Iran Agricultural Research 10:103-114 (1991)

EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY ON THE RESPONSE OF *PHASEOLUS VULGARIS* TO SALINITY

S. HAJRASULIHA, M. NASIRI-MAHALLATI, G.H. SARMADNIA AND D.K. CASSEL[1]
College of Agriculture, Isfahan University of Technology, Isfahan, Iran and Department of Soil Science, North Carolina State University, Raleigh, NC 27695-7619, U.S.A.
(Received: May 12, 1990)

ABSTRACT

Soil salinity adversely affects plant growth in many arid and semi-arid regions, but the magnitude of the response to salinity varies with environmental conditions. This study evaluated the effects of temperature and relative humidity (RH) on plant response to salinity. Red kidney bean (*Phaseolus vulgaris* L. cv. "Naz") at the 2-leaf stage was transplanted into triplicate containers of (1) a basal nutrient solution and (2) the same nutrient solution but salinized with 80 M m^{-3} NaCl. The plants were grown under four environmental conditions: (1) cool-dry, temperature at 18°C and RH at 25%, (2) temperate-dry, temperature at 25°C and RH at 25%, (3) temperate-humid, temperature at 25°C and RH at 85% and (4) hot-dry, temperature at 35°C and RH at 25%. Environmental conditions affected xylem water potential, leaf area, total plant weight and shoot: root ratio. The maximal reduction in xylem water potential for the saline-treated plants was 0.3 MPa for temperate-humid and > 0.8 MPa for all other environmental conditions. Saline-treated plants in the hot-dry environment died 4 wk after transplanting. Leaf area for the saline-treated plants was reduced 4, 64, 67, and 100% below the control plants for the temperate-humid, cool-dry, temperate-dry, and hot-dry environments, respectively. Reductions in total dry weight of plants and the shoot: root ratio followed the same patterns as leaf area. Total weight of saline-treated plants at 6 wk was reduced by 4% for the temperate-humid, 46% for the cool-dry and 43% for temperate-dry conditions.

---

1. *Professor of Soil Science, Former Graduate Student and Assistant Professor of Agronomy and Professor of Soil Science, respectively.*

تحقیقات کشاورزی ایران
۱۰:۱۰۳-۱۱٤ (۱۳۷۰)

اثر درجه حرارت و رطوبت نسبی هوا بر رشد گیاه در شرایط شور

شاپور حاج رسولیها، مهدی نصیری محلاتی، غلامحسین سرمدنیا و دی. ك. کسل
بترتیب استاد خاکشناسی، دانشجوی سابق کارشناسی ارشد زراعت، استادیار زراعت دانشکده کشاورزی دانشگاه صنعتی اصفهان و استاد خاکشناسی دانشگاه ایالتی کارولینای شمالی.

چکیده

اثر منفی شوری بر رشد گیاه در بسیاری از مناطق خشک و نیمه خشک به ثبوت رسیده است. اما شدت مسئله با شرایط اقلیمی در ارتباط است. در این بررسی اثر درجه حرارت محیط ورطوبت نسبی هوا در ارتباط با اثر شوری بر گیاه لوبیا مورد مطالعه قرار گرفت. نهالهای جوان در مرحله دو برگی به محلولهای غذائی جانسون (شاهد) و محلول غذائی جانسون شور شده با ۸۰ مول کلرورسدیم بر متر مکعب در اطاقکهای کشت کنترل شده انتقال یافتند. چهار تیمار اقلیمی بشرح ذیل:

۱ - اقلیم سرد و خشک (دمای ۱۸ درجه سانتی گراد و رطوبت نسبی ۲۵ درصد)
۲ - اقلیم معتدل و خشک (دمای ۲۵ درجه سانتی گراد و رطوبت نسبی ۲۵ درصد)
۳ - اقلیم معتدل و مرطوب (دمای ۲۵ درجه سانتی گراد و رطوبت نسبی ۸۵ درصد)
٤ - اقلیم گرم و خشک (دمای ۳۵ درجه سانتی گراد ورطوبت نسبی ۲۵ درصد)

انتخاب و هر تیمار در سه تکرار انجام شد.

نتیجهٔ بررسی نشان داد که در شرایط اقلیمی متفاوت پتانسیل آب در آوندهای چوبی برگ، سطح برگ، وزن کل گیاه و نسبت ساقه به ریشه در تیمارهای مختلف تفاوت کلی داشته است. حداکثر کاهش پتانسیل آب در آوندهای چوبی برگ گیاهان کاشته شده در شرایط شور، ۰/۳ مگاپاسکال برای اقلیم معتدل و مرطوب و بالاتر از ۰/۸ مگاپاسکال برای اقلیمهای دیگر بود. چهار هفته پس از انتقال نهالهای جوان به محلولهای غذائی شور شده در شرایط اقلیمی گرم و خشک این گیاهان تماماً از بین رفتند. بطور کلی کاهش سطح برگ گیاهان کاشته شده در محلولهای شور شده (در مقایسه با شاهد) برای اقلیمهای معتدل ومرطوب، خنک و خشک، معتدل و خشک، و گرم و خشک به ترتیب ٤، ٦٤، ٦٧ و ۱۰۰ درصد بود. در این بررسی کاهش وزن خشک کل گیاه و نسبت ساقه به ریشه از روندی مشابه روند کاهش سطح برگ پیروی کرد و بطور کلی ٦ هفته بعد از کاشت، کاهش وزن خشک گیاهان کاشته شده در محلولهای شور شده ٤ درصد برای اقلیم معتدل و مرطوب، ٤٦ درصد برای اقلیم خنک و خشک و ٤۳ درصد برای اقلیم معتدل و خشک بوده است.

INTRODUCTION

Salinity of soil and irrigation water can adversely affect plant growth and crop production both by decreasing the osmotic potential of soil water and by increasing accumulation of certain ions within plant tissues to toxic levels (1,2,9). The reduction in osmotic potential of soil water decreases the ability of plant roots to absorb water. If osmotic potential is reduced to levels that inhibits water uptake by roots, the plants will undergo water stress unless transpiration is also restricted to an equivalent extent. Excessive accumulation of ions in plant tissues, particularly in leaves, in response to the transpirational process may adversely affect physiological processes within the plant.

Factors that alter these effects of salinity include climate, genotypic tolerance of plants to salinity, soil texture, depth to water table, irrigation efficiency, irrigation method, tillage and cultural practices (1). Temperature and relative humidity (RH) of the air are the two additional environmental factors that affect response to salinity. The transpirational demand for water by plants increases as temperature increases and as the vapor pressure of water in air decreases. Because RH is related to the vapor pressure of water at a given temperature, RH is often used as a proxy for vapor pressure measurements. Hence the transpirational demand for water increases as RH decreases. Hoffman and Rawlins (4,5), in a study on the effect of RH to salinity at a given temperature, found that tolerance of beans to soil salinity markedly increased at higher RH's. They also reported that high RH (90%) significantly increased the salinity level at which the yield was reduced to 50% of the non-saline yield for onion (*Allium cepa* L.) and radish (*Raphanus sativus* L.), but did not affect this level for beet (*Beta vulgaris* L.). On the other hand, cotton (*Gossypium hirsutum* L.) was only slightly affected by RH (6). In a greenhouse study, dry weight of bean plants grown in nutrient solution salinized with 80 mol m^{-3} NaCl was lower under long, hot and sunny days of summer than under shorter, cooler and cloudy days of fall and winter (3).

Few data address the influence of interacton between RH and temperature on crop response to salinity. The purpose of this study was to evaluate the effect of several combinations of temperature and RH on response of bean plants growing in saline and non-saline nutrient solutions.

MATERIALS AND METHODS

Red kidney beans that had been germinated in washed sand, were transplanted to the nutrient solutions at the 2-leaf stage. All nutrient solutions were prepared in 0.013 m^3 (35 by 25 by 15 cm) plastic containers. Macronutrient concentrations for plants grown in the control solution (non-saline) were one-half those of the solution used by Johnson *et al.* (8). Micronutrients were added as recommended, except the molybdenum concentration which was twice the concentration used by the above investigators. Compositions of the control solution for macronutrients were NO_3^-=7, $H_2PO_4^-$=1, NH_4^+=1, Ca^{2+}=2, Mg^{2+}=0.5, K^+=3 and SO_4^{2-}=0.5 M m^{-3}. Micronutrient concentrations for Cl, B, Mn, Zn, Cu, Mo and Fe were 50, 25, 5, 2, 0.5, 0.2 and 4m M m^{-3}, respectively. The saline solutions were prepared by adding NaCl to the control solution to obtain a final NaCl concentration of 80 M m^{-3}. The NaCl was added in three parts, with one third added prior to transplanting the beans, one third added two days after transplanting and the final third added two days later. The containers were fitted with plywood covers containing 42 holes. A thin, soft piece of sponge was wrapped around the stem of each seedling, and seedlings were placed in 40 of the holes. The remaining two holes were used for routing air tubing and adding water and salt solutions. Distilled water was added daily to compensate for transpiration losses. In order to maintain the desired concentrations of nutrients and NaCl, the experimental solutions were changed weekly.

The experiments were conducted under four controlled environments within a Hareous Growth Chamber, Model 1350[2]. The environmental conditions were: (1) cool-dry, temperature of 18°C and RH at 25%, (2) temperate-dry, temperature of 25°C and RH at 25% (3) temperate-humid, temperature of 25°C and RH at 85% and (4) hot-dry, temperature of 35°C and RH at 25%. Temperature and RH were continuously monitored with a recording hygrometer located at the level of the plants. All environmental conditions at both salinity levels were replicated three times. Temperature was maintained within ±1°C and RH within ±5% of the values mentioned above. Photosynthetic photon flux density during a 13-h light period was about 350 μM m^{-2} s^{-1} from a combination of fluorescent and incandescent lamps.

Plant material was collected from all treatments at transplanting time and weekly thenafter for 6 wk after complete salinization of the saline solution. The number of plants harvested for the 1st, 2nd, 3rd, 4th, 5th and 6th harvests were 18, 9, 5, 4, 2 and 2, respectively. Immediately after each harvest, stem height and root length were measured with a meterstick, xylem water potential of the portion of the stem containing three of the most recent mature leaves was determined by an Ogawa pressure bomb apparatus and total leaf area of one randomly selected plant from each replicate was determined from the outline of each leaf traced onto graph paper with 1-mm grids.

Each plant was separated into shoots and roots, rinsed with distilled water, blotted between layers of paper towel, and dried at 60°C for 3 days. Dry weights of the roots and shoots were determined.

RESULTS AND DISCUSSION

Xylem water potential was lower for the saline-treated plants than for the control under all four environments (Fig. 1). The reduction was least for the temperate-humid environment. The differences in xylem

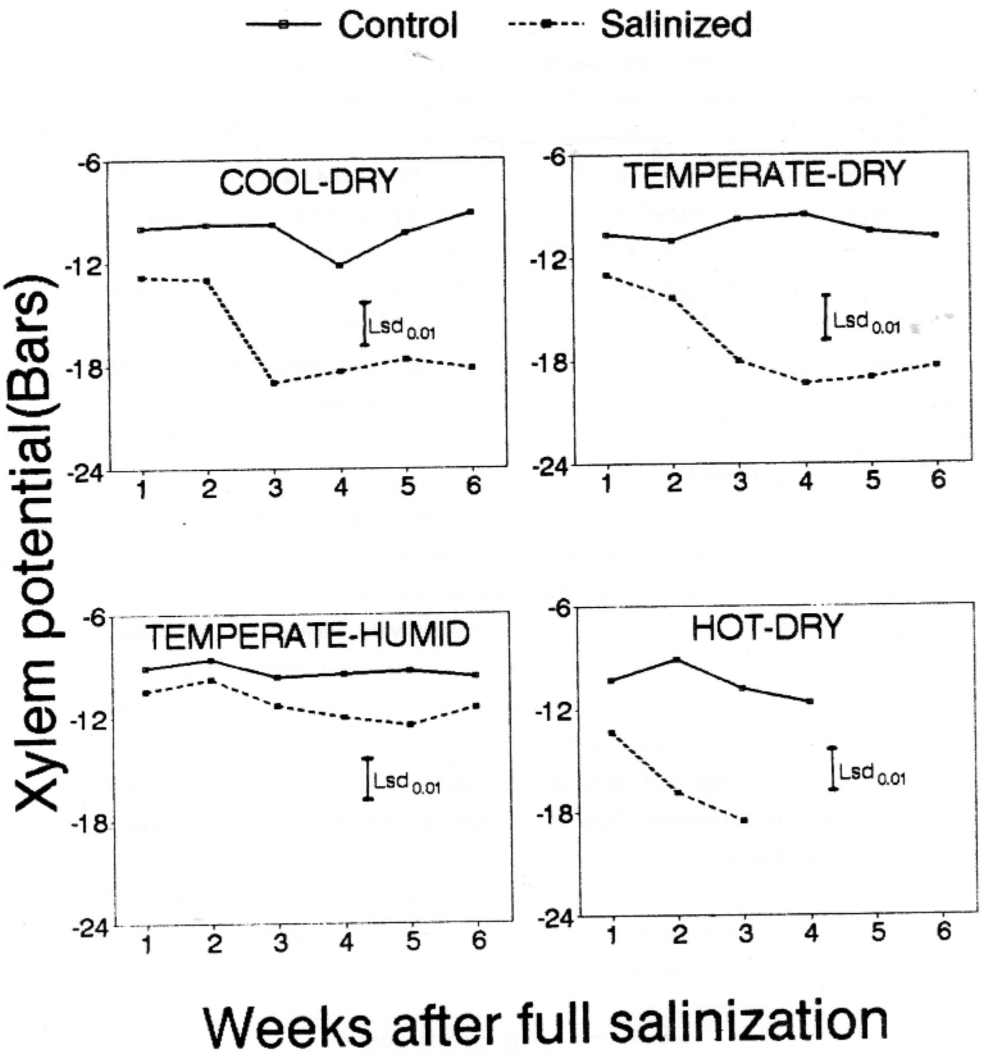

Fig. 1. Effect of climate on xylem water potential of salinized vs control bean plants.

water potential between the salinized and control plants were relatively constant with time for the temperate-humid condition. The differences generally increased for the other treatments and was most pronounced for the temperate-dry environment. Plants in the hot-dry environment died before the end of fourth week after full salinization of the nutrient solution.

The magnitude of the difference in leaf area and total dry weight between plants grown in the control and in saline solutions was significantly related to environment (Figs. 2 and 3). Six weeks after transplanting, the reductions in both leaf area and total dry weight were only 4% for the saline-treated plants grown in the temperate-humid environment. The reductions in leaf area for plants grown under cool-dry and temperate-dry environments were 64% and 67%, respectively, but the reduction in dry weight was smaller for the temperate-dry than for cool-dry environment. Plants grown under saline condition in the hot-dry environment had the greatest reduction in leaf area and dry weight.

The shoot-root ratio (Fig. 4) for plants grown in the salinized solution varied with environment. Plants had the highest shoot-root ratio in the temperate-humid environment. Hoffman *et al.* (6) reported that the shoot-root ratio of cotton plants increased with higher relative humidity. They suggested that this response, which is predicted by some plant growth models, stems from conditions which cause the plant to lose turgor under lower RH and induce roots to grow at the expense of shoots. Low RH should increase transpirational demand and reduced turgor. In this study, the shoot-root ratio was the lowest for the plants under the hot-dry environment, indicating that although root growth was restircted, shoot growth was affected to a greater extent. The shoot-root ratio of saline-treated plants in the cool-dry environment was only slightly higher than that of the temperate-dry environment.

The concomitant reduction in leaf area and leaf water potential in each of the treatments underscores a relationship among xylem water potential, cell turgidity and leaf expansion (7). For example, as long as

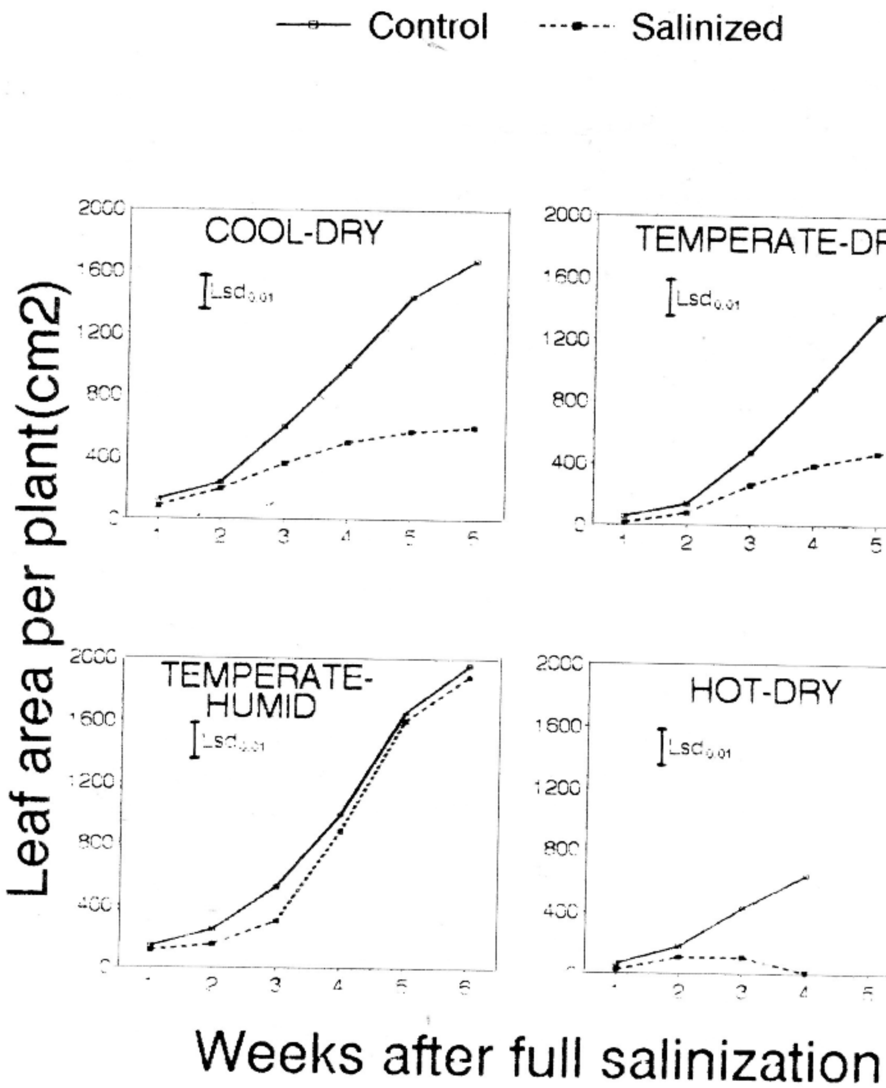

Fig. 2. Effect of climate on leaf area of salinized vs control bean plants.

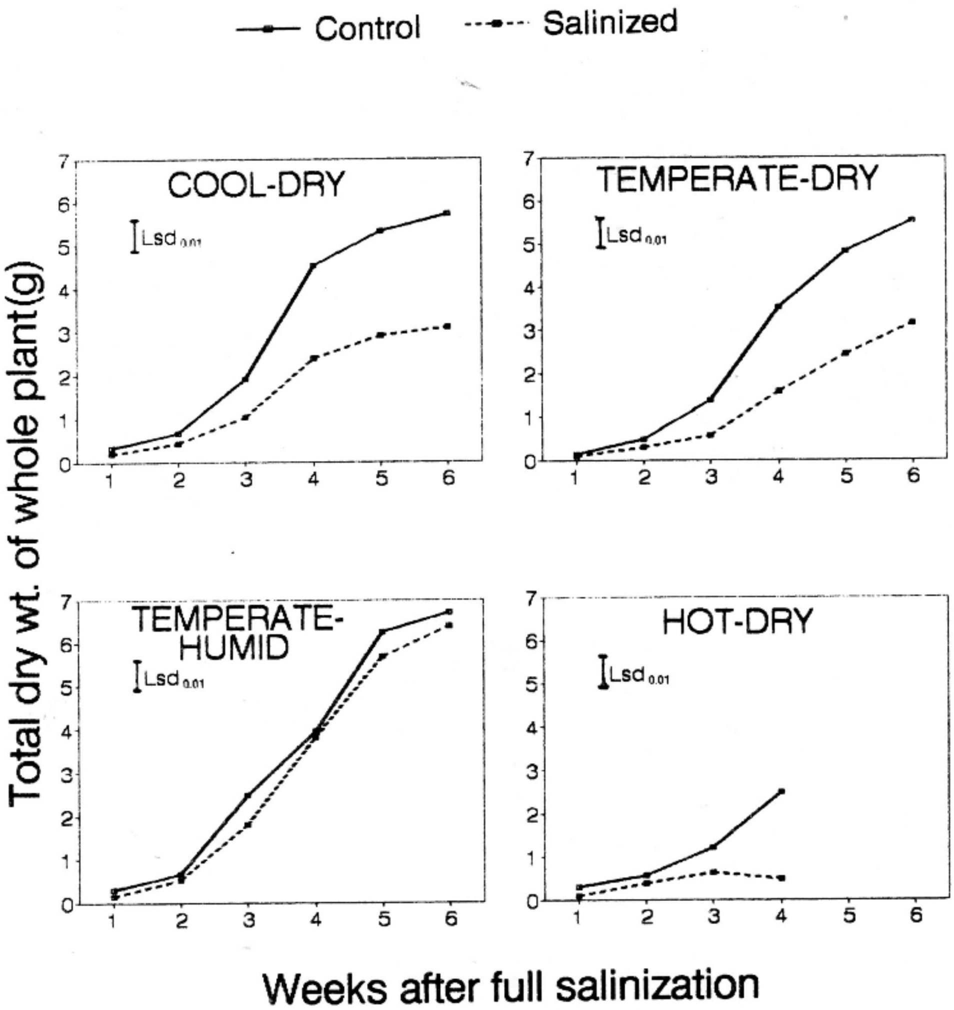

Fig. 3. Effect of climate on dry weight of whole plants of salinized vs control bean plants.

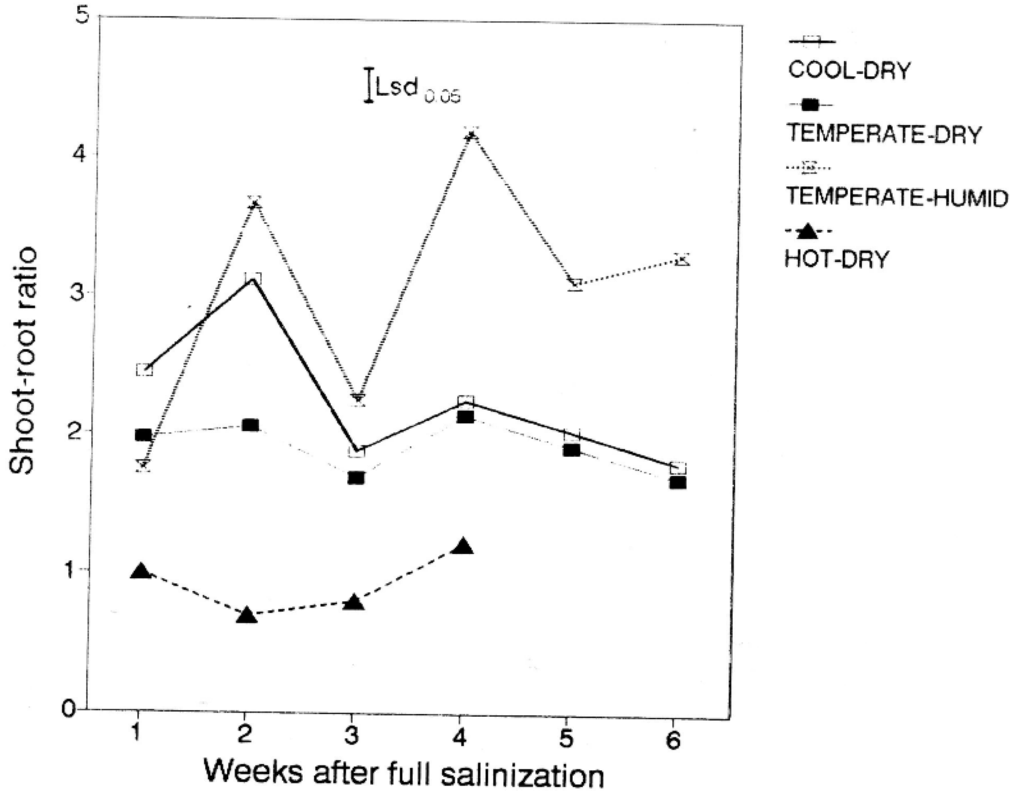

Fig. 4. Shoot-root ratio of bean grown in a saline solution unde various environments.

xylem water potential was greater than -1.20 MPa in this study, cell turgidity apparently was sufficient for leaf expansion and little reduction in leaf area occurred. High RH of the temperate-humid environment would be expected to reduce the transpiration rate. Thus, under the saline condition, transpirational loss of water barely exceeded water uptake, and xylem water potential in the temperate-humid environment barely declined below -1.20 MPa. As a result, leaf area and plant dry weight were little affected by the 80 M m^{-3} NaCl salinity. Because the saline root media for all environments were maintained at the same osmotic potential, differences in growth at the lower RH's would be explained by the effects of vapor pressure deficits, which are a function of temperature and RH, on increasing transpirational demand in excess of reduced water absorption at the higher solution osmotic potentials.

Based upon results of this experiment and the work of others, we conclude that certain factors must be considered when attempting to define the effects of salinity on plant response. Environmental conditions, age of plant and possibly time of exposure to saline conditions are important. One critical parameter is the relationship between root surface and osmotic resistance to water movement and leaf surface, and increased transpirational loss and how this may change with time (e.g., root-shoot ratio). When the plants were small, and root mass relative to leaf area was large, the net result of these interacting factors was that sufficient water could be taken up by the plant to meet transpirational losses. As age of the plant increased and the leaf area increased relative to root growth, the environmental conditions could affect transpiration differently. Various degrees of water stress and growth suppression occurred with the maximum suppression occurring for the hot-dry environment.

Environmental conditions were found to have important effects on plant growth in this salinity study. In the context of predicting the effects of climatic conditions on plant growth, future salinity experiments should be conducted using the temperature and RH conditions that are representative of the geographical area under consideration. Because the effects of salinity on plant response for some plants is dependent on climate, the use of world-wide or country-wide soil salinity or water quality classification systems have limited practical value. Soil salinity and water quality classification systems would be more useful if environmental conditions were also taken into consideration.

LITERATURE CITED

1. Ayers, R.S. and D.W. Westcot. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 (Rev. 1). FAO, Rome.
2. Bernstein, L. 1975. Effects of salinity and sodicity on plant growth. Ann. Rev. Phytopathol. 13:295-312.
3. Hajrasuliha, S. 1968. Accumulation and toxicity of several ions in bean plants in relation to climate. Ph.D. Dissertation. University of California, Davis (Diss. Abstr. 30/04 B, order # 69-16352).
4. Hoffman, G.J. and S.L. Rawlins. 1970. Design and performance of sunlit climate chambers. Trans. Amer. Soc. Agric. Eng. 13:656-660.
5. Hoffman, G.J. and S.L. Rawlins. 1971. Growth and water potential of root crops as influenced by salinity and relative humidity. Agron. J. 63:877-880.
6. Hoffman, G.J., S.L. Rawlins, M.J. Garber and E.M. Gullen. 1971. Water relations and growth of cotton as influenced by salinity and relative humidity. Agron. J. 63:822-826.
7. Hsaio, T.C. 1973. Plant responses to water stress. Ann. Rev. Plant Physiol. 24:519-570.
8. Johnson, C.M., P.R. Stout, T.C. Broyer and A.B. Carton. 1957. Comparative chlorine requirements of different plant species. Plant Soil. 8:337-353.
9. United States Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook 60. U.S. Govt. Print. Office, Washington, D.C., U.S.A.