AMERICAN
JOURNAL OF BOTANY

VOL. VIII FEBRUARY, 1921 No. 2

INFLUENCE OF TEMPERATURE ON THE RELATIONS BETWEEN NUTRIENT SALT PROPORTIONS AND THE EARLY GROWTH OF WHEAT

W. F. GERICKE

(Received for publication August 5, 1920)

Russell[1] has stated that "Potash-starved plants are the first to suffer in a bad season or to succumb to disease. The Broadbalk wheat plots receiving potassium salts give conspicuously better results than others whenever the year is unfavorable to plant growth. . . . The badness of the season may be connected with high rainfall and correspondingly low temperatures." This statement emphasizes the fact that climatic conditions may exert no inconsiderable influence upon what may be regarded as the best set of proportions of the nutrient salts in the medium in which plants are rooted. What is a good set of salt proportions with one set of climatic conditions may not be a good one with another climatic complex, etc. Results obtained from an experimental study carried out in 1918–19, in the Laboratory of Plant Physiology of the Johns Hopkins University,[2] seem to bear on this general and important proposition, and some of these results are here reported in a preliminary way.

The investigation was planned to bring out the relations between maintained temperature, on the one hand, and the physiological properties of various nutrient solutions, on the other. The germination and early seedling phases in the development of "Marquis" wheat were studied, the grains being supported on paraffined mosquito netting held just beneath the surface of the solution, which was renewed every 24 hours. The containers were glass tumblers having a capacity of 300 cc. Twenty-five seeds were used for each test, and all tests have been repeated at least once. Seven

[1] Russell, E. J. Soil conditions and plant growth. 2d ed. 1915 (pp. 42, 43). 3d ed. 1917 (pp. 43, 44).

[2] This study was carried on as part of a cooperation between the committee on salt requirements of representative agricultural plants, of the Division of Biology and Agriculture of the National Research Council, and the laboratory named above. It was partially financed from the war-emergency funds of the Council. The writer wishes to express his appreciation of much kindly interest and advice received from Prof. B. E. Livingston.

[The Journal for January (8: 1–58) was issued March 9, 1921.]

different maintained temperatures were employed, and light was excluded from the experiment chambers. The nutrient solutions used were the 126 3-salt solutions described by the committee on salt requirements,[3] and each solution was tested for every one of the seven different temperatures. These 3-salt solutions are of 6 types;[4] according to the salts employed, and 21 different solutions were tested for each type, each of these having its own peculiar set of salt proportions. The familiar triangular diagram was used to represent the difference in salt proportions. The salts employed were the nine possible combinations of the following six chemical units; K, Ca, Mg, NO_3, H_2PO_4, and SO_4. No iron was added to any of these solutions. As to total concentration, the solutions were all about alike and very weak, being only one tenth as concentrated as the corresponding 1-atmosphere solutions described in the plan above referred to.

The present paper will be confined to certain points brought out for the two temperatures 28° C. and 17° C. (one about optimum and the other distinctly below the optimum temperature for the early growth phases of wheat). Only those solutions of each of the six types tested will be considered that gave the best growth values, determined by the criteria of total shoot elongation per culture and average elongation per seedling of the cultures, for a period of 110 hours, beginning with the placing of the seeds on the net. The best values obtained for the set of 21 solutions for each of the six types for each of the different temperatures tested were considered the "good" solutions, if their growth values obtained lay within the upper one fourth of the total range of values for the same temperature and the same solution type. For example, if the 21 solutions of the type containing the salts KH_2PO_4, $Ca(NO_3)_2$, and $MgSO_4$, gave a growth value ranging from 1.00 to 1.80 for the average of both the criteria used, tested at a temperature of 28° C., then those solutions whose value lay between 1.60 and 1.80 would be classed as the "good" solutions for the type at that given temperature. The total-shoot-elongation value simply represented the total growth obtained from a solution. The average elongation value per seedling per culture was obtained by dividing the total shoot elongation in centimeters by the number of seedlings the culture contained. The reason these two criteria were employed was to offset any appreciable error that may accrue in the growth value from a failure of some of the seeds to germinate. The following table shows what solutions belong to the "good" class for each type and for each of the two temperatures here dealt with. In the solution designations, which refer to the triangular diagrams, the

[3] Committee on salt requirements of representative agricultural plants, Division of Biology and Agriculture, National Research Council. A plan for cooperative research on the salt requirements of representative agricultural plants. Edited by Burton E. Livingston. 2d ed. Baltimore, 1919.

[4] For an outline of the chemical scheme of these six types, on which the committee's plan was based, see: Livingston, B. E., and Tottingham, W. E. A new three-salt nutrient solution for plant cultures. Amer. Jour. Bot. 5: 337–346. 1918.

number following the letter "R" indicates the number of eighths (of the total molecular concentration) that are due to the potassium salt, the number following the letter "S" indicates the number of eighths due to the calcium salt, and the difference between 8 and the sum of these two numbers is the number of eighths due to the magnesium salt.

TABLE 1. *Good nutrient solutions of the six different salt types tested at two different maintained temperatures*

Temperature	Type I KH_2PO_4, $Ca(NO_3)_2$, $MgSO_4$	Type II K_2SO_4, $Ca(NO_3)_2$, $Mg(H_2PO_4)_2$	Type III KNO_3, $Ca(H_2PO_4)_2$, $MgSO_4$	Type IV K_2SO_4, $Ca(H_2PO_4)_2$, $Mg(NO_3)_2$	Type V KNO_3, $CaSO_4$, $Mg(H_2PO_4)_2$	Type VI KH_2PO_4, $CaSO_4$, $Mg(NO_3)_2$
28° C.	R1S3 R1S4 R3S4 R4S1 R4S2	R1S3 R1S4 R2S1	R1S3 R1S4 R1S6 R2S1 R2S2	R1S4 R1S5	R1S3 R1S5 R2S1	R1S3 R1S4 R3S4 R4S2 R4S3 R5S1 R5S2
17° C.	R3S2 R3S3 R4S1 R4S3 R5S1	R3S3 R5S1 R5S2	R2S5 R3S4 R4S1 R5S1	R4S1 R5S1 R5S2	R5S1 R5S2	R4S3 R5S1 R5S2

It is seen at once that the "good" group of each type of solution comprises from two to seven different solutions. It appears that there is generally a marked difference between the sets of salt proportions that proved good with the higher temperature, on the one hand, and those that proved good with the lower ones, on the other. For types II, III, IV, and V, low partial concentrations (1 or 2 eighths) of the potassium salt characterize the group for 28°, while high partial concentrations (2–5 eighths) of this salt characterize the group for 17°. There is a suggestion of this same generalization for types I and VI also. For type I the potassium salt has partial concentrations of from 1 to 4 units for the higher temperature, while the corresponding values for the lower temperature lie between 3 and 5. Similarly, for type VI, the potassium-salt values lie between 1 and 5 for the higher temperature and between 4 and 5 for the lower. It is thus indicated that the proportion of the potassium salt should be high for the low temperature, and low for the high temperature, if the solution is to give good growth values. Since three different potassium salts are involved, it appears that this suggested generalization really applies to the partial concentration of potassium itself rather than to that of the salt that supplies this element.

It is to be noted that the two types (I and VI) for which this statement concerning potassium is least definitely applicable, are both characterized by the fact that the potassium salt is the phosphate. But, for three other types (II, IV, and V), high partial concentrations of H_2PO_4 characterize the good solutions for the higher temperature, while lower concentrations of H_2PO_4 mark the good ones for the lower temperature. It is thus suggested that the H_2PO_4-relation (to growth and to temperature) may be the reverse of the K-relation. Potassium phosphate being employed in types I and VI as the only source of K as well as of H_2PO_4, a sort of antagonistic effect might be expected in these cases, and this expectation seems to have been realized. A study of the two groups of good solutions for each of these two types suggests an inversion of the H_2PO_4-relation (*low* partial concentrations for the *higher* temperature, etc.) and a masking of the K-relation, as has been mentioned. Type III furnishes no evidence in this regard.

It appears from these results that temperature is of prime moment in determining the mineral requirements for good germination and initial growth in this wheat, at least within the general limits of these experimental tests, and it seems safe to suppose that other climatic conditions may not be without influence. It is suggested that some of the unexplained discrepancies that are commonly encountered in comparative studies on plant salt requirements and on the application of fertilizers to agricultural soils, may be related to climatic influences. It seems clear that all influential conditions should be quantitatively considered in such studies.