Influence of matric and osmotic potentials on germination and seedling growth

U. Schmidhalter and J.J. Oertli

Department of Crop Science, ETH, Zürich, Switzerland

The single and combined effects of osmotic and matric potentials, as well as specific ion effects on germination and seedling growth were investigated. In general, the rate at which plants absorb water from a drying soil decreases as the soil water potential decreases. Matric and osmotic potentials may affect plant growth to varying degrees and by differing mechanisms.

Materials and methods. Germination and seedling growth of carrots (Daucus carota L.) were investigated in solution and soil systems. The experiments were conducted in germinators at constant temperatures (8,12,16, 21 °C). Fluorescent lighting was provided for 12 hours daily at an intensity of 95 $\mu Em^{-2}s^{-1}$. The experiments ran for 25 days. Seeds were considered germinated when the length of the coleoptiles exceeded 2 mm. Petri dishes (6 cm in diameter, 1 cm high), containing cotton fibre wetted with 20 ml 1/2 strength Hoagland nutrient solution with equal parts by weight of $CaCl_2$ and NaCl, sown with 50 seeds, were used for the solution experiments. Various matric and osmotic potentials in soil were created on the one hand by equilibrating soil which had previously been saturated with different salt solutions on the pressure membrane apparatus and on the other hand by adding different amounts of salt solutions to the same mass of air dried soil. After mixing, the moist soil was placed in tightly closed plastic boxes and left for 1 week for further equilibration. Thereafter the prepared soil was sieved to 2 mm, placed in cylindrical soil containers (8.5 cm in diameter, 2.5 cm high), sown with 50 seeds at a depth of 0.8 cm and incubated in tightly sealed transparent boxes (9 cm in diameter, 5 cm high). The sand, silt, and clay contents were 15, 78, and 7 %, respectively. In another experiment, the silty soil was mixed with 18 % or 36 % by weight of sand with grain diameters of 0.8-1.2 mm, and 1.5-2.2 mm, respectively. All experiments were replicated four times and subjected to analyses of variance.

Results.Increasing salt concentrations slowed and reduced germination. Seedling growth was inhibited to a greater extent than was germination. Seedling root growth was less affected by salt stress than was shoot growth. No significant specific toxic effects were observed in mixed salt solutions up to salt concentrations of 12 mS/cm. Increased Mg concentrations showed significant toxic effects at 16 mS/cm salt concentration. A significant interaction of salt stress and temperature effects on germination and seedling growth was observed. Germinating seeds were more sensitive to low osmotic potentials at low temperatures than at a higher optimal temperature. The combined effects of temperature and salt stress caused a much greater reduction in shoot growth than in root growth.
At high soil moisture potentials, germination decreased significantly in the silty soil. Such a decrease was not found at equivalent osmotic potentials. Germination was influenced neither by matric nor by osmotic potentials ranging from -0.015 MPa to -0.5 MPa. Seedling growth showed a much higher sensitivity to changes in soil water potential. Optimum shoot growth was at matric potentials between -0.025 MPa and -0.1 MPa. At higher matric potentials a marked decrease occurred, whereas at lower potentials a gradual decrease was observed. Seedling growth was not affected by osmotic

potentials ranging from 0 to -0.5 MPa. Root growth responded most sensitively to moisture stress. High matric potentials severely inhibited root growth, whereas lower matric potentials caused a marked increase in root growth. Restricted oxygen supply did not interfere with salinity.
Germination in silty soils to which varying amounts of different sands had been added was not affected by osmotic potentials ranging from 0 to -0.5 MPa, whereas decreasing matric potentials in the same range strongly inhibited germination. Soil water potentials, composed of equivalent matric and osmotic potentials, showed intermediate effects as compared to soil water potentials consisting mainly of either matric or osmotic components. The negative effects were due primarily to the matric component. Seedling growth was not affected by osmotic potentials as low as -0.5 MPa. Shoot growth was optimum at matric potentials of -0.05 to -0.1 MPa, whereas lower matric potentials caused marked reductions. The results showed an optimum matric potential for root growth, shifting according to the particle size of the medium, at -0.1, -0.2, and -0.3 MPa, respectively. At lower potentials, root growth decreased.
Osmotic and matric potentials did not have equivalent effects on plant growth. This is in contrast to the suggestions of Wadleigh and Ayers (1) who postulated that yield is related to total soil water potential, regardless of which component or combination of components contributes to the total potential. Additive effects of matric and osmotic potentials on plant growth were assumed by Richards and Wadleigh (2), Childs and Hanks (3), Sharma (4) and are also described in the textbooks of Hillel (5) and Bresler et al. (6). The non equivalence of matric and osmotic potential effects on plant growth may be explained by the following factors: Plants differ greatly in their ability to adjust to matric and osmotic stress. Osmotic adjustement to water stress is less efficient and of limited duration. The theoretically expected osmotic potentials will only be realized, if plants behave as ideal osmometers.
A generalized relationship of relative plant yield to decreasing potentials is illustrated in Figure 1. Interactive effects of matric and osmotic potentials are indicated for two possible cases.

Prognosis of potential yields as well as optimal management strategies require a knowledge of the functional relationship of soil water potential to plant yield. The model in Figure 1 could contribute to a better understanding of this relationship.

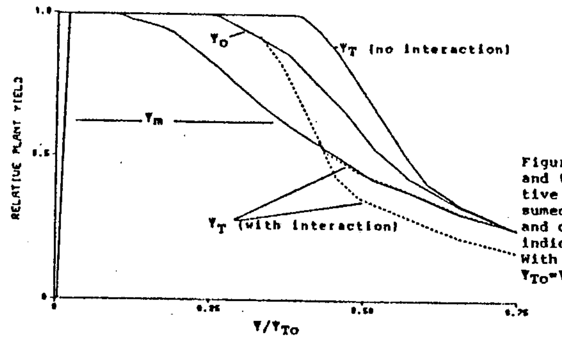

Figure 1. Influence of matric, osmotic and total soil water potential on relative plant yield. For Ψ_T, which is assumed to consist of equivalent matric and osmotic components, three cases are indicated: 1. No interaction. 2. and 3. With interaction of $\Psi_m+\Psi_O$ (dashed lines). $\Psi_{TO}=\Psi_T$ with relative yield zero

References: (1) Plant Phys. 1945:20 (2) Agr. Mon. 1952:3 (3) Soil Sci.Soc. Am.Proc. 1975:39 (4) Agr.J. 1976:68 (5) Academic Press. 1980 (6) Springer Verlag. 1982

Nr.29