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The response of Evapotranspiration to osmotic potential in small-scale lab lysimeters

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Background

- Evapotranspiration is a function of different plant, meteorological and soil factors.
- Soil water potential is one of the major soil related factors which influence evapotranspiration. It consists of two main components; matric and osmotic potential.
- Unlike the other factors, the impact of osmotic potential in evapotranspiration has not been sufficiently investigated in experimental studies so far. However, the impact of osmotic potential is becoming more important in wide areas of the world due to the influence of climate change on irrigation water and soil quality.
- In this study, we try to find out the role of osmotic potential on daily evapotranspiration rate from small-scale lab lysimeters planted with grass.

Experimental Approach

- An growth experiment was performed in the lab with small weighable lysimeters that were internally equipped with sensors for water content, electrical conductivity, temperature and matric potential. The experiment consists of two irrigation water quality treatments with two replicates.
- Different levels of osmotic potential treatments were created in the lysimeters by irrigation with different concentrations of saline solutions. In a control treatment, distilled water was used.
- Sensors were installed at two different depths in each treatment for monitoring the changes in soil moisture, salinity, temperature and matric potential during the study period.
- Evapotranspiration was estimated from weighing, using balances placed under each lysimeter and connected to data loggers.
- We calculate the effect of the osmotic potential on total soil water potential and look for relations to the evapotranspiration rate.

Methods (1/4)

- Four lab lysimeters made of PVC cylinders:

- Inner diameter 230 mm, height 200 mm, volume 8.3 L.

- Packed with sandy loam soil material (11,8 kg of air dry material in each lysimeter).

Sand	Silt	Clay	EC (1:1)	Bulk density
0.65 kg.kg ⁻¹	0.29 kg.kg ⁻¹	0.06 kg.kg ⁻¹	0.59 dS.m ⁻¹	1.43 g.cm ⁻³

- TEROS 12 soil sensors were installed at two different depths
- T5 Tensiometers installed at the same depths
- Lysimeters placed on weighing balances and connected to data loggers.
- Two computers were used to collect the data.
- Irrigation applied to the surface of the lysimeters with distilled water.
- When the moisture content reached proper level the lysimeters were planted.
- Grass seeds were planted in each lysimeter. The amount of seeds were 1.3 g for each lysimeter distributed evenly at soil surface.

Methods (2/4)



Figure (1) preparing lysimeters

Methods (3/4)

- Irrigation with distilled water for all treatments continued after seed germination until the plants had reached appropriate height and density to apply the treatments.
- The experiment consisted of two irrigation water quality treatments with two replicates.
 - Irrigation with distilled water ($EC = 0 \text{ dS.m}^{-1}$).
 - Irrigation with 2560 mg/L NaCl solution ($EC = 4.79 \text{ dS.m}^{-1}$).



Figure (2) experimental setup

Methods (4/4)

- Volumetric water content for all treatments was maintained at 15-20%. When moisture content reached 15% irrigation were applied to increase the volumetric water content to 20%.
- The changes in moisture, bulk electric conductivity, temperature and matric potential for each lysimeter were continuously monitored.
- Osmotic potential in each lysimeter was calculated by USDA formula according to the changes in soil bulk electric conductivity.

$$\Psi_s = -0.36 \times EC$$



Figure (3) lysimeters setup

Results (1/5): Variation in osmotic potential

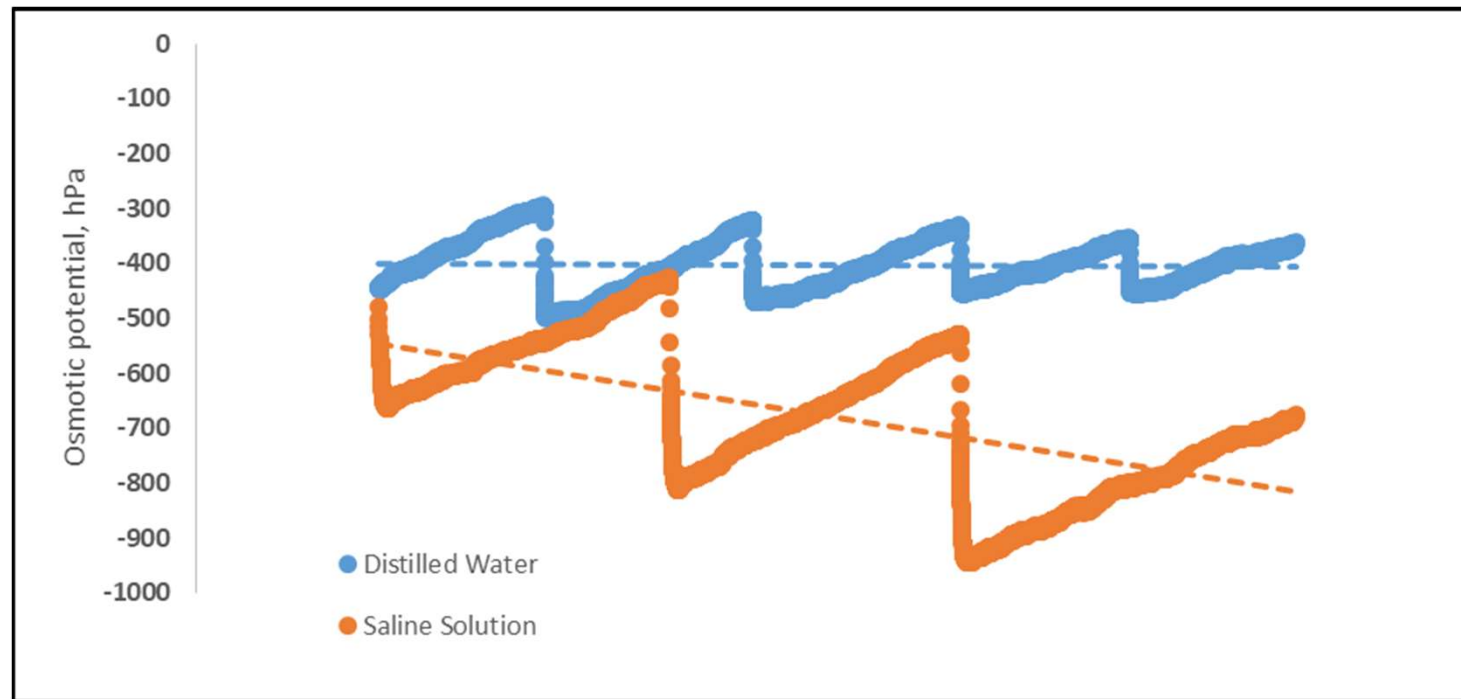


Figure (4) the change in osmotic potential due to the added salts in the mid of the experiment

Results (2/5): Daily Evapotranspiration

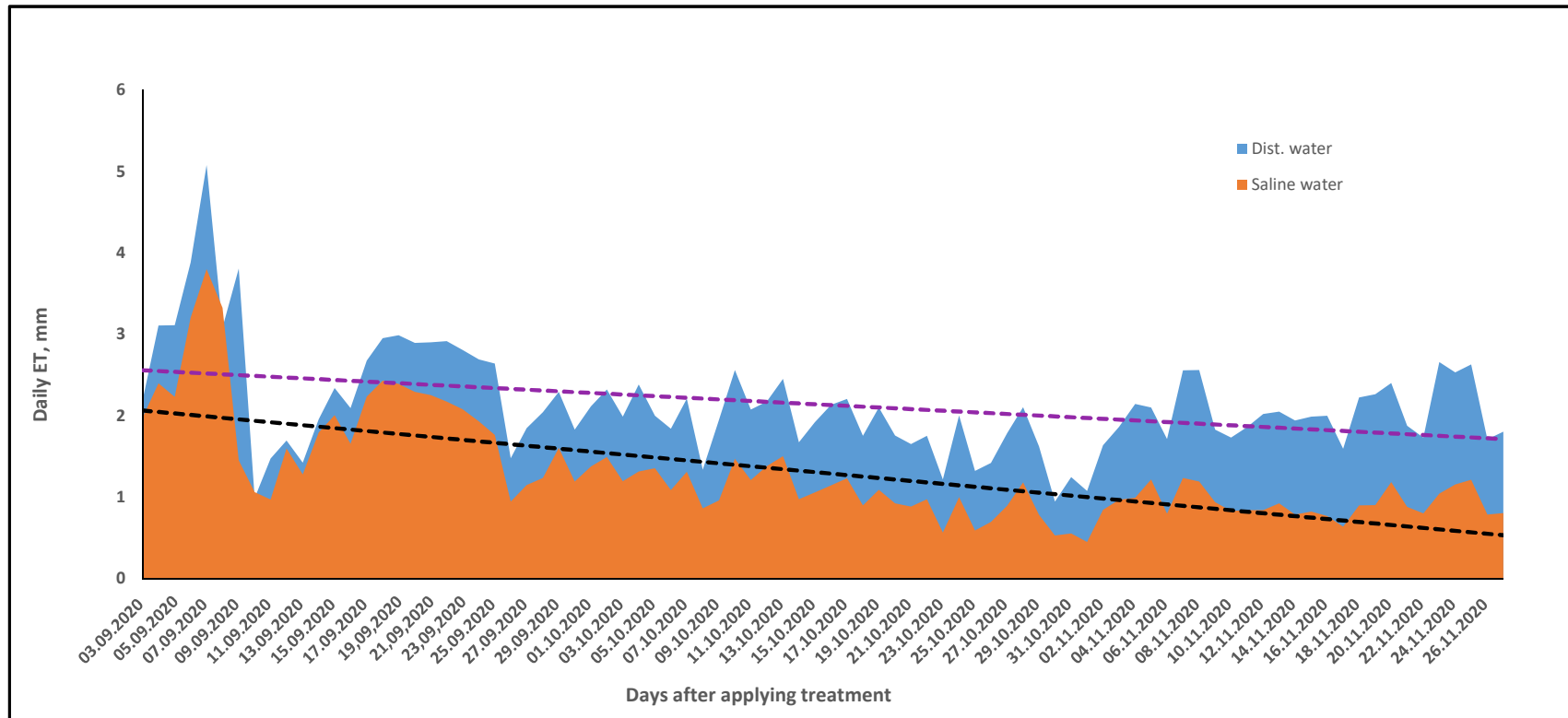


Figure (5) daily ET

Results (3/5): Accumulative Evapotranspiration

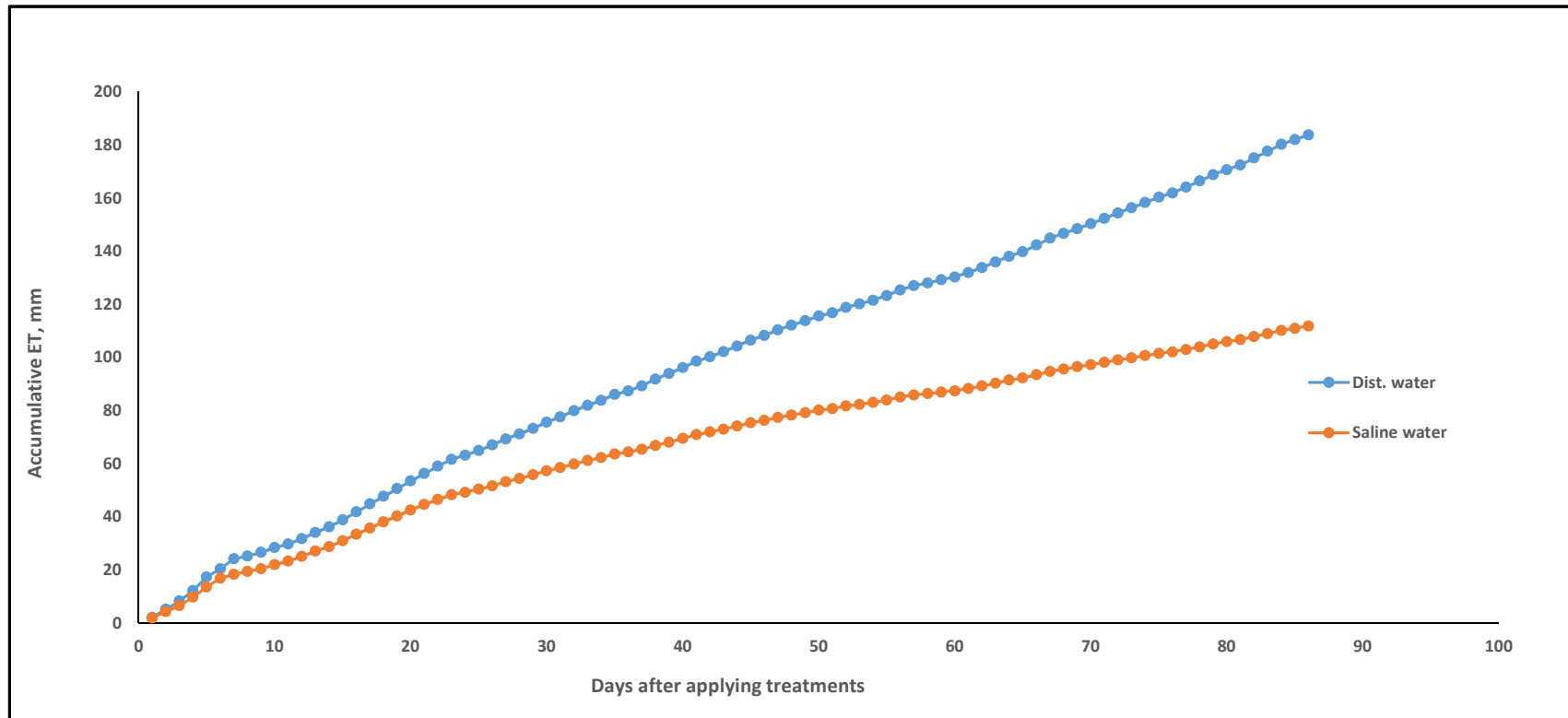


Figure (6) accumulative ET

Results (4/5): Effect on Growth and Vitality after 20 days

Distilled water



Saline water



Figure (7) the influence on grass growth after 20 days

Results (5/5): Effect on Growth and Vitality at the end of experiment

Distilled water



Saline water



Figure (8) the influence on grass growth after 87 days

Conclusions

- Osmotic potential significantly influenced ET. Accumulative ET reduced by 39% at the end of the experiment for the treatments that irrigated with saline solution in comparing with distilled water treatments.
- Reduction in ET value observed from the first irrigation cycle. Daily ET value reduced about 8% in the first day after apply the treatments and the reduction reached 55% at the end of experiment (87 days duration).
- The reduction in ET values are due to:
 - The effect in total water potential.
 - The effect in plant health.
- The influence in plant health observed after 20 days (4 irrigation cycles).
- Large scale field studies are required to investigate the roles of different salts and concentrations in ET.

Abstract

Drought and climatic change are among the main environmental stressors for the water and soil qualities. Soil water potential is the major soil-related factor controlling water availability to plants and their evapotranspiration. It consists of two main components: matric and osmotic potential. Although the effect of matric potential on plant evapotranspiration has been extensively studied under various conditions, there is still a lack of quantitative studies on the effects of osmotic potential on evapotranspiration.

In our study, we investigated the influence of soil osmotic potential on the daily evapotranspiration rate and cumulative evapotranspiration of grass planted in small laboratory lysimeters. A sandy loam soil material was packed in four lysimeters with a volume of 6000 cm³ and equal bulk density. The soil material was air dried, freed from roots and passed through a 2 mm sieve. Each lysimeter was equipped with soil sensors at two different depths to monitor soil moisture, bulk electrical conductivity, temperature, and matric potential. To obtain continuous mass balance measurements, each lysimeter was placed on a balance connected to the computer. Grass seeds were planted in each lysimeter at the same density and irrigated with distilled water until plant height was 12 cm. Irrigation water of two different qualities (EC= 0 and 4.79 dS/m) was then applied to produce different levels (0 and -0.17 MPa) of osmotic potential. The volumetric water content was adjusted to a value between 15 and 20 % in each lysimeter during the grass growth period. When the volumetric water content reached 15 %, irrigation water was added to the lysimeters to increase it to 20 %. Data were collected to calculate changes in osmotic potential relative to changes in total soil water potential. In addition, the relationship between osmotic potential and evapotranspiration rate during the growing season was determined.

Our results indicate a controlling role of soil osmotic potential on total soil water potential. This role results a significant reductions in evapotranspiration in response to increases in osmotic potential, in addition to effects on plant health. Osmotic potential has a significant function on total soil water potential when the soil becomes dry and poor water qualities are used in irrigation.