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THE EFFECT OF THE LEVEL OF SALINITY OF WATER USED FOR IRRIGATION ON THE AMOUNT OF WATER AVAILABLE FOR PLANTS

S. Żakowicz

Faculty of Land and Forest Reclamation, Warsaw Agricultural University
Nowoursynowska 166, 02-766 Warsaw, Poland

A b s t r a c t. The paper presents, against the background of literature of the subject, results of studies, based on several plants, on the changes in the water stress index as a function of soil solution salinity. This allows, already at the design-operational stage, to optimize the calculations of the maximum permissible time intervals between successive irrigations. Relative biomass gains given in the figures as a function of salinity facilitate economical control of irrigation.

The method of studies developed by the author can be also used for other plants to determine the water stress moisture content and the permissible crop yield decrease under the conditions of irrigation with salinated water.

K e y w o r d s: water salinity, irrigation, water available for plants

INTRODUCTION

The progressing intensification of agricultural production and the increasing level of mineral fertilization bring about the problems of the negative effect of salts dissolved in soil water and of decreased availability of water for plants. These problems are aggravated by the high salinity, increasingly an frequently encountered in Poland, of open waters used as a source of water for irrigation. Examples can be found among certain rivers in the region of the Upper Noteć River, where water salinity very often exceeds 4 mS/cm=4EC, which, according to Thorn and Peterson [5], is the limit for water used in irrigation.

The objective of the study presented here was to determine the effect of the level of water salinity on the amount of water available for plants, as expressed by the range within the limits of permissible soil moisture content levels. Authors describing this range up to now provided a fairly satisfactory specification of the maximum levels of soil moisture. Determination of the other limit of the range, i.e., the level of the minimum permissible soil moisture content, is a highly complex matter. It is necessary to consider the energy status of the plant, determining the value of biomass increase [3,6].

Water controls the flow of energy through the plant at three levels. The first of these is the photosynthetic apparatus, the second - labile energy storage by the plant, and the third - the structural level. As it uses up the water available at a certain soil moisture level, water stress condition appears in the plant.

The distribution of energy for crop generation and maintaining the system under the condition of water stress occurrence is strictly unfavourable. This can be illustrated graphically (Fig. 1), after Carlson [2], as a relative decrease in crop yield for a hypothetical cereal plant.

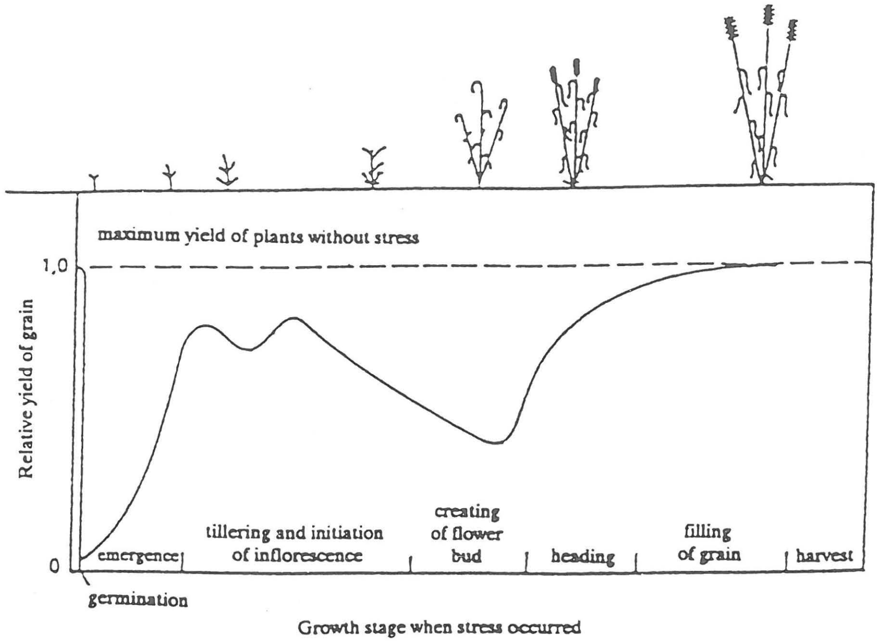

Fig. 1. Relative decrease in crop yield due to the effect of water stress at various stages of cereal plant development.

The level of soil moisture at which plant water stress occurs depends, among other things, on the level of evapotranspiration and on the concentration of the soil solution.

In Poland, with increasing contamination of waters constituting the source of irrigation water, the problem of the effect of salinity on the losses in plant production plays a role which is greater and greater. This results from the fact that salts dissolved in water, even if they are not toxic, have a decreasing effect on the potential of water in the soil solution and thus limit, in spite of the phenomenon of homeostasis, water uptake by the plant roots. Potassium and chloride ions are especially active in the process of homeostasis since they are absorbed very fast and can be accumulated at very high levels of concentration. Therefore, salination with chlorides can often be less harmful than salination with sulphates, assuming that the subject of comparison is isoosmotic concentration and that Cl^- ions do not have a direct toxic effect on the plant.

METHODS

The effect of salinity on the amount of water easily available (WEA) can be expressed by means of the index of water stress (IWS) which represents the ratio of WEA to the amount of water generally available (WGA) according to the formula:

$$IWS = \frac{WEA}{WGA} = \frac{\theta_{FWC} - \theta_{WSP}}{\theta_{FWC} - \theta_{PWP}}$$

where θ_{FWC} - soil moisture at field water capacity (% vol.), θ_{WSP} - soil moisture at water stress point of the plant (% vol.), θ_{PWP} - soil moisture at permanent wilting point (% vol.).

Basing on studies performed for selected plants, the paper presents the results of the relationship between salinity, amount of available water, and increase in biomass.

The studies were conducted for two crop plants, clover and lucerne, and two vegetables - lettuce and beans. The crop plants were collected in three replications, 10 plants at a time, in rings 80 mm in diameter and 150 mm high.

Lettuce and beans were grown under laboratory conditions and planted out into compost soil in pots 170 mm in upper diameter and 130 mm high. The crop plants with the soil in rings were placed over specially made dust filters allowing for any ground water table to be simulated. In the studies an 80 mm ground water table was simulated. Prior to tests, minilysimeters with plants prepared in the manner described above were subjected to several days of optimum growing conditions in order to eliminate the adaptation stress. During that period the plants were irrigated with distilled water. Then the lysimeters in rings and in pots were washed, using a type 335 metering micropump, with salt solutions of strictly controlled concentrations varying for each series of plants from EC = 0 (distilled water) to EC = 24. Samples prepared in this way were placed in plastic bags in order to eliminate uncontrolled water losses. Twice a day, at the same times, the samples were weighed using an automatic laboratory balance, ova-labor type 772.01, with an accuracy of 0.01 g. The condition of the plants, according to a biological scale, was observed at the same time as the determinations of transpiration and soil moisture were made. If water stress appeared, the samples were washed with distilled water and several days were allowed to bring them back to a state of biological equilibrium. Then the experiment was repeated at least three times. Following the completion of the experiment, the absolute dry mass increase and the final salinity of the soil were determined in the particular layers of the root zone. For all the soils used in the experiments, a study was made of their physical properties and mechanical composition, and their retentive characteristics were determined in the form of the pF curves. The salinity of the water used for irrigation in the series was prepared using pure NaCl common salt, MICRO 2 garden fertilizer, and a liquid fertilizing nutrient which was a mixture of the basic NPK components. Measurements of salinity were taken using type OK-102/1 conductometer according to FAO standards.

RESULTS

The retentive characteristics of the compost soil under lettuce and beans is presented in Fig. 2; that of strong loamy sand under lucerne, and of light loam under clover are presented in Fig. 3. Changes in the amount of water easily available (WEA), as expressed by the IWS index, are clearly related to the potential value of plant transpiration. Therefore, in order to eliminate the effect of this factor, throughout the experiment the value of potential transpiration was kept at a level of about 3 mm/day. The results obtained for changes in the value of the water stress index (IWS) with relation to the level of salinity of

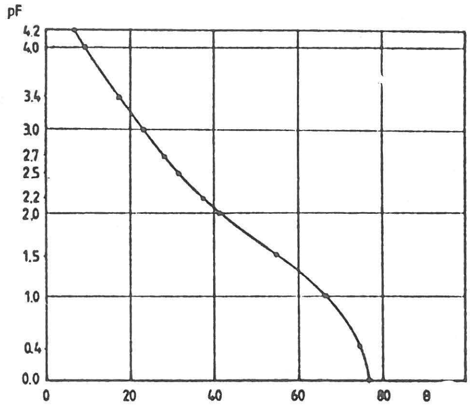

Fig. 2. Retentive characteristics of compost soil under lettuce and beans.

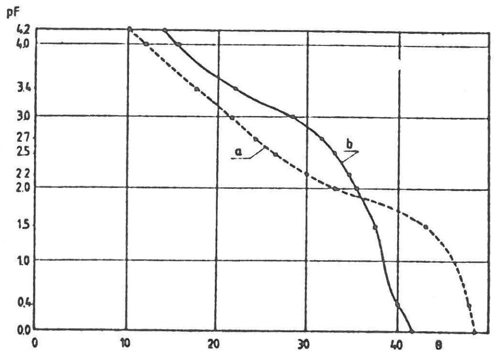

Fig. 3. Retentive characterisitcs of: a - strong loamy sand under lucerne, b - light loam under clover.

water used for irrigation (ECw) for lettuce and beans are presented in Fig. 4, and the results of mean relative biomass increases (*q*) for these plants, as a function of salinity, are presented in Fig. 5.

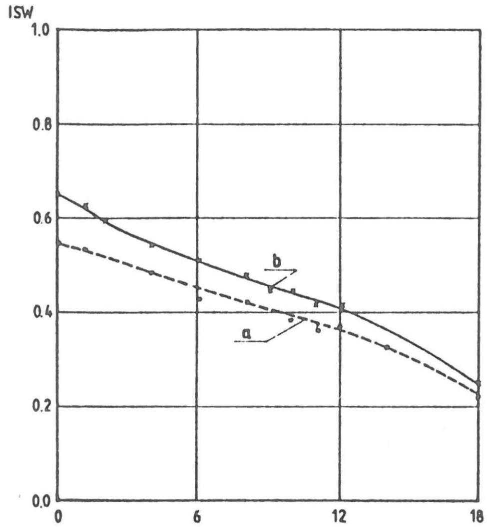

Fig. 4. Changes in the water stress index (IWS) with relation to the level of salinity of water used for irrigation (ECw) for: a - lettuce, b - beans.

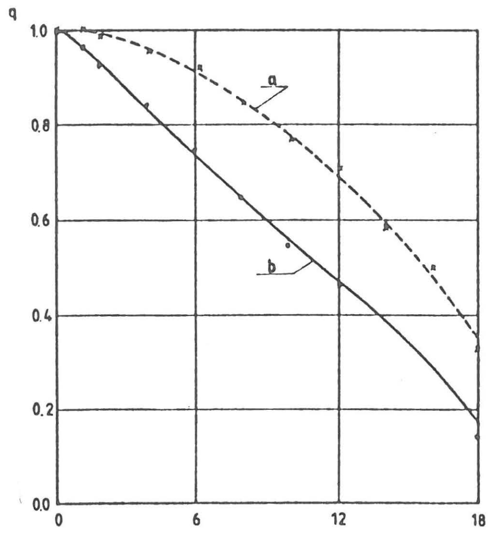

Fig. 5. Relationship between the relative biomass gain (q) and the salinity of water used for irrigation (ECw) for: a - lettuce, b - beans.

Changes in the water stress index (IWS) and in the relative increase in biomass (*q*) as a function of salinity (ECw) for clover are presented in Fig. 6, and for lucerne - in Fig. 7. The results obtained indicate that the amount of water easily available decreases with increasing salinity of water used for irrigation, this function being related also to the type of plant.

Plant response as expressed by the relative increase in biomass with relation to the level of salinity is specific for each of the plants tested. This probably results from the resistance of

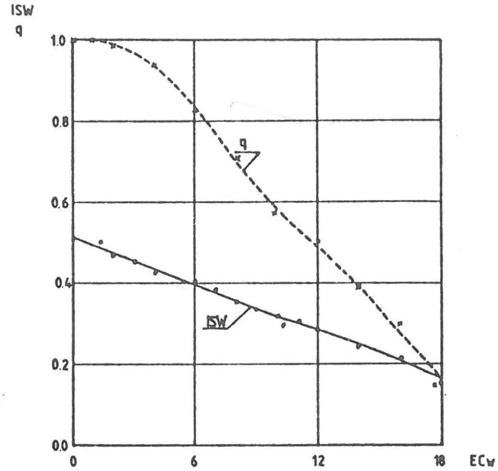

Fig. 6. Changes in the water stress index (IWS) and the relative biomass gain (q) as a function of salinity of water used for irrigation (ECw) for clover.

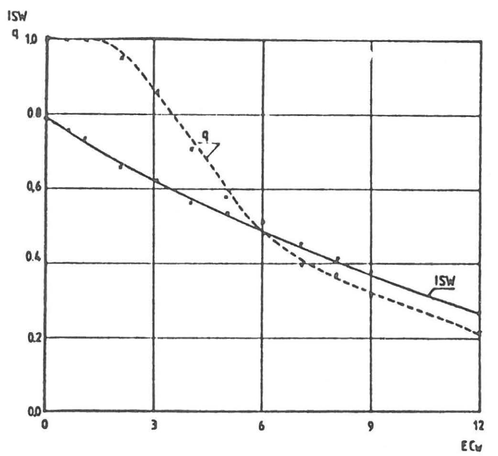

Fig. 7. Changes in the water stress index (IWS) and the relative biomass gain (q) as a function of salinity of water used for irrigation (ECw) for lucerne.

chloroplasts to ionic concentration levels.

Although Marschner and Possingham (after Mengel and Kirkby [4]) showed that a high concentration of Na^+ ions in the soil solution results in an expansion and growth of plant cells in the plants of sugar beet and spinach, despite a detrimental effect on chlorophyll synthesis, in agricultural practice attempts are made to classify plants with respect to their resistance to the salinity of water used for irrigation (ECw) and the permissible salinity of soil in the root zone (ECe). An example of this is the table of plant tolerance to salinity, for particular plant groups with relation to decrease in crop yield, included in the FAO publication by Ayers and Westcot [1976]. Results obtained from experiments indicate that in the case of lower potential transpiration, at a level of 3 mm/day, and a decrease in the IWS index due to the level of salinity of water used for irrigation, the decrease observed in the biomass increase is less than that quoted by Ayers and Westcot in the FAO material. This indicates that under the Polish climatic conditions rational control of irrigation with salinated water will allow for higher crop yields to be obtained.

CONCLUSIONS

1. Studies on the amount of water available for plants under the conditions of using salinated water for irrigation allow the conclusion that the amount of water easily available decrease dynamically with increasing levels of salinity.

2. There is a clear relationship between the level of salinity of water used for irrigation and the increase in plant biomass. This appears to be an individual feature of plant species. Among the plants tested, beans was the plant most sensitive to the salinity of water used for irrigation.

3. The results obtained indicate that in the case of transpiration at the level of 3 mm/day and a decrease in the value of the IWS index due to the level of salinity of water used for irrigation (ECw) the decrease in the biomass gain is lower than that quoted in the FAO material by Ayers and Westcot [1].

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