ON SIMILARITY IN THE BEHAVIOR OF SODIUM AND POTASSIUM

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(WITH FOUR FIGURES)

It is commonly mentioned by textbooks, as worthy of remark, that sodium and potassium agree closely in chemical behavior, but differ fundamentally in their effects upon plants.

This general statement is founded on the study of the nutritive functions of sodium and potassium. There is no a-priori reason for supposing it to be true in the field of toxic or of protective action. As this is a point of general interest I have made some experiments with reference to it.

Two extensive series of experiments, one on sodium, the other on potassium, were carried on simultaneously. They were found to show a remarkable degree of agreement in the action of these two substances.

The experiments relating to sodium have already been described,[1] while those on potassium have been withheld from publication, pending thecompletion of further observations on the mutually antagonistic action of sodium and potassium.

Most of the experiments were made with a variety of wheat known as Early Genesee. The technique has been fully described in a previous paper.[2]

TOXIC ACTION

In the earliest studies which I made on balanced solutions, I was struck with the fact that Na and K agree closely in their toxic effect on plants.

These results I have found to hold in an extensive series of experiments, including algae, liverworts, Equisetum, and some thirteen genera of flowering plants. While there are doubtless some exceptions, the general rule seems to be that Na and K are closely similar in their toxic action.

[1] Jahrb. Wiss. Bot. 46:121. 1908.

[2] Bot. Gazette 44:266. 1907.

The most careful quantitative studies which we possess on this point are those of Miss MAGOWAN.[3] These studies show that the toxicity curves for K and Na are practically identical, while the corresponding curve for Mg shows a much higher, and that for Ca a much lower degree of toxicity.

ANTAGONISTIC ACTION[4]

The antagonistic action of monovalent kations on each other has especial interest in view of the experiments of LOEB[5] on Fundulus, which offer a certain analogy with those of LINDER and PICTON.[6] In these experiments monovalent kations antagonized bivalent but did not antagonize other monovalent kations.

The curve of antagonism between NaCl and KCl shows two maxima. The location of these maxima, however, is not constant, but varies somewhat in different series of experiments. Table I and *fig. 1* show the average result of four series. The antagonism

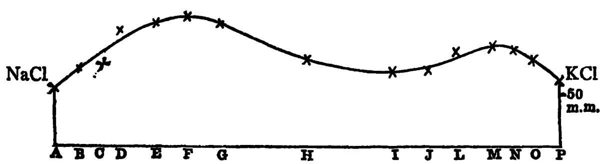

FIG. 1.—Antagonism curve, NaCl vs. KCl. The ordinates represent millimeters of growth of the roots of wheat. The ordinate at A represents the growth in pure NaCl, that at P the growth in pure KCl. The other ordinates represent growth in mixtures of NaCl and KCl, the proportions of which are found opposite the corresponding letters in table I: thus the ordinate at H represents growth in a mixture of 100^{cc} NaCl + 100^{cc} KCl.

is comparatively slight. I have also noticed antagonism between Na and K in liverworts.

Table II and *fig. 2* show that both Na and K antagonize NH_4, and that their effects are very similar.

[3] *Ibid.*, 45:45. 1908.

[4] Cf. facts and literature given by KEARNEY and CAMERON, Rept. No. 71, U. S. Dept. Agr. 1902; and by BENECKE, Ber. Deutsch. Bot. Gesells. 25:322. 1907.

[5] American Journal of Physiology 3:327. 1900.

[6] Cf. HOBER UND GORDON, Hofmeister's Beitr. Chem. Physiol. und Pathol. 5:432. 1904.

TABLE I

WHEAT (GROWTH DURING 30 DAYS). ALL QUANTITIES GIVEN ARE CUBIC CENTIMETERS OF 0.12 *m* SOLUTIONS

Culture solution	Corresponding point on curve (*fig. 1*)	Aggregate length of roots per plant in mm
NaCl..........	A	55
100 NaCl, 5 KCl	B	75
100 NaCl, 10 KCl	C	80
100 NaCl, 15 KCl	D	115
100 NaCl, 25 KCl	E	120
100 NaCl, 35 KCl	F	130
100 NaCl, 50 KCl	G	121
100 NaCl, 100 KCl	H	85
50 NaCl, 100 KCl	I	75
35 NaCl, 100 KCl	J	80
25 NaCl, 100 KCl	L	95
15 NaCl, 100 KCl	M	100
10 NaCl, 100 KCl	N	95
5 NaCl, 100 KCl	O	85
KCl..........	P	65

Distilled water, 725^{mm}

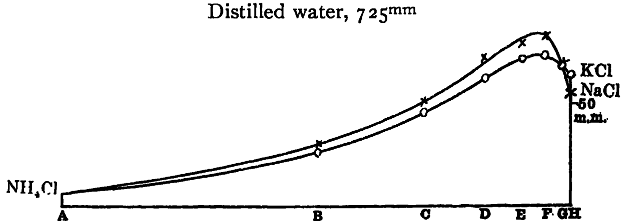

FIG. 2.—Antagonism curve, NH_4Cl vs. NaCl (upper curve -x-x-x-) and NH_4Cl vs. KCl (lower curve -o-o-o-). Each ordinate represents the amount of growth of wheat roots in a solution whose composition is given opposite the corresponding letter in table II.

TABLE II

WHEAT (GROWTH DURING 30 DAYS). ALL QUANTITIES GIVEN ARE CUBIC CENTIMETERS OF 0.12 *m* SOLUTIONS

Culture solution	Aggregate length of roots per plant in mm	Corresponding point on curve (*fig. 2*)	Culture solution	Aggregate length of roots per plant in mm
NHC_4l	6.2	A	NH_4Cl	6.2
100 NH_4Cl, 100 NaCl	31	B	100 NH_4Cl, 100 KCl	27.5
40 NH_4Cl, 100 NaCl	52	C	40 NH_4Cl, 100 KCl	46
20 NH_4Cl, 100 NaCl	74	D	20 NH_4Cl, 100 KCl	62
10 NH_4Cl, 100 NaCl	80	E	10 NH_4Cl, 100 KCl	72.5
5 NH_4Cl, 100 NaCl	85	F	5 NH_4Cl, 100 KCl	75
1 NH_4Cl, 100 NaCl	67	G	1 NH_4Cl, 100 KCl	68
NaCl	55	H	KCl	66

Distilled water, 725 mm

Experiments with magnesium show that it is antagonized in about the same degree by both Na and K (table III and *fig. 3*).

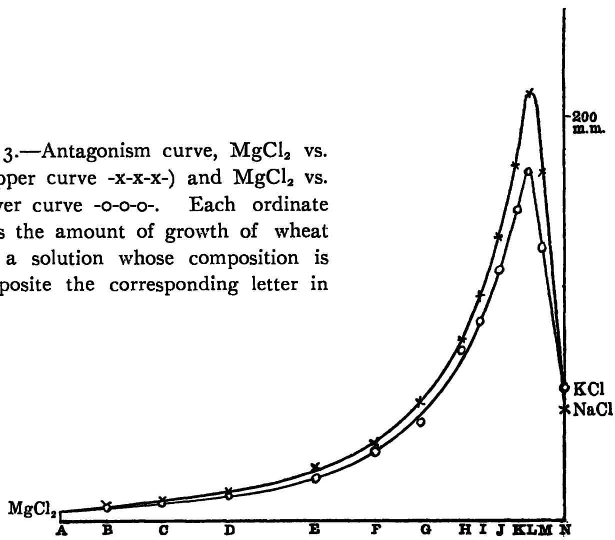

FIG. 3.—Antagonism curve, $MgCl_2$ vs. NaCl (upper curve -x-x-x-) and $MgCl_2$ vs. KCl (lower curve -o-o-o-. Each ordinate represents the amount of growth of wheat roots in a solution whose composition is given opposite the corresponding letter in table III.

TABLE III

WHEAT (GROWTH DURING 30 DAYS). ALL QUANTITIES GIVEN ARE CUBIC CENTIMETERS OF 0.12 *m* SOLUTIONS

Culture solution	Aggregate length of roots per plant in mm	Corresponding point on curve (*fig. 3*)	Culture solution	Aggregate length of roots per plant in mm
$MgCl_2$	5	A	$MgCl_2$	5
100 $MgCl_2$, 10 NaCl	7.5	B	100 $MgCl_2$, 10 KCl	7.5
100 $MgCl_2$, 25 NaCl	10	C	100 $MgCl_2$, 25 KCl	8.7
100 $MgCl_2$, 50 NaCl	13.7	D	100 $MgCl_2$, 50 KCl	12.5
100 $MgCl_2$, 100 NaCl	25	E	100 $MgCl_2$, 100 KCl	21
60 $MgCl_2$, 100 NaCl	37.5	F	60 $MgCl_2$, 100 KCl	34
40 $MgCl_2$, 100 NaCl	50.7	G	40 $MgCl_2$, 100 KCl	48.7
25 $MgCl_2$, 100 NaCl	90	H	25 $MgCl_2$, 100 KCl	84
20 $MgCl_2$, 100 NaCl	112	I	20 $MgCl_2$, 100 KCl	99
15 $MgCl_2$, 100 NaCl	140	J	15 $MgCl_2$, 100 KCl	125
10 $MgCl_2$, 100 NaCl	176	K	10 $MgCl_2$, 100 KCl	152
7.5 $MgCl_2$, 100 NaCl	210	L	7.5 $MgCl_2$, 100 KCl	171
5 $MgCl_2$, 100 NaCl	172	M	5 $MgCl_2$, 100 KCl	135
NaCl	55	N	NaCl	66

Distilled water, 725 mm

In algae I have found that $MgCl_2$ is much more strikingly antagonized by KCl than by NaCl.

The experiments with calcium show a more marked antagonism than any of the other cases. We find that Ca is antagonized to a slightly greater degree by K than by Na (table IV and *fig. 4*).

Similar results were obtained with algae, liverworts, Equisetum, and some fifteen genera of flowering plants.

From the facts here set forth it is clear that in their toxic and protective effects sodium and potassium show great similarity. As this does not seem to be the case in the field of nutritive effects, we

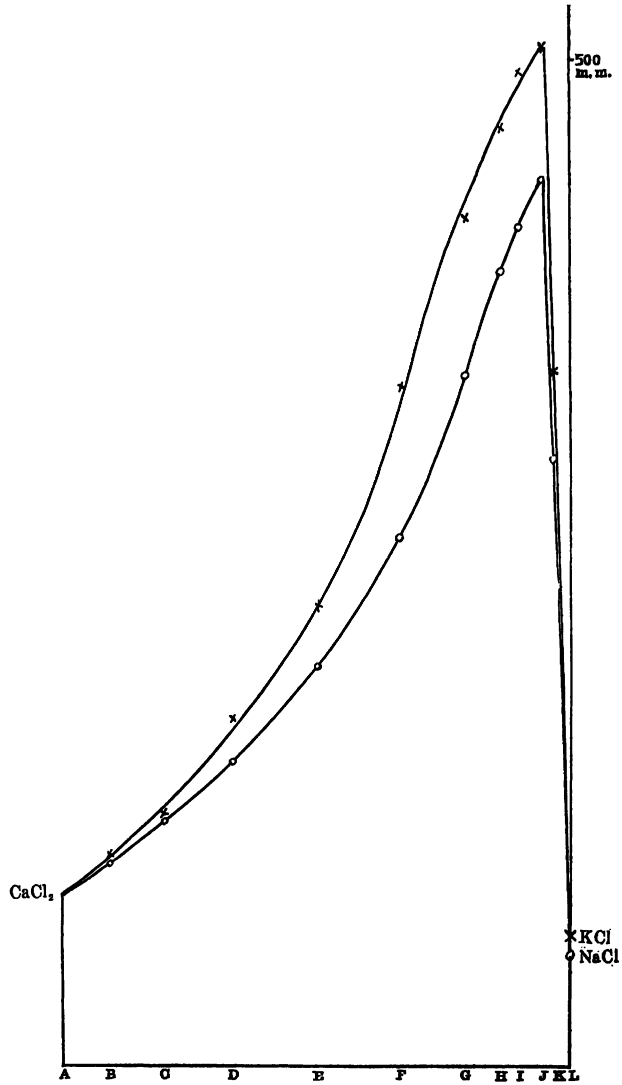

FIG. 4.—Antagonism curve, $CaCl_2$ vs. KCl (upper curve -x-x-x-) and $CaCl_2$ vs. NaCl (lower curve o-o-o). Each ordinate represents the amount of growth of wheat roots in a solution whose composition is given opposite the corresponding letter in table IV

seem to have in this case a means of distinguishing clearly between nutritive and protective action.

TABLE IV

WHEAT (GROWTH DURING 30 DAYS). ALL QUANTITIES GIVEN ARE CUBIC CENTIMETERS OF 0.12 *m* SOLUTIONS

Culture solution	Aggregate length of roots per plant in mm	Corresponding point on curve (*fig. 4*)	Culture solution	Aggregate length of roots per plant in mm
$CaCl_2$	85	A	$CaCl_2$	85
100 $CaCl_2$, 10 NaCl	100	B	100 $CaCl_2$, 10 KCl	105
100 $CaCl_2$, 25 NaCl	117	C	100 $CaCl_2$, 25 KCl	125
100 $CaCl_2$, 50 NaCl	150	D	100 $CaCl_2$, 50 KCl	174
100 $CaCl_2$, 100 NaCl	198	E	100 $CaCl_2$, 100 KCl	230
50 $CaCl_2$, 100 NaCl	262	F	50 $CaCl_2$, 100 KCl	337
25 $CaCl_2$, 100 NaCl	342	G	25 $CaCl_2$, 100 KCl	420
15 $CaCl_2$, 100 NaCl	390	H	15 $CaCl_2$, 100 KCl	464
10 $CaCl_2$, 100 NaCl	416	I	10 $CaCl_2$, 100 KCl	492
5 $CaCl_2$, 100 NaCl	440	J	5 $CaCl_2$, 100 KCl	507
1 $CaCl_2$, 100 NaCl	300	K	1 $CaCl_2$, 100 KCl	346
NaCl	55	L	KCl	66

Distilled water, 725 mm

SUMMARY

The accepted idea that sodium and potassium have entirely different effects upon plants is not valid in the field of toxic and protective action. Here their behavior shows the close similarity which their near chemical relationship would lead us to expect.

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