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Sedum Response to Sea Water Salinity under Different Irrigation Methods

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Abstract: Globally arid and semiarid areas are facing salinization of soils along with the acute shortage of water resources. The utilization of marginal waters for agriculture is getting considerable importance in such regions. During our experiment sedum (*Sedum aizoon* var. *floibundum*) plants, which are tolerant to the water stress, were tested for growth parameters in response to irrigation with diluted sea water either by surface or shower method. The sea water was diluted to the salinity levels of 0.7, 15, 30 and 46 dS m^{-1}. The results of the experiment demonstrated that evapo-transpiration was affected negatively by the salinity treatments. The electrical conductivity of the soil and drainage water increased significantly with higher saline water. Fresh water gave the highest plant biomass whereas diluted sea water apparently decreased plant biomass with increasing salinity. However, the conjunctive use of sea water with higher dilution gave more sedum biomass yield than less diluted sea water. Plant growth was not affected by the method of irrigation during the experiment. Water deficit increased with increasing the salinity level. The ratios of dry and fresh plant weights were significantly increased with increasing salinity levels.

Key words: Surface irrigation . shower irrigation . salt accumulation . plant growth

INTRODUCTION

The fresh water resources available for agriculture are declining quantitatively and qualitatively. Therefore, the use of lower-quality supplies will inevitably be practiced for irrigation purposes to maintain economically viable agriculture. Several countries have adopted the use of marginal water for irrigation to overcome water scarcity [1]. The management of poor quality water is the critical challenge for a sustainable agricultural production system. Sedum is the vegetation which successfully develops groundcover especially in the hot and dry climate. It is a perennial plant, which grows under natural moisture condition with low magnitude of soil [2]. Sedum potentially offer dry resistance and can prevent fire. It is commonly named as stone-crop and grows well in the rocky areas; absorb substantial water in its thick leaves. It is easy to propagate sedum plants. The tiny leaf or piece of the stem that touches the ground can produce the root system. Some types of sedum invasively prevail on the soil surface but can easily be controlled since the roots never go deep [2]. The studies on the growth and survival of sedum under saline water conditions are scanty and not well documented. Therefore the objective of this study was to monitor sedum response to saline water irrigation either by surface or shower method.

MATERIALS AND METHODS

The pot experiment was carried out in a glasshouse at Arid Land Research Center, Tottori University, Japan. The relevant properties of the soil used during the experiment are shown in Table 1. Soil texture was determined by the pipette method. Exchangeable cations were leached from the soil with neutral ammonium acetate and their concentrations were determined using a Polarized zeeman atomic absorption spectrophotometer (Model Z-2300 Hitachi corp, Japan). The Cation Exchange Capacity (CEC) was measured according to the procedure described by the Jackson [3].

Electrical conductivity and pH of the soil: water suspensions (1:5) were also measured with pH meter (Accumut M-10) and EC meters (Horiba DS-14) respectively. Sand dune soil was placed in 4 L pots. Sedum (*Sedum aizoon* var. *floibundum*) was planted in 24 pots at the planting density of 4 plants per pot during July 2005. One group of the pots was irrigated with the saline water directly on the surface of the soil and the other group of pots was showered by the same water treatments. Irrigation with saline water was started after 14 days of planting. Saline water treatments were consisted of four levels: i) fresh water (0.7 dS m^{-1}), ii) saline (15 dS m^{-1}), iii) highly saline (30 dS m^{-1}) and iv) sea water (46 dS m^{-1}). Sea water was diluted by tap water to achieve these EC_w levels of irrigation water. A

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Table 1: Selected physico-chemical characteristics of the soil

Property	Value
EC (1:5) water	0.03 dS m^{-1}
pH	6.36
Exchangeable K^+	0.06 $cmol_c\ kg^{-1}$
Exchangeable Ca^{2+}	0.34 $cmol_c\ kg^{-1}$
Exchangeable Mg^{2+}	0.45 $cmol_c\ kg^{-1}$
Exchangeable Na^+	0.10 $cmol_c\ kg^{-1}$
Cation exchange capacity	2.40 $cmol_c\ kg^{-1}$
Bulk density	1.47 g cm^{-3}
Infiltration rate	30.00 mm min^{-1}
Hydraulic conductivity	0.05 cm sec^{-1}
Texture	Sand

basal dose of NPK liquid fertilizer was added to the pots in the irrigation water. Four saline water treatments were combined with two types of irrigation methods e.g., surface or normal irrigation (N) and shower or sprinkler irrigation (S). These treatments are denoted as 0.7(N), 0.7(S), 15(N), 15(S), 30(N), 30(S), 46(N) and 46(S) respectively. Plants were irigated twice a week depending on the loss of evapo-transpiration (ETc) which was estimated by gravitational measurement. Extra water at the rate of 10% was added for leaching purpose. Evaporation was measured by using evaporation pan (class A). Drainage water for each treatment was regularly collected and the Electrical Conductivity (EC_d) was measured by calibrated conductivity meter (Horiba DS-14). Air temperature and relative humidity were measured during the day as well as night by Hobo meter (Pro series, onset, USA). Prior to the harvesting of the plants for their fresh and dry weight, plant height and leaf area (by portable area meter LI-3000A) were also measured. Post-harvest soil samples were collected from each pot at a depth of 0-20 cm. Soil Electrical Conductivity (EC) was measured in the 1:5 soil-water suspensions. Data were analyzed statistically for analysis of variance (ANOVA) and the means were compared at the probability level of 5% using Least Significant Difference (LSD) test (4).

RESULTS AND DISCUSSION

During the experiment weather fluctuated with the average glasshouse temperature of 29°C and humidity of 74%. Changes in the temperature and humidity during the experiment are shown in Fig. 1. Under fresh water treatment the plants exhibited the highest values of evapo-transpiration as compared to saline water treatments (Fig. 2). In general the higher level of evapo-transpiration and accumulation of salts on the soil surface was caused by the variations in the temperature over time.

Fresh water encouraged evaporation process more than saline water. Maximum evapo-transpiration occurred with good quality water. Since the plants absorb water in saline conditions with higher pressure therefore the water losses through transpiration were retarded. Thus the magnitude of the evapo-transpiration was inversely related to the amount of salts in the irrigation water. Reduced bioavailability of water and retarded plant growth under saline irrigation produced poor evapo-transpiration in the system. On the other hand presence of salts in the saline irrigation inhibits evap-transpiration and reduces water consumption. Water density, viscosity and formation of salt crust are factors that could reduce evaporation and maintain higher water in the soils. Al-Busaidi and Cookson [5] reported salt crust formation on the soil surface due to saline irrigation inhibited evaporation and reduced

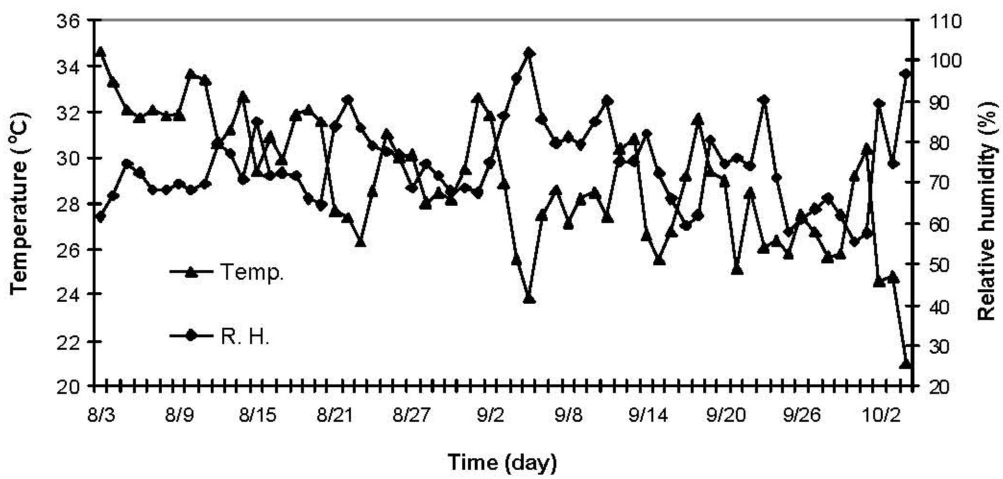

Fig. 1: Variations in temperature and humidity during study period

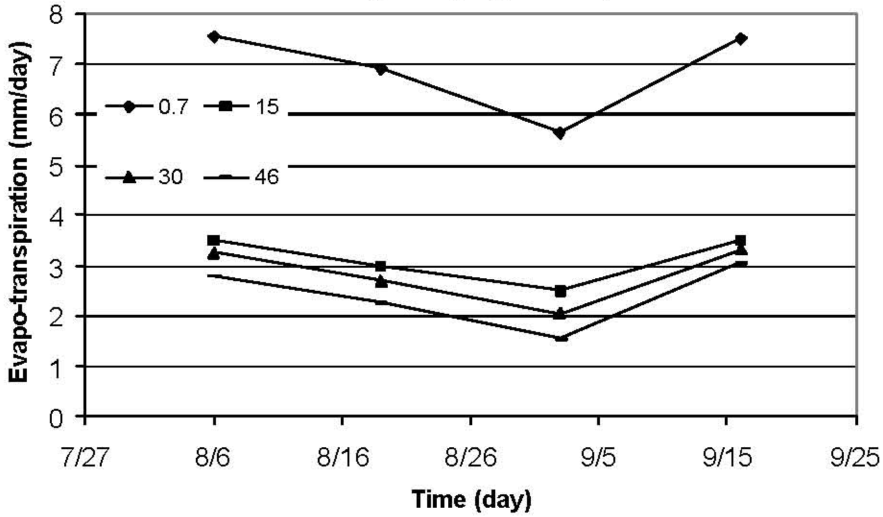

Fig. 2: Variability in the evapo-transpiration as affected by saline treatments

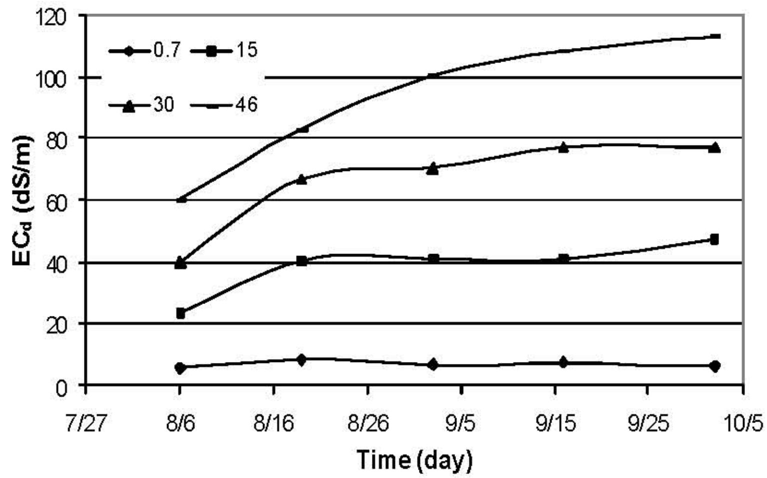

Fig. 3: Drainage water salinity as affected by saline water treatments

leaching efficiency. It has been reported elsewhere that salt accumulation in root zone causes the development of osmotic stress and reduces plant development [6, 7].

Salinity of drainage water reflects the occurrence of salts in the soils and the quality of the irrigation water. As expected the lowest salinity in the drainage waster was recorded under normal water treatment whereas the enhanced salinity level was occurred with diluted or undiluted sea water applications (Fig. 3). Since the drainage is a leaching process, the leaching fraction at the rate of 10% transported sufficient salts out of the soil in the drained water. Therefore the leaching at such fraction could be acceptable in the soils irrigated with higher saline waters. Shalhevert [8] also reported that leaching is the key to the successful use of saline water for irrigating crops. Oron *et al.* [1] reported that high saline water has an agricultural potential under proper management of irrigation. By increasing the volume of irrigation water, the soil salinity may be reduced due to water percolation below the root zone [9].

Application of irrigation water with certain level of salts results the deposition of soluble salts in the soils. Evaporation and transpiration of irrigation water eventually accumulate excessive amounts of salts in the soils unless an adequate leaching and drainage systems are not practiced [10].

Usually soil salinity is monitored either from the drainage water or through analyzing soil samples. During the study, a low electrical conductivity of soil was noted under normal water whereas sea water irrigation largely increased the salinity level of soil (Fig. 4). The saline water accumulated salts in the soil in spite of the leaching process. Petersen [9] reported that the accumulation and release of salts could depend on the quality and quantity of irrigation water, soil type and plant response. Abu-Awwad [11] reported high salt concentration on the soil surface due to evaporation.

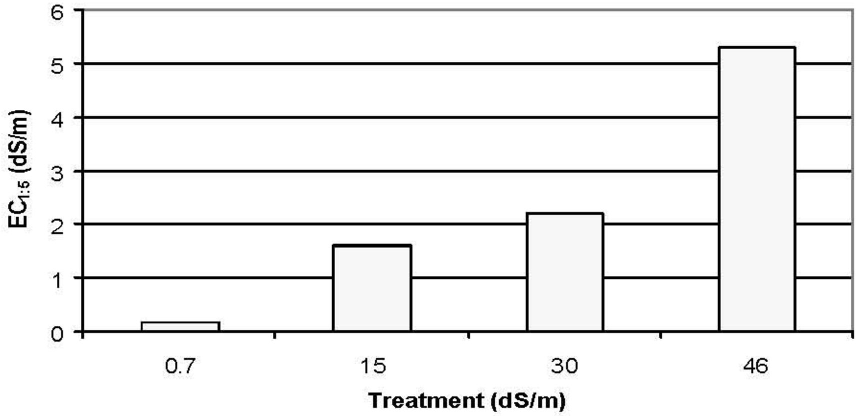

Fig. 4: Soil salinity under different saline irrigation treatments

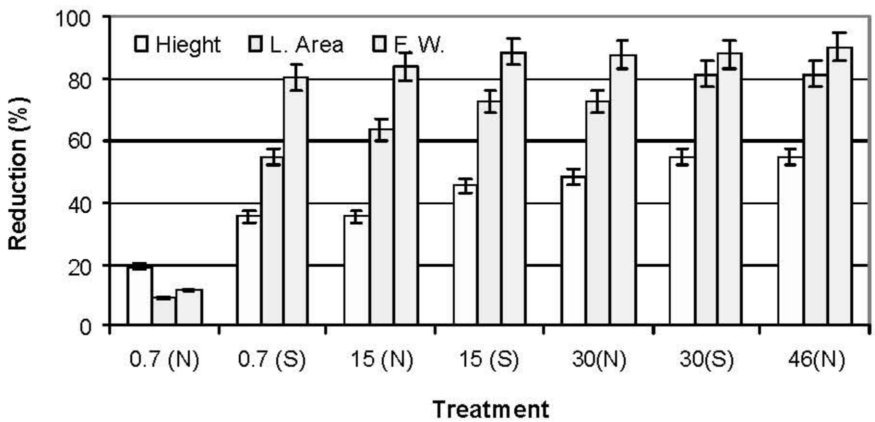

Fig. 5: Reduction in plant parameters as affected by saline irrigation waters

Plant growth: Plant parameters were the function of irrigation water treatments. Sedum plant grew well under non- saline conditions. Highest plant fresh and dry biomass, plant height and leaf area were noticed with normal irrigation water. While, sea water treatment gave the lowest values of the plant parameters (Table 2). Soil salinity was the main reason behind the lower plant growth whereas the effects of irrigation methods were statistically found insignificant. Sedum plants accumulated more salts and leaf injuries were seen especially under high saline treatments. The physiological thickness of the sedum leaves with higher water absorbing potential could possibly facilitate sedum plants to survive under high saline conditions.

There is a general consensus that higher salinity profoundly impaired plant growth parameters. The response of crops to salinity could depend upon plant species, soil texture, water holding capacity and composition of the salts. Abu-Awwad [11] reported that saline soils with considerable soluble salts interfered the growth of crop species. Heakal *et al.* [6] reported that dry matter yield of plants decreased with increasing salinity of irrigation water.

Table 2: Plant parameters as affected by saline water irrigation

Treatment	Plant height (cm)	Leaf area (cm^2)	Fresh weight (g)	Dry weight (g)
0.7 (N)	31	11	355	44
0.7 (S)	25	10	314	39
15 (N)	20	5	69	22
15 (S)	20	4	57	16
30 (N)	17	3	39	17
30 (S)	16	3	43	18
46 (N)	14	2	42	17
46 (S)	14	2	35	20

From Fig. 5, higher reduction in the values of plant parameters was noted with increasing salinity as compared to the control or normal water. Among the parameters a highest reduction in the fresh biomass of the sedum plants was observed with saline treatments. Similar trend of the reduction in the plant height, leaf area and fresh weight due to salinity of water was recorded. It was also reported by the US Salinity Laboratory [10] that excessive soil salinity reduced yields by lowering plant stand and growth rate.

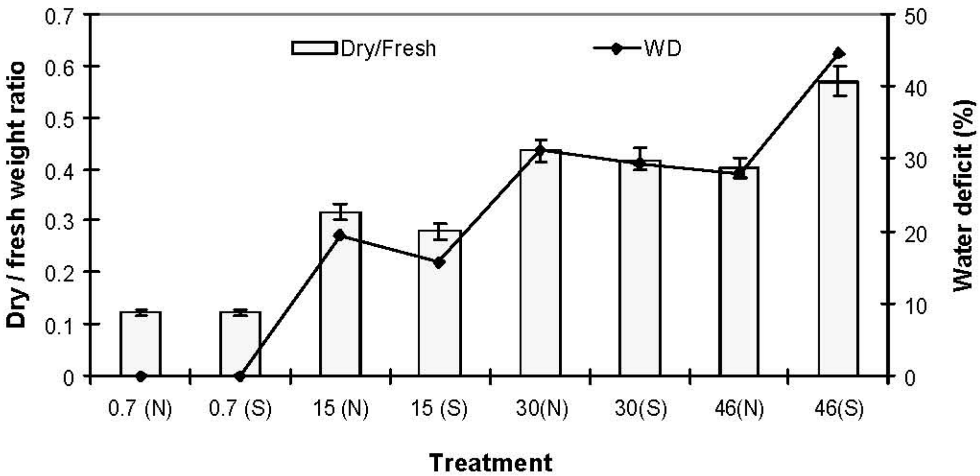

Fig. 6: The ratio of dry to fresh weight and Water Deficit (WD) as affected by the saline treatments

Table 3: Summary of two-way analysis of variance on the effects of saline water and irrigation method on plant parameters

	P-value		
Parameter	Saline water (S)	Irrigation method (I)	SxI
Plant height	0.0001*	0.0001*	0.0002*
Leaf area	0.0001*	NS	NS
Fresh weight	0.0001*	0.0001*	0.0001*
Dry weight	0.0001*	0.0006*	0.0001*

*Denotes the level of significance at P value < 0.05 and NS denotes non-significance

In general the plant biomass is dependent absolutely on the growth of plants. Differences were found in the fresh and dry weights among the irrigation treatments. Water deficit level increased with the increasing salinity (Fig. 6). The ratio of dry weight to fresh plant weight increased significantly with the increasing level of salinity treatments. The stress caused by the ion concentrations allows the water gradient to decrease, making it more difficult for water and nutrients to move through the root membrane [12]. Accumulation of salts in the root zone affects plant performance through creation of water deficit and disruption of ion homeostasis [13] which in turn cause metabolic dysfunctions. The differences in the water content of the plants between the irrigation methods could reflect the efficiency of surface irrigation which can provide enough water to the plant without physically touching the leaves. Sprinkler or shower irrigation adds salts directly on the leaves and may disturb its normal functions.

Water salinity and irrigation method can affect plant growth. Moreover, the interaction effect of both independent parameters was affecting plant height and biomass (Table 3). However, it can be seen that all dependent parameters were significantly affected by applied treatments.

Volkmar *et al.* [12] reported that plants grown in saline soils have diverse ionic compositions and concentrations of salts. The fluctuations in the salts concentrations could be related to the changes in the water source, drainage, evapo-transpiration and solute availability. The two major environmental factors that currently reduce plant productivity are drought and salinity and these stresses cause similar reactions in plants due to water stress [14].

CONCLUSION

Our experiment could confirm that sedum plants can tolerate salinity stress and can also survive with water deficit conditions. The saline waters remarkably affected the evapo-transpiration rate, salts accumulation in the soils and plant biomass production. We attribute the sedum growth to its potentially higher water absorbing thick leaves under stress conditions. Water deficit increased with the increasing salinity level. The salinity of the soil and drainage water significantly increased with higher saline water. The plant growth was not affected by the surface or sprinkler irrigation system. The use of sea water up to certain dilution could be an option for sedum production in water scarce areas.

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