state. Thus, photosynthesis is suppressed, and growth was reduced accordingly (Araki, 2002; Oguchi, 2009). It is also presumed that the root water absorptive function is inhibited due to the decline of soil water potential.

In addition, photosynthesis type of iceplant has the ability to convert to the CAM type from C3 type when it encounters stress. Because CAM type photosynthesis requires more energy, growth rate is slower than C3 type photosynthesis (Hayatsu, 2007). It is considered that the photosynthetic type is fixed as the CAM type and the growth rate was markedly suppressed because we have set the experiment treatments in high stress situation.

3.4. Salts absorption characteristic

Figure 9 shows leaf EC in each irrigation and salinity concentration pattern (on the last day). 3% concentration of Fair and Poor treatments resulted in higher EC of leaves than compared to all other treatments. The treatments also had the most inhibited growth. The treatments also had low water content and high salinity in soil thus suggesting water potential in soil was lower. Also, there was a trend of higher EC under lower soil water potential conditions in all irrigation patterns. From these results, it is presumed that lower water content in soil can increase the salt absorption function of iceplant.

3.5. Detecting the state of salt absorption by NDVI

Iceplant leaf surface reflectances were measured using Spectroradiometer (FieldSpec HandHeld2, ASD Co. Ltd.) and Normalized Difference Vegetation Index (NDVI) was calculated

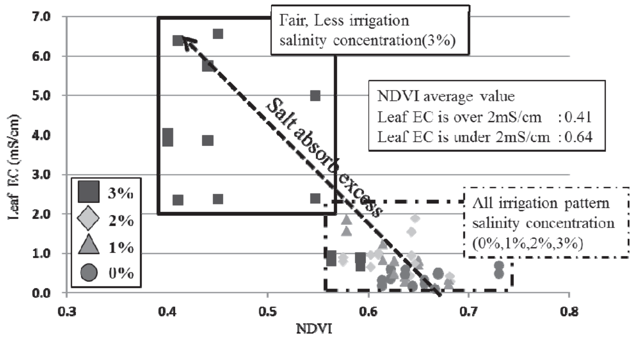

Fig. 10. Relationship between NDVI and leaf EC.

by the following equation

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where, NIR indicates the reflectance in the wavelength between 770 - 895 nm, and RED indicates the reflectance in the wavelength between 630 - 690 nm.

Figure 10 shows the relationship between NDVI and leaf EC. We can divide the activity status of leaf into two types from the leaf EC and NDVI space (Fig. 10): Salt affected leaf (leaf EC > 2.0 mS/cm and NDVI < 0.55) and active leaf (leaf EC < 2.0 mS/cm and NDVI > 0.55). Leaf EC of more the 2 mS/cm is surrounded by a black line frame and below the 2 mS/cm is surrounded by a dotted line frame. From this result of NDVI average values, there is a tendency to reduce physiological activity by accumulating salts to the leaves. Therefore, it is suggested that NDVI detects plant activity and can be a good index to show the state of saturation of absorbed salts.

4. Conclusion

We found the following outcomes on water and saline stressed iceplant in this study:

- Growth was inhibited as the water potential of the soil became lower.
- There was a tendency to absorb salts as soil water content is lower.
- NDVI detects plant activity and can be a good index to show the state of saturation of absorbed salts and plant activity.

As an outcome of this study, we propose that it is possible, by monitoring the leaf maximum salt accumulation with NDVI, to desalinate effectively saline soil.

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