GROWTH OF *ATRIPLEX HALIMUS* L. IN SODIUM CHLORIDE SALINATED CULTURE SOLUTIONS AS AFFECTED BY THE RELATIVE HUMIDITY OF THE AIR

By J. Gale,* R. Naaman,* and A. Poljakoff-Mayber*

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Summary

A. halimus plants were grown in saline nutrient solution (Knop's), in growth chambers, under two different conditions of relative humidity of the air: $27 \pm 3\%$ (dry) and $65 \pm 3\%$ (humid). All other climatic factors (temperature, illumination, etc.) were identical. Relative humidity was programmed to remain constant irrespective of day and night temperature changes. The salinity range was 0 to -20 atm NaCl.

Under dry air conditions typical optimum growth curves were obtained (final dry weight, relative growth rate, and height), with maximum growth always at about -5 atm. Under humid conditions no such optimum curves were obtained; growth was greatest in the non-saline controls and decreased with each increment in the salinity of the growth medium.

Apparently small amounts of NaCl are needed by *A. halimus* in order to overcome the stress caused by low relative humidity of the air. Under conditions of low evaporative demand, salinity is harmful to growth at all concentrations.

I. Introduction

In a previous study of the effect of salinity on the growth, photosynthesis, and transpiration of *Atriplex halimus* L., it appeared that one of the most prominent effects of NaCl salinity was on plant–water relations, particularly as expressed by changes in succulence (Gale and Poljakoff-Mayber 1970). *A. halimus* plants growing in different seasons of the year showed somewhat varying patterns of growth and physiological behaviour. For example, the values of mesophyll resistance to CO_2 uptake differed in plants grown in non-salinized media, in the spring and summer seasons (Gale and Poljakoff-Mayber 1970).

Severe climatic conditions have sometimes been observed to increase the damage caused by salinity, although the effect varied in different plants, and the interdependence of the climate and salinity effects has not always been clearly demonstrated (Magistad *et al.* 1943; Lunt, Oertlii, and Kohl 1960; Gale, Kohl, and Hagan 1967). Furthermore there has usually been a lack of differentiation between the various parameters of the environment, e.g. heat and low relative humidity of the air. In view of the effects of salt on the water relations of *A. halimus*, it seemed

* Department of Botany, Hebrew University of Jerusalem, Jerusalem, Israel.

possible that different conditions of evaporative demand would modify the plant's response to salinity.

This paper describes an experiment in which *A. halimus* plants were grown in media salinated with NaCl under two climatic regimes which differed in just one parameter: relative humidity of the air.

II. Methods

A. halimus seeds, gathered from wild plants in the Northern Negev, Israel, were germinated in sand in a greenhouse. When the seedlings reached a height of about 5 cm they were transferred, individually, to 100-ml dark-walled bottles, containing Knop's nutrient solution, which was changed every 2–3 days. After 2 weeks of growth the seedlings were transferred to plastic containers, four seedlings per container. There were 4 litres of aerated Knop solution in each container. Five containers were placed in each of two controlled growth chambers (Isco Co., model E-3). Climatic conditions were the same in the two chambers apart from relative humidity of the atmosphere, which in the "dry" chamber was maintained at $27 \pm 3\%$ R.H. and in the "humid" chamber at $65 \pm 3\%$ R.H. (Percentage relative humidity was programmed to be the same irrespective of temperature.) Other conditions were as follows:

Time of Day	Illumination (f.c.)	Total Radiation (cal cm^{-2} min^{-1})	Time of Day	Temp. (°C)
0400–0800	1100	0·11	0600–0800	24
0800–1100	2800	0·29	0800–1600	28
1100–1300	4800	0·51	1600–1800	24
1300–1600	2800	0·29	1800–0600	20
1600–2000	1100	0·11		
2000–0400	Dark	—		

Metalarc lamps supplemented with incandescent bulbs were used as a light source.

The fresh weights of the seedlings were taken before they were placed in the growth chambers. At the same time, the fresh and dry weights of 16 other seedlings were measured. The average fresh weight to dry weight ratio of this group was used to calculate the dry weights of the plants of the experiment, from their initial fresh weights.

Salination with NaCl was started after the plants had grown for 1 week in Knop solution in the growth chambers. Rate of salination did not exceed −1 atm per day until the following osmotic potentials were attained: 0, −3, −5, −10, and −20 atm in addition to the −0·25 atm of the Knop solution (24 m-equiv/l NaCl were required to decrease the osmotic potential by 1 atm). There was one container, with four plants, for each osmotic concentration, in each of the two chambers. After the desired level of salinity was reached, the salinized nutrient solutions were changed every 2–3 days.

The plants were harvested after a further 5 weeks and measurements were made of plant height and of fresh and dry weights of the leaves, branches, and roots.

The entire experiment was repeated and the results from the two series were pooled. Thus there were eight replicate plants for each of the 10 treatments (two humidities; five salinities).

III. Results

There was a very apparent difference in the growth of the plants under the two conditions of humidity. This can be seen in Figures 1 and 2 which show the first series of plants just before they were harvested.

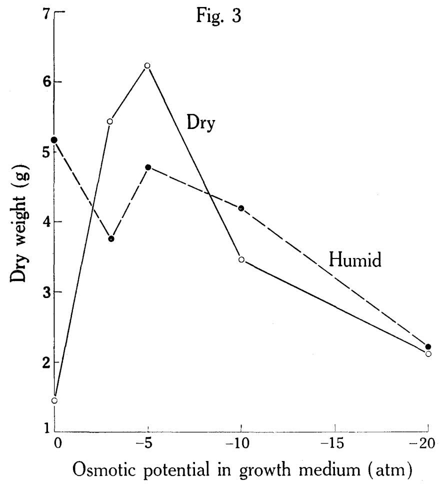
Pooled data on the growth of the two series of plants are given in Figures 3 (final dry weight) and 4 (relative growth rate). The relative growth rate was calculated from the time the plants were set out in the chambers, although fully saline conditions (of the highest concentration) were attained only some 22 days later.

Figures 1 and 2 and the data in Figures 3 and 4 show that there was a very large difference between plants grown in non-saline media under the two conditions of humidity. Under conditions of low humidity (high evaporative demand) growth was severely retarded (compare the controls in Figs. 1 and 2). On addition of NaCl to the

Figs. 1 and 2.—Effect of low (Fig. 1) and high (Fig. 2) relative humidity on the growth of *A. halimus* plants at 0 (control), −3, −5, −10, and −20 atm osmotic potential [in addition to the −0·25 atm of the Knop (control) culture solution]. The various osmotic potentials were obtained by adding differing amounts of NaCl to Knop nutrient solution (see Section II).

nutrient solutions to give an osmotic potential of —5 atm the growth of the plants in the dry chamber increased to the level of plants from the humid chamber (the difference between the two groups of plants at —5 atm was not significant).

Moreover, under the humid air conditions (low evaporative demand) there was no beneficial effect of NaCl on growth and each increment of salinity resulted in a further reduction in relative growth rate (Fig. 4).



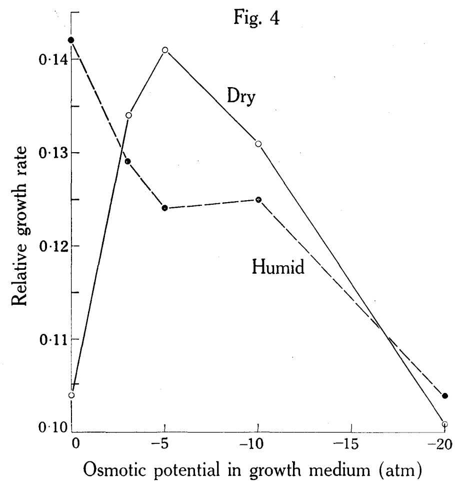


Fig. 3.—Effect of salinity on final dry weight of *A. halimus* plants at two different relative humidities. Mean standard error for dry and humid chambers is $\pm 0 \cdot 99$ and $\pm 1 \cdot 08$ respectively. In Figures 3–7 osmotic potentials in the growth medium are in addition to the $-0 \cdot 25$ atm of the Knop nutrient solution.

Fig. 4.—Effect of salinity on relative growth rate of *A. halimus* plants at two different relative humidities. Mean standard error for both dry and humid chambers is $\pm 0 \cdot 01$.

Despite the high relative humidity in the "humid" chamber, plants grown without NaCl had a low fresh weight to dry weight ratio (Fig. 5). Under conditions of

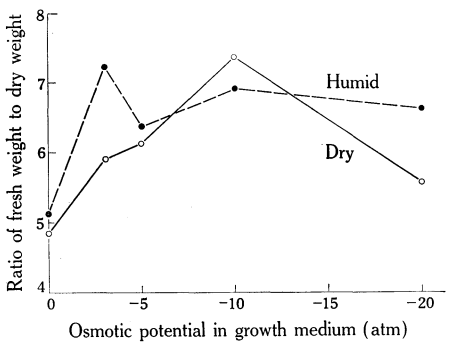


Fig. 5.—Ratio of fresh weight to dry weight of *A. halimus* plants grown at two different relative humidities in relation to salinity of the growth medium. Mean standard error for dry chamber $\pm 0 \cdot 67$, for humid chamber $\pm 0 \cdot 76$.

high relative humidity, the maximum level of the fresh weight to dry weight ratio was obtained at a lower level of salinity (-3 atm) than under conditions of low humidity (-10 atm). However, variability was great and the difference at -3 atm was of a low order of significance ($P > 0 \cdot 05$).

Plant height, which is also considered to be dependent on internal water balance, and especially turgor, was also strongly affected by humidity (Fig. 6). In the absence of NaCl plant height was much reduced under conditions of low humidity. However, if salt was present in the media at a level to give an osmotic potential of —5 atm or more, the height of the plants was equal to that of the plants grown at this level of salinity under conditions of high humidity. Under these latter conditions plant height was greatest in the absence of salt and was reduced by each increase in salinity.

There was a strong effect of NaCl on the leafiness of the plants (Fig. 7), as previously reported (Gale and Poljakoff-Mayber 1970). This effect (expressed as the ratio of the dry weight of the leaf to that of the stem) was more pronounced under conditions of high than of low humidity. Although the difference in slope under the two conditions of humidity was not great, it was statistically significant ($P < 0\cdot01$).

Fig. 6

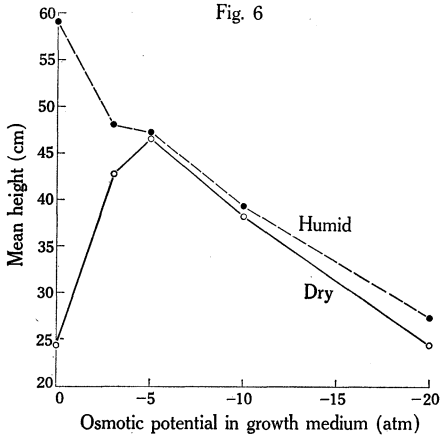


Fig. 7

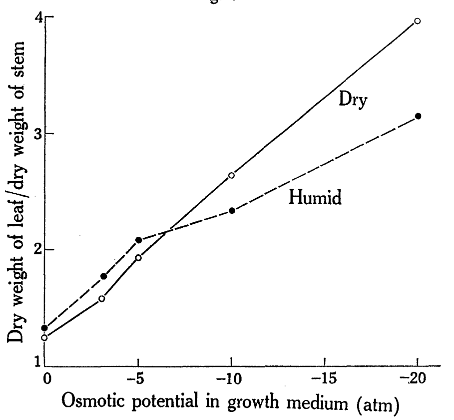


Fig. 6.—Mean height of *A. halimus* plants grown at two different relative humidities in relation to salinity of the growth medium. Mean standard error for dry chamber $\pm 5\cdot 34$, for humid chamber $\pm 5\cdot 49$.

Fig. 7.—Effect of salinity on leafiness of *A. halimus* plants grown at two different relative humidities.

IV. Discussion

Sodium chloride has often been shown to increase the growth of halophytes such as *Atriplex* spp. (Ashby and Beadle 1957; Brownell and Jackman 1966; Blumenthal-Goldschmidt and Poljakoff-Mayber 1968; Greenway 1968; Jennings 1968). The data presented above show that the beneficial effect of NaCl on growth of *A. halimus* is mainly in the alleviation of the adverse effect of moisture stress conditions, such as are brought about by low atmospheric humidity (Figs. 1–4). Only a relatively small concentration of salt (equivalent to an osmotic potential of —5 atm) was required in order to produce this increased tolerance. Higher concentrations of salt reduced plant growth. However, under conditions of high humidity even the lowest concentrations of salt reduced plant growth.

The response of *Atriplex* spp. to low salinity differs from that of most of the few glycophytes whose climate–salinity interactions have been studied. In glycophytes, conditions of high evaporative demand have often, but not always, increased the effect of salinity on growth (Magistad *et al.* 1943; Gale, Kohl, and Hagan 1967).

The fact that NaCl was not beneficial to growth under conditions of high air humidity does not exclude the possibility that microquantities of NaCl are essential for the plant's growth, as found by Brownell (1965). Microquantities of NaCl were certainly present as impurities, even in the basic Knop solution.

The present findings may provide at least a partial explanation for the rarity of the appearance of *A. halimus* and many other halophytic plants in non-saline areas in the Mediterranean region. It is possible that in the absence of salt, such plants are unable to survive the lengthy summer dry periods which are frequently more severe than the conditions which prevailed in the low humidity conditions of this experiment.

V. Acknowledgments

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