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INFLUENCE OF THE SALTS COMMON IN ALKALI SOILS UPON THE GROWTH OF RICE PLANTS.

By

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The influence of alkali salts upon the germination and growth of plants has been studied by various investigators. Since alkali soils were discovered to be extensively distributed in western parts of United States of America, the toxicity of the salts common in alkali soils upon the growth of different plants was made the subject of special study by many American scientists. They found that not only the critical concentration of the same salt was very different for different plants, but the toxicity of the various salts also differed widely, and moreover that the presence of a second salt, notably calcium sulphate, not only greatly increases the endurable concentration of the more toxic salt, but tends to equalize the toxicity of the different salts.

In regard to the influence of the alkali salts upon the germination and growth of rice, which is the most important field crop in our country, no special investigation has been reported up to the present time.

In 1909 alkali soils were found for the first time in our country by Prof. K. Oshima and K. Shibuya[1], to be widely distributed in central and southern parts of Formosa, Japan. Since then, the distribution, nature and method of reclamation of the alkali lands there are being studied by the Government of Formosa. The principal soluble salts found in alkali soils of Formosa are sulphates and chlorides of sodium, potassium, calcium, and magnesium, while the carbonates are found in much smaller amount.

Under the circumstances, it seemed to us to be of much practical importance as well as scientific interest to study the influence of various salts

1) *Cf.* K. Shibuya—Investigations on Alkali Soils of Formosa (in Japanese)—Publ. by the Bureau of Productive Industries, Government of Formosa, 1912.

found in alkali soils upon the germination and growth of rice plants.

The present investigation was undertaken at the suggestion of Prof. Dr. K. Oshima, to whom the author owes his acknowledgement for the kind interest he has taken in the work.

In the present paper the results of experiments thus far completed are described. The results of other experiments now being conducted in our laboratory will be reported in a future paper.

I. Influence of single Salts upon the Germination and Growth of Rice.

For the experiments we selected magnesium sulphate, magnesium chloride, calcium chloride, sodium sulphate, sodium chloride, sodium carbonate and sodium bicarbonate as the salts to be examined.

A. Experiment with Salts in pure Solutions as regards their Influence upon the Germination of Rice Seeds.

On June 16th (1911), 100 seeds of rice (Akake), which were almost uniform in size and specific gravity (1.185—1.200), were sown in glass dishes of about 9.5 cm. diameter and 1.7 cm. deep, each containing 30 cc. of 1/2, 1/5, 1/10, 1/50, 1/100, 1/500, 1/1000 and 1/5000 normal solution of each salt above mentioned with distilled water as control. These dishes were covered with glass plates and kept in a room of ordinary temperature. The evaporated water was supplemented with distilled water from time to time to keep the solutions always in their original concentration. The germinated seeds were counted every day with the following results.

Result with $MgSO_4$.

Concentration	Date																				Total number of germinated seeds up to			Germination Capacity
	June														July						June 21	June 22	June 23	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6				
$\frac{1}{2}$ N.	0	4	4	2	1	1	1	14	7	4	3	6	1	2	0	0	0	0	0	0	11	12	13	50
$\frac{1}{5}$ N.	2	4	3	4	9	21	10	23	11	2	2	3	0	0	0	0	0	0	0	0	22	43	53	94
$\frac{1}{10}$ N.	2	2	5	7	15	25	15	11	5	2	2	0	0	0	0	0	0	0	0	0	31	56	71	91
$\frac{1}{50}$ N.	4	4	1	5	22	25	11	12	3	3	0	0	0	0	0	0	0	0	0	0	36	61	72	90
$\frac{1}{100}$ N.	10	4	3	5	21	30	9	5	4	3	0	0	0	0	0	0	0	0	0	0	43	73	82	94
$\frac{1}{500}$ N.	8	6	3	6	33	18	8	5	4	2	0	0	0	0	0	0	0	0	0	0	56	74	82	93
$\frac{1}{1000}$ N.	6	5	2	6	30	21	11	9	1	2	0	0	0	0	0	0	0	0	0	0	49	70	81	93
$\frac{1}{5000}$ N.	6	2	1	3	33	23	13	4	7	1	0	0	0	0	0	0	0	0	0	0	45	68	81	9
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with $MgCl_2$.

Concentration	Date																				Total number of germinated seeds up to			Germination Capacity
	June														July						June 21	June 22	June 23	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6				
$\frac{1}{2}$ N.	0	2	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	6
$\frac{1}{5}$ N.	3	6	2	2	3	2	7	16	13	6	3	9	3	3	3	0	0	0	0	0	16	18	25	81
$\frac{1}{10}$ N.	2	1	2	4	7	25	12	24	5	5	1	1	1	0	0	0	0	0	0	0	16	41	53	90
$\frac{1}{50}$ N.	5	3	3	6	29	20	12	11	5	1	1	1	0	0	0	0	0	0	0	0	46	66	78	97
$\frac{1}{100}$ N.	7	5	2	6	29	30	7	6	1	4	0	0	0	0	0	0	0	0	0	0	49	79	86	97
$\frac{1}{500}$ N.	7	8	3	5	33	23	10	5	4	0	0	0	0	0	0	0	0	0	0	0	56	79	89	98
$\frac{1}{1000}$ N.	7	6	2	7	28	26	11	9	3	2	0	0	0	0	0	0	0	0	0	0	51	77	88	90
$\frac{1}{5000}$ N.	2	1	1	12	29	33	8	5	1	2	0	0	0	0	0	0	0	0	0	0	45	78	86	94
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with $CaCl_2$.

Concentration	Date																			Total number of Germinated seeds up to			Germination Capacity
	June														July						June	June	June	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	21	22	23	
$\frac{1}{2}$ N.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\frac{1}{5}$ N.	5	0	1	3	3	4	0	0	6	0	0	1	0	0	0	1	0	0	0	0	12	16	16	24
$\frac{1}{10}$ N.	3	3	2	4	2	23	8	20	15	5	3	1	3	0	0	0	0	0	0	0	14	37	45	92
$\frac{1}{50}$ N.	3	5	3	6	19	25	9	9	7	2	2	2	0	0	0	0	0	0	0	0	36	61	70	92
$\frac{1}{100}$ N.	1	5	4	5	27	27	10	1	3	0	0	0	0	0	0	0	0	0	0	0	40	67	77	92
$\frac{1}{500}$ N.	5	5	2	6	24	29	10	4	4	3	1	0	0	0	0	0	0	0	0	0	42	71	81	93
$\frac{1}{1000}$ N.	2	2	4	11	25	27	8	4	4	2	2	1	0	0	0	0	0	0	0	0	44	71	79	92
$\frac{1}{5000}$ N.	4	3	3	7	33	24	12	3	5	1	0	0	0	0	0	0	0	0	0	0	50	74	86	94
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with Na_2SO_4.

Concentration	Date																			Total number of germinated seeds up to			Germination Capacity
	June														July						June	June	June	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	21	22	23	
$\frac{1}{2}$ N.	0	0	0	0	0	6	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	6	6	9
$\frac{1}{5}$ N.	0	0	1	7	4	10	2	16	11	10	4	9	3	3	1	4	1	1	0	0	12	22	24	87
$\frac{1}{10}$ N.	0	0	5	6	9	30	10	22	12	2	1	1	0	0	0	0	0	0	0	0	20	50	60	98
$\frac{1}{50}$ N.	3	3	7	9	10	33	4	13	5	5	1	1	0	0	0	0	0	0	0	0	32	65	69	94
$\frac{1}{100}$ N.	3	1	3	7	18	38	7	8	2	1	2	1	0	0	0	0	0	0	0	0	34	72	79	93
$\frac{1}{500}$ N.	3	2	3	8	20	35	7	8	3	2	1	1	0	0	0	0	0	0	0	0	36	71	78	93
$\frac{1}{1000}$ N.	6	4	3	6	22	30	10	7	3	1	2	0	0	0	0	0	0	0	0	0	41	71	81	94
$\frac{1}{5000}$ N.	4	1	3	10	21	32	7	8	1	2	1	1	0	0	0	0	0	0	0	0	39	71	78	91
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with NaCl.

Concentration	Date																				Total number of germinated seeds up to			Germination Capacity
	June														July						June	June	June	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	21	22	23	
$\frac{1}{2}$ N.	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	4
$\frac{1}{5}$ N.	1	3	1	4	1	4	1	3	10	2	0	5	2	2	0	0	0	1	3	0	10	14	15	43
$\frac{1}{10}$ N.	1	4	2	3	5	16	12	20	12	3	4	3	1	2	0	1	0	0	0	0	15	31	43	89
$\frac{1}{50}$ N.	2	5	1	5	19	32	13	12	3	2	1	0	0	0	0	0	0	0	0	0	32	64	77	96
$\frac{1}{100}$ N.	2	4	3	9	12	38	8	9	2	2	1	0	0	0	0	0	0	0	0	0	30	68	76	90
$\frac{1}{500}$ N.	4	5	2	13	12	32	9	6	3	3	4	0	0	0	0	0	0	0	0	0	36	68	77	93
$\frac{1}{1000}$ N.	1	4	6	11	17	36	10	6	2	1	0	0	0	0	0	0	0	0	0	0	35	75	85	94
$\frac{1}{5000}$ N.	4	1	3	9	17	35	12	7	2	3	0	0	0	0	0	0	0	0	0	0	34	69	81	93
Control	4	1	1	4	23	24	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with Na_2CO_3.

Concentration	Date																				Total number of germinated seeds up to			Germination Capacity
	June														July						June	June	June	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	21	22	23	
$\frac{1}{2}$ N.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
$\frac{1}{5}$ N.	1	0	0	0	0	6	0	6	9	2	4	3	7	1	0	0	0	0	0	0	1	7	7	39
$\frac{1}{10}$ N.	1	1	1	8	6	22	11	20	10	6	2	0	0	0	0	0	0	0	0	0	17	39	50	88
$\frac{1}{50}$ N.	2	1	2	5	24	30	14	9	7	2	2	0	0	0	0	0	0	0	0	0	33	63	77	98
$\frac{1}{100}$ N.	2	1	2	8	14	37	11	10	7	3	0	0	0	0	0	0	0	0	0	0	29	65	76	95
$\frac{1}{500}$ N.	4	3	1	6	20	32	12	10	6	1	0	0	0	0	0	0	0	0	0	0	47	67	79	95
$\frac{1}{1000}$ N.	4	2	1	9	20	33	12	5	2	3	0	0	0	0	0	0	0	0	0	0	36	69	81	91
$\frac{1}{5000}$ N.	3	1	4	10	12	36	13	6	5	3	0	0	0	0	0	0	0	0	0	0	30	66	79	93
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

Result with $NaHCO_3$.

Concentration	Date																				Total number of germinated seeds up to			Germination Capacity
	June														July						June 21	June 22	June 23	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6				
$\frac{1}{2}$ N.	1	1	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	0	2	2	2	7
$\frac{1}{5}$ N.	4	2	2	3	22	27	13	8	5	0	0	0	2	1	0	0	3	0	0	0	33	60	75	89
$\frac{1}{10}$ N.	2	2	3	4	17	38	14	13	1	1	1	1	0	0	0	0	0	0	0	0	29	67	81	97
$\frac{1}{50}$ N.	5	1	4	2	23	36	14	7	1	1	1	1	0	0	0	0	0	0	0	0	35	71	85	96
$\frac{1}{100}$ N.	10	2	1	10	25	31	6	4	2	2	1	1	0	0	0	0	0	0	0	0	48	79	85.	95
$\frac{1}{500}$ N.	3	1	3	8	25	36	10	3	1	2	1	1	0	0	0	0	0	0	0	0	40	76	86	94
$\frac{1}{1000}$ N.	1	3	4	8	22	35	8	3	3	1	1	1	1	0	0	0	0	0	0	0	38	75	81	91
$\frac{1}{5000}$ N.	8	1	1	5	25	34	9	4	3	2	1	0	0	0	0	0	0	0	0	0	40	74	83	93
Control	4	1	1	4	23	34	10	6	5	2	2	0	0	0	0	0	0	0	0	0	33	67	77	92

For convenience, the results above tabulated are brought together in the following table. (See p. 247).

As a result of the observation of above table, it is evident that each salt except magnesium sulphate and sodium bicarbonate, in concentrations greater than 1/5 normal was decidedly toxic upon the germination of rice seeds while the latter two salts were toxic in concentration of 1/2 normal. It is further evident that all the salts except sodium bicarbonate in concentrations greater than 1/10 normal seemed to delay the germination while sodium bicarbonate showed the same effect in concentration of 1/5 normal. Moreover, it is clear that, in certain dilutions of each salt, there were indication of a stimulating action upon the germination of the seeds. The maximum stimulation of magnesium sulphate and chloride appeared in concentration of 1/5000 normal of each while that of sodium

		Salts used	Concentration								
			$\frac{1}{2}$ N.	$\frac{1}{5}$ N.	$\frac{1}{10}$ N.	$\frac{1}{50}$ N.	$\frac{1}{100}$ N.	$\frac{1}{500}$ N.	$\frac{1}{1000}$ N.	$\frac{1}{5000}$ N.	Control
Total number of germinated seeds up to	June 21	$MgSO_4$	11	22	31	36	43	56	49	45	33
		$MgCl_2$	5	16	16	46	49	56	51	45	33
		$CaCl_2$	0	12	14	36	40	42	44	50	33
		Na_2SO_4	0	12	20	32	34	36	41	39	33
		NaCl	3	10	15	32	30	36	35	34	33
		Na_2CO_3	1	1	17	33	29	47	36	30	33
		$NaHCO_3$	2	33	29	35	48	40	38	40	33
	June 22	$MgSO_4$	12	43	56	61	73	74	70	68	67
		$MgCl_2$	5	18	41	66	79	79	77	78	67
		$CaCl_2$	0	16	37	61	67	71	71	74	67
		Na_2SO_4	6	22	50	65	72	71	71	71	67
		NaCl	3	14	31	64	68	68	75	69	67
		Na_2CO_3	1	7	39	63	65	67	69	66	67
		$NaHCO_3$	2	60	67	71	79	76	73	74	67
	June 23	$MgSO_4$	13	53	71	72	82	82	81	81	77
		$MgCl_2$	5	25	53	78	86	89	88	86	77
		$CaCl_2$	0	16	45	70	77	81	79	86	77
		Na_2SO_4	6	24	60	69	79	78	81	78	77
		NaCl	3	15	43	77	76	77	85	81	77
		Na_2CO_3	1	7	50	77	76	79	81	79	77
		$NaHCO_3$	2	73	81	85	85	86	81	83	77
Germination	Capacity	$MgSO_4$	50	94	91	90	94	93	93	97	92
		$MgCl_2$	6	81	90	97	97	98	90	94	92
		$CaCl_2$	0	24	92	92	92	93	92	94	92
		Na_2SO_4	9	87	98	94	93	93	94	91	92
		NaCl	4	43	89	96	90	93	94	93	92
		Na_2CO_3	1	39	88	98	95	95	91	93	92
		$NaHCO_3$	9	89	97	96	95	94	91	93	92

sulphate and chloride appeared in concentration of 1/1000 normal. Calcium chloride showed its highest stimulation in 1/5000 normal while sodium carbonate and bicarbonate showed in concentrations of 1/500—1/1000 and 1/100 normal respectively.

In regard to the influence of the salts, under our examination, upon the germination of seeds, many results of investigations have been reported up to the present time. According to Zeller[1)], sodium carbonate was toxic even in concentration of 1/300 while magnesium sulphate had a good effect in concentration of 1/100 upon the germination of cress and oats. Calcium chloride acted as a stimulant in a pretty strong solution upon the germination of these plants. Lea[2)] has also observed a poisonous action of sodium carbonate on the germination of seeds. Fleischer[3)] found that rape and clover seeds died in 1/8 concentration of sodium carbonate, while hemp was not affected. He also observed that sodium sulphate and chloride in concentration up to 11 % were indifferent for the germination of spelt wheat, barley, buckwheat and sunflower, while wheat, rape, flax and hemp were indifferent in the former, but affected badly by the latter salt. Tautphoeus[4)] studied the influence of potassium chloride, sulphate and phosphate, sodium chloride and nitrate, and calcium nitrate upon the germination of wheat, rye, rape, maize, peas and beans, and found that these salts were more or less injurious even in 0.5 % solution upon the germination of all of the above plants except rape. On the contrary, Nesslers[5)] observed that 0.5 % solution of sodium chloride was toxic upon the germination of rape and clover, while wheat seeds were well germinated even in 1 % solution. It was also observed by Hindolf[6)] that magnesium and calcium chloride in dilute solution had a good in-

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1). Zeller,—Inaugural Diss. (1876); Nobbe,—Handbuch der Samenkunde, Berlin, pp. 268–270 (1876).

2). Lea,—Amer. Jour. of Sc. and Arts, p. 197 (1867); Nobbe,—Ibid.

3). Fleischer.—Nobbe,—Ibid.

4). Tautphoeus,—Inaugural Diss. (1875); Jahresber. Agrikchem., **18** u. **19**, p. 240 (1875–1876).

5). Nesslers,—Wochenblatt des landw. Vereins im Grossherzogthum Baden, No. 6 (1877); Jahresber. Agrikchem., **20**, p. 193 (1877).

6). Hindolf,—Just Bot. Jahresber., **1**, p. 139 (1887).

fluence on the germination and the early development of many cultivated plants. According to Yoshii[1], sodium chloride, calcium chloride and magnesium chloride were toxic on the germination of rice seeds in concentration of 0.2 %, 0.1 % and 0.5 % respectively. Recentry, Coupin[2] proved, that carbonate, phosphate, sulphate, chloride and nitrate of potassium acted as stimulant on the germination of wheat, in very dilute solution. Kato[3] also studied the influence of sodium chloride upon the germination of rice and found that, in concentration of 1.2 %, the germination period was greatly delayed while, in 2.8 % concentration, germination was completely checked.

All of these results point to show that the salts, in large amounts, are highly injurious to the germination of seeds, but, in a slight concentration, act as stimulating agents. This is confirmed by the results of our own experiments.

B. Experiments with Salts in pure Solutions as regards their Influence upon the Growth of Rice Seedlings.

In the first experiment we began with the young rice seedlings, 15–16 mm. high, which were grown in distilled water from seeds of almost uniform size and specific gravity (1.2–1.25). Fifty six beakers of about 5.5 cm. diameter and 7 cm. deep, each containing 50 cc. of 1/2, 1/10, 1/20, 1/100, 1/200, 1/1000, 1/2000 and 1/10000 molecular solution of each salt already mentioned, were used for the experiment, the seedlings being placed in the solution on Aug. 3rd (1911), while one beaker with distilled water served as control. Twenty five seedlings were grown in each culture at ordinary temperature and the evaporated water was supplemented with distilled water from time to time to keep the solutions always in their initial dilutions. After ten days, the difference in development was very striking, when the following determination was made.

1). Yoshii,—Jour. Scie. Agric. Soc., Tokyo, 2, p. 17 (1889) (in Japanese).

2). Coupin,—Compt, rend., 132. p. 1582 (1901).

3). Kato,—Jour. Scie. Agric. Soc., Tokyo, 105, pp. 1–13 (1911) (in Japanese).

Salts used		Concentration								
		$\frac{1}{2}$ M.	$\frac{1}{10}$ M.	$\frac{1}{20}$ M.	$\frac{1}{100}$ M.	$\frac{1}{200}$ M	$\frac{1}{1000}$ M.	$\frac{1}{2000}$ M.	$\frac{1}{10000}$ M.	Control
$MgSO_4$	Length of leaf.[1] mm.	20	40	60	80	83	112	97	90	80
	Length of root.[1] mm.	35	65	65	80	85	140	118	100	125
	Number of roots.	1	1	1	3	3	9	6	5	6
$MgCl_2$	Length of leaf.		27	56	80	83	93	100	88	80
	Length of root.	died	42	45	70	90	165	110	112	125
	Number of roots.		1	1	2	2	6	8	6	6
$CaCl_2$	Length of leaf.		30	47	73	80	90	90	105	80
	Length of root.	died	25	40	97	100	150	100	150	125
	Number of roots.		3	6	6	6	8	9	7	6
Na_2SO_4	Length of leaf.		33	42	120	107	100	97	93	80
	Length of root.	died	30	50	90	85	90	100	100	125
	Number of roots.		1	1	7	7	9	7	9	6
NaCl	Length of leaf.		42	67	97	95	85	82	82	80
	Length of root.	died	30	63	150	130	70	110	130	125
	Number of roots.		3	6	5	5	4	7	7	6
Na_2CO_3	Length of leaf.			33	83	117	117	97	85	80
	Length of root.	died	died	20	30	145	145	105	85	125
	Number of roots.			1	5	5	6	7	7	6
$NaHCO_3$	Length of leaf.		30	40	105	115	110	103	103	80
	Length of root.	died	18	45	90	140	60	90	105	125
	Number of roots.		1	1	6	5	6	6	7	6

The results show that each salt acted as a toxic or stimulant upon the growth of rice seedlings, according to its concentration. Magnesium sulphate and chloride, calcium chloride and sodium carbonate were injurious when the concentrations were greater than 1/200 Mol, while sodium sulphate, chloride and bicarbonate were toxic when the concentrations were greater than 1/100 Mol. In every salt, when the concentration was such that the toxic action ceased, the stimulating effect began and attained its highest degree in the following concentration; magnesium sulphate 1/1000 Mol.,

1) The length of root is that of longest rootlet while that of leaf is an average.

magnesium chloride 1/2000 Mol., calcium chloride 1/10000 Mol., sodium sulphate 1/100 Mol., sodium chloride 1/100 Mol., sodium carbonate 1/200–1/1000 Mol., and sodium bicarbonate 1/200 Mol.

To verify the results obtained in the above experiment, we planned another series of experiments in the following manner.

On June 13th (1912), 25 rice seeds of almost uniform size and specific gravity (1.158–1.185) were sown in beakers, about 5.5 cm. in diameter and 7 cm. deep, each containing 30 cc. of 1/2, 1/5, 1/10, 1/50, 1/100, 1/500, 1/1000 and 1/5000 normal solutions of each salt, while distilled water served as control. These beakers were kept in a room of ordinary temperature and covered with a glass plate until the seedlings attained a height of about 15 mm. The evaporated water was supplemented with distilled water from time to time to keep solutions always in their initial concentrations. After 36 days, the difference in their development was very striking when the measurements were made as shown in Table I p. 252.

In this case as in the previous experiment, the growth of the seedlings was also injured[1] or stimulated by each salt according to the concentration. In the concentration at which the toxic action ceased, the stimulating action began and attained its maximum point in certain dilution. The growth was injured by magnesium sulphate in concentration of greater than 1/100 normal and highly stimulated by 1/500 normal. Magnesium chloride was also toxic in concentration greater than 1/100 normal and attained its highest stimulating point in concentration of 1/5000 normal. The toxic concentration of calcium chloride, sodium sulphate, sodium chloride, sodium carbonate and bicarbonate was each in concentration greater than 1/100, 1/50, 1/100, 1/100, 1/50 normal respectively and their highest stimulation was reached in dilution of 1/1000, 1/100, 1/100, 1/500 and 1/500 normal respectively.

For the sake of convenience of comparison, the concentration of toxicity and stimulation of the seven salts in the above two experiments are brought together in Table II p. 252.

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1) It is assumed that the plant is ill affected by the salts, if the length of root be half that of control plants, even though the length of leaf be greater than that of the control leaf.

Table I.

Salts used		Concentration								
		$\frac{1}{2}$ N.	$\frac{1}{5}$ N.	$\frac{1}{10}$ N.	$\frac{1}{50}$ N.	$\frac{1}{100}$ N.	$\frac{1}{500}$ N.	$\frac{1}{1000}$ N.	$\frac{1}{5000}$ N.	Control.
$MgSO_4$	Length of leaf mm.	Only 18 seeds germinated.	22	30	85	100	130	110	120	100
	Length of root mm.		—	—	10	60	80	80	100	115
	Number of roots		—	—	1	4	6	6	6	6
$MgCl_2$	Length of leaf	No seed germinated.	All seed germinated but not one developed.	25	83	105	100	105	107	100
	Length of root			—	30	105	100	120	143	115
	Number of roots			—	3	3	6	6	6	6
$CaCl_2$	Length of leaf	No seed germinated.	Only 6 seeds germinated.	18	85	105	110	145	95	100
	Length of root			—	40	75	90	190	130	115
	Number of roots			—	5	6	6	6	6	6
Na_2SO_4	Length of leaf	No seed germinated.	12	23	150	165	145	120	100	100
	Length of root		—	—	30	70	85	75	80	115
	Number of roots		—	—	4	4	6	7	7	6
NaCl	Length of leaf	No seed germinated.	4	35	155	137	110	110	110	100
	Length of root		—	—	95	125	130	120	120	115
	Number of roots		—	—	6	6	6	7	7	6
Na_2CO_3	Length of leaf	No seed germinated.	Only 5 seeds germinated.	5	85	120	120	110	110	100
	Length of root			—	27	40	78	100	135	115
	Number of roots			—	6	7	7	7	7	6
$NaHCO_3$	Length of leaf	No seed germinated.	17	55	95	120	125	100	100	100
	Length of root		—	2	105	105	105	100	100	115
	Number of roots		—	2	4	5	6	6	7	6

Table II.

Salts used	Concentration of toxicity		Dilution of maximum stimulation	
	In former Exp.	In latter Exp.	In former Exp.	In latter Exp.
$MgSO_4$	$> \frac{1}{200}$ M. ($\frac{1}{100}$ N.)	$> \frac{1}{100}$ N.	$\frac{1}{1000}$ M. ($\frac{1}{500}$ N.)	$\frac{1}{500}$ N.
$MgCl_2$	" " "	" "	$\frac{1}{2000}$ M. ($\frac{1}{1000}$ N.)	$\frac{1}{5000}$ N.
$CaCl_2$	" " "	" "	$\frac{1}{10000}$ M. ($\frac{1}{5000}$ N.)	$\frac{1}{1000}$ N.
Na_2SO_4	" $\frac{1}{100}$ M. ($\frac{1}{50}$ N.)	" $\frac{1}{50}$ N.	$\frac{1}{100}$ M. ($\frac{1}{50}$ N.)	$\frac{1}{100}$ N.
NaCl	" " ($\frac{1}{100}$ N.)	" $\frac{1}{100}$ N.	$\frac{1}{100}$ M. ($\frac{1}{100}$ N.)	$\frac{1}{100}$ N.
Na_2CO_3	" $\frac{1}{200}$ M. ($\frac{1}{100}$ N.)	" "	$\frac{1}{200}$-$\frac{1}{1000}$ M. ($\frac{1}{100}$-$\frac{1}{500}$ N.)	$\frac{1}{500}$ N.
$NaHCO_3$	" $\frac{1}{100}$ M. ($\frac{1}{50}$ N.)	" $\frac{1}{50}$ N.	$\frac{1}{200}$ M. ($\frac{1}{100}$ N.)	$\frac{1}{500}$ N.

As seen in the above table, both results almost coincide in the toxic and stimulating point. A slight fluctuation of the stimulation point is probably due to the fact that the plant growth varies, to a certain extent, with the temperature and other factors, since these experiments were not carried on at constant temperature and under identical conditions.

The influence of the salts under our examination upon the growth of young seedlings, have been studied by many investigators. In 1887, Hindolf[1] observed a good influence of magnesium and calcium chloride upon the early development of many cultivated plants. Coupin[2] studied the toxic influence of many salts upon the growth of the young root of wheat, and found that calcium chloride was toxic in concentration of 1/200. Hebert[3] also investigated the toxicity of chromium, aluminium and magnesium salts upon the growth of germinated seeds of wheat and rape and observed that the toxic action of magnesium salt was least among these salts and often harmless. An elaborate investigation of the toxic concentration of various alkali salts upon the growth of seedings of many plants has been made specially by Kearney and Harter[4]. Their results are shown in the following table.

Critical concentration of pure solutions.

Salts used	Plants tested								
	White-lupine		Alfalfa	Wheat	Maize	Sorghum	Oats	Cotton	Beet
	I	II							
$MgSO_4$	0.00125N.	0.007 N.	±0.001N.	0.005 N.	0.25 N.	0.00375N.	0.001875N.	0.000312N.	0.0005 N.
$MgCl_2$	0.0025 „	0.0075 „	±0.002 „	0.005 „	0.08 „	0.00125 „	0.001875 „	0.0004 „	0.0005 „
Na_2CO_3	0.005 „	0.0125 „		0.0125 „	0.015 „	0.00675 „	0.00625 „	0.005 „	0.00625 „
Na_2SO_4	0.0075 „	0.04 „		0.04 „	0.05 „	0.0125 „	0.0175 „	0.005 „	0.00875 „
NaCl	0.02 „	0.045 „		0.045 „	0.04 „	0.015 „	0.02 „	0.00625 „	0.025 „
$NaHCO_3$	0.02 „	0.03 „		0.025 „	0.05 „	0.00875 „	0.0075 „	0.00625 „	0.0075 „

1). Hindolf,—l. c.

2). Coupin,—l. c. p. 645.

3). Hebert,—Bull. Soc. chim., France, 4, Ser. 1, 18. p. 1026 (1907); Jahresber. Agrikchem., 11 p. 252 (1908).

4). Kearney and Harter,—Bull. No. 113, Bureau of Plant Industry, U. S. Dept. of Agriculture (1907).

From the results, they concluded that the different species of plants differ vastly in the absolute degree of their resistance to the toxic action of these pure solutions, also the order of toxicity of the several salts varies considerably according to the species. Furthermore, the salts of magnesium are generally more toxic than those of sodium to all the plants tested with the single exception of maize.

Burlingham[1] has studied the influence of magnesium sulphate upon the growth of seedlings of abutilon, peas and corn, and his results were summarized as follows: "Magnesium sulphate in solutions of greater concentration than m/8192 has a toxic action on most seedlings, the degree of toxicity varying with the type of seedlings and with conditions. An m/8192 solution is toxic to pea seedlings, slightly stimulating to abutilon, while it has a marked stimulating effect on corn seedlings. Maximum stimulation in magnesium sulphate results in solution from m/32768 to m/131072, the point again varying according to the kind of seedlings grown. When magnesium sulphate is used in proper dilutions there may be produced a total growth nearly double that in the control; or in the case of abutilon seedlings, a growth of the primary root increased, but the lateral roots develop sooner, are more numerous, and attain a greater growth. Furthermore the stimulation is not limited to the root system, but the magnasium forces a more rapid and a greater growth of the hypocotyl and plumule. In the same concentration, calcium nitrate causes very little stimulation. In addition to the marked stimulation which magnesium sulphate causes when it is used in dilutions from m/16384 to m/524288, it increases the vitality of the seedlings. The seedlings grown in the magnesium sulphate outlived those in the control by two or three weeks, and in some cases by a greater period.

From the foregoing results and conclusions, it is evident that magnesium sulphate, in the absence of other salts, is not neccessarily injurious in its effect, but on the other hand may be highly beneficial, while any inhibitory action is due to the presence of a relatively large proportion of magnesium in solution".

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1). Burlingham,—Jour. Amer. Chem. Soc., **29** pp. 1095–1112 (1907).

From the results of the investigations above noted, it will be observed that the salts act on the growth of young seedlings as a toxic or a stimulating agent, according to their concentration. Our results with rice confirm the same view.

Taking the results of our own experiments and those of Kearney and Harter into consideration, it may be inferred that maize is decidedly the most resistant of cereals. The resistant power of wheat and rice stands next to maize, while sorghum and oats are on the whole the least resistant cereals.

C. Experiments with Salts in Soil as regards their Influence upon the Growth of Rice Plants.

As it is shown by Kearney, Cameron[1] and others that the point and order of toxicity of the salts determined by the experiments with pure solutions differ materially from those obtained by field experiments, the following experiments were planned and carried out.

One hundred porcelain pots, each holding 2000 grams of poor soil, were arranged in two series and 1200 cc. of water was then added to each pot. On June 21th (1911), three seedlings of about 15 cm. high were transplanted in each pot. While plants in one pot served for control, to the other 49 pots in two series each salt was added in the amount of 1, 1/2, 1/10, 1/20, 1/100, 1/200 and 1/1000 gram molecular weight. The given amount of each salt was added in five fractions, in the form of solution, on July 12, 17, 22, 27 and August 2. The evaporated water was supplemented with water from time to time until the period of the blossom. When the total amount of each salt was entirely added, the difference in their growth was striking; on September 13, the following determinations of the height of plants were made.

1). Kearney, and Cameron,—Bull. No. 71, Bureau of Plant Industry, U. S. Dept. of Agriculture (1902).

Salts used	Amount of salt added to 2000 grams of soil							
	1 g. mol. wt.	$\frac{1}{2}$ g. mol. wt.	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{20}$ g. mol. wt.	$\frac{1}{100}$ g. mol. wt.	$\frac{1}{200}$ g. mol. wt.	$\frac{1}{1000}$ g. mol. wt.	Control.
		cm.	cm.	cm.	cm.	cm.	cm.	cm.
$MgSO_4$	died	38.0	50.0	53.0	51.0	52.0	50.0	45.0
$MgCl_2$	"	died	47.0	48.0	54.0	51.0	47.0	45.0
$CaCl_2$	"	"	died	36.0	53.0	51.0	47.0	45.0
Na_2SO_4	"	"	41.0	45.0	45.0	47.0	50.0	45.0
NaCl	"	"	38.0	46.0	47.0	47.0	46.0	45.0
Na_2CO_3	"	"	died	39.0	46.0	48.0	50.0	45.0
$NaHCO_3$	"	"	44.0	45.0	46.0	48.0	47.0	45.0

On September 30, the plants were harvested and weighed in air dry state with the results as shown in p. 257.

These results show beyond doubt that the growth of plants was injured or stimulated by the salts according to their amounts. Calcium chloride was most toxic and its injurious effect was noticeable in amount of 1/100 gram molecular weight per 2000 grams of soil, while magnesium chloride, sodium sulphate, chloride and carbonate were injurious in amount of 1/20 gram molecular weight. Magnesium sulphate and sodium bicarbonate was least toxic and each in amounts of 1/10 gram molecular weight per 2000 grams soil showed an injurious effect. The stimulating action of each salt attained its highest degree in the pot to which had been added magnesium sulphate 1/20, magnesium chloride 1/100, calcium chloride 1/200, sodium sulphate 1/200, sodium chloride 1/100, sodium carbonate 1/200–1/1000 and sodium bicarbonate 1/200 gram molecular weight respectively.

On 1912, the experiment was repeated with the same pots and the soil which was used in the previous experiment. To each pot, 1200 cc. of water was added and well mixed. On June 20th, five seedlings about 15 cm. in height were transplanted. The pots were kept in the glass house and the evaporated water was supplemented from time to time as in the previous experiment.

(The number denotes the sum of weight in two pots).

Salts used		Amount of salt added to 2000 grams of soil							
		1 g. mol. wt.	$\frac{1}{2}$ g. mol. wt.	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{20}$ g. mol. wt.	$\frac{1}{100}$ g. mol. wt.	$\frac{1}{200}$ g. mol. wt.	$\frac{1}{1000}$ g. mol. wt.	Control.
			g.	g.	g.	g.	g.	g.	g.
$MgSO_4$	Total yield	—	3.75	4.85	5.45	4.65	4.45	4.40	4.20
	Seed	—	—	1.45	2.00	1.75	1 55	1.55	1.55
	Straw	—	2.90	2.55	2.50	2.25	2.20	2.05	2.00
	Root	—	0.85	0.85	0.95	0.70	0.70	0.80	0.65
$MgCl_2$	Total yield	—	—	4.50	4.90	5 00	4.70	4.40	4.20
	Seed	—	—	0 60	1.35	1.70	1.70	1.55	1.55
	Straw	—	—	3.30	2.75	2.60	2.45	2.15	2.00
	Root	—	—	0.60	0.80	0.70	0.70	0.70	0.65
$CaCl_2$	Total yield	—	—	—	3.90	4.50	4.95	4.40	4.20
	Seed	—	—	—	0.20	0.95	1.75	1.55	1.55
	Straw	—	—	—	3.00	2.75	2.50	2.15	2.00
	Root	—	—	—	0 80	0.80	0.70	0.70	0.65
Na_2SO_4	Total yield	—	—	4.10	4.60	4.70	5.00	4.70	4.20
	Seed	—	—	0.25	1.05	1.60	1.80	1.80	1.55
	Straw	—	—	2.90	2.75	2.40	2.40	2.10	2.00
	Root	—	—	0.80	0.80	0.75	0.80	0.80	0.65
$NaCl$	Total yield	—	—	2.80	4.50	4.90	4.40	4.30	4.20
	Seed	—	—	0.40	1.35	1.60	1.55	1.55	1.55
	Straw	—	—	2.00	2.50	2.65	2.10	2.00	2.00
	Root	—	—	0.40	0.65	0.65	0.75	0.75	0.65
Na_2CO_3	Total yield	—	—	—	2.50	4.30	4.90	4.90	4.20
	Seed	—	—	—	0.65	1.55	1.60	1.65	1.55
	Straw	—	—	—	1.45	2.10	2.65	2.60	2.00
	Root	—	—	—	0.40	0.65	0.65	0.65	0.65
$NaHCO_3$	Total yield	—	—	3.90	4.55	4.55	4.60	4.35	4.20
	Seed	—	—	1.10	1.55	1.55	1.60	1.55	1.55
	Straw	—	—	2.20	2.25	2.25	2.30	2.10	2.00
	Root	—	—	0.60	0.75	0.75	0.70	0.70	0.65

On September 18, the measurement of the height was made. The results were as follows.

Salts used	Amount of salts added to 2000 grams of soil							
	1 g. mol. wt.	$\frac{1}{2}$ g. mol. wt.	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{20}$ g. mol. wt.	$\frac{1}{100}$ g. mol. wt.	$\frac{1}{200}$ g. mol. wt.	$\frac{1}{1000}$ g. mol. wt.	Control.
			cm.	cm.	cm.	cm.	cm.	cm.
$MgSO_4$	died	died	45.0	45.0	40.5	43.5	43.5	39.0
$MgCl_2$	"	"	died	32.0	36.0	45.0	42.0	39.0
$CaCl_2$	"	"	"	18.0	39.0	40.5	46.5	39.0
Na_2SO_4	"	"	36.0	39.0	40.5	45.0	48.0	39.0
NaCl	"	"	34.0	34.5	37.5	43.5	45.0	39.0
$N\ _2CO_3$	"	"	died	35.0	42.0	45.0	48.0	39.0
$NaHCO_3$	"	"	50.0	46.5	51.0	43.5	46.5	39.0

On October 15, the plants were harvested and weighed in the air dry state. The results obtained are shown in p. 259.

In this case as in the previous experiment, the growth of the plants was also injured or stimulated by each salt according to the amount. The toxic effect of magnesium chloride, calcium chloride, sodium chloride and carbonate appeared in amounts greater than 1/100 gram molecular weight, while that of sodium sulphate and bicarbonate and magnesium sulphate appeared in greater amount than 1/20, 1/20 and 1/10 gram molecular weight respectively. The highest stimulation was reached in amount of magnesium sulphate 1/20, magnesium chloride 1/200, calcium chloride 1/1000, sodium sulphate 1/1000, sodium chloride 1/200, sodium carbonate and bicarbonate each 1/100 gram molecular weight.

If we compare this result with that obtained in the previous experiment, we find that there is no slight difference in the amount of each salt regarding the toxicity and stimulation. The results obtained in the

(The weight refers to that of five plants).

Salts used		Amount of salts added to 2000 grams of soil							
		1 g. mol. wt.	$\frac{1}{2}$ g. mol. wt.	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{20}$ g. mol. wt.	$\frac{1}{100}$ g. mol. wt.	$\frac{1}{200}$ g. mol. wt.	$\frac{1}{1000}$ g. mol. wt.	Control.
				g.	g.	g.	g.	g.	g.
$MgSO_4$	Total yield	—	—	2.45	2.20	2.10	2.30	2.25	2.00
	Seed	—	—	0.45	0.50	0.50	0.70	0.65	0.50
	Straw	—	—	1.70	1.30	1.30	1.30	1.30	1.20
	Root	—	—	0.30	0.40	0.30	0.30	0.30	0.30
$MgCl_2$	Total yield	—	—	—	0.70	1.40	2.30	2.20	2.00
	Seed	—	—	—	0.10	0.20	0.70	0.65	0.50
	Straw	—	—	—	0.45	0.95	1.30	1.25	1.20
	Root	—	—	—	0.15	0.25	0.30	0.30	0.30
$CaCl_2$	Total yield	—	—	—	0.20	1.95	2.00	2.35	2.00
	Seed	—	—	—	0.00	0.45	0.50	0.85	0.50
	Straw	—	—	—	0.10	1.20	1.20	1.25	1.20
	Root	—	—	—	0.10	0.30	0.30	0.35	0.30
Na_2SO_4	Total yield	—	—	0.95	1.90	2.45	2.50	3.10	2.00
	Seed	—	—	0.00	0.40	0.85	0.85	0.90	0.50
	Straw	—	—	0.70	1.20	1.25	1.30	1.60	1.20
	Root	—	—	0.25	0.30	0.35	0.35	0.60	0.30
NaCl	Total yield	—	—	0.60	1.20	2.20	2.70	2.40	2.00
	Seed	—	—	0.10	0.20	0.70	1.00	0.80	0.50
	Straw	—	—	0.30	0.80	1.20	1.30	1.30	1.20
	Root	—	—	0.20	0.20	0.30	0.40	0.30	0.30
Na_2CO_3	Total yield	—	—	—	1.50	2.35	2.70	3.40	2.00
	Seed	—	—	—	0.20	0.70	1.00	1.50	0.50
	Straw	—	—	—	1.10	1.25	1.30	1.40	1.20
	Root	—	—	—	0.15	0.40	0.40	0.50	0.30
$NaHCO_3$	Total yield	—	—	2.45	3.40	3.10	2.65	2.55	2.00
	Seed	—	—	0.45	1.25	0.85	0.80	0.75	0.50
	Straw	—	—	1.60	1.55	1.55	1.35	1.35	1.20
	Root	—	—	0.35	0.60	0.70	0.50	0.45	0.30

second experiment are generally smaller than those of the first experiment as will be seen in the following table:

Salts used	Toxic amount		Highest stimulating amount	
	I	II	I	II
$MgSO_4$	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{10}$ g. mol. wt.	$\frac{1}{20}$ g. mol. wt.	$\frac{1}{200}$ g. mol. wt.
$MgCl_2$	$\frac{1}{20}$ " " "	$\frac{1}{100}$ " " "	$\frac{1}{100}$ " " "	$\frac{1}{200}$ " " "
$CaCl_2$	$\frac{1}{100}$ " " "	$\frac{1}{100}$ " " "	$\frac{1}{200}$ " " "	$\frac{1}{1000}$ " " "
Na_2SO_4	$\frac{1}{20}$ " " "	$\frac{1}{100}$ " " "	$\frac{1}{200}$ " " "	$\frac{1}{1000}$ " " "
$NaCl$	$\frac{1}{20}$ " " "	$\frac{1}{20}$ " " "	$\frac{1}{100}$ " " "	$\frac{1}{200}$ " " "
Na_2CO_3	$\frac{1}{20}$ " " "	$\frac{1}{20}$ " " "	$\frac{1}{200}$-$\frac{1}{1000}$ " "	$\frac{1}{100}$ " " "
$NaHCO_3$	$\frac{1}{10}$ " " "	$\frac{1}{10}$ " " "	$\frac{1}{200}$ " " "	$\frac{1}{100}$ " " "

For the causes which occasioned this difference, we have not sufficient data for an explanation, but it is probably due 1st to the exhaustion of soil nutrients, 2nd to the presence of toxic salts in large amount already at the begining of the experiment, 3rd to the difference of temperature, light and other factors, which have influence on the growth of plants, since the two experiments were not carried on under the same conditions. Loughridge[1] once investigated the tolerance of alkali by various cultures. As the result of field observation, he concluded that amount of alkali tolerated varies with the variety of the plants and the nature of the soil.

If we again compare the results obtained in the experiment with soil with those in pure solutions, we find that the toxic as well as stimulating effect of each salt appears generally in the latter case with a smaller amount than in the former, as will be seen in the following table, with the exception of the sodium salts regarding the point of maximum stimulation.

1). Loughridge.—Bull. No. 133. Agric. Exp. Stat., Univ. of California. (1901).

Salts used	Toxic amount		Highest stimulating amount	
	in Solution	in Soil	in Solution	in Soil
		Per 1000 g. Soil.		Per 1000 g. Soil.
$MgSO_4$	1/200 Mol. (1/100 N.)	1/20 g. mol. wt.	1/1000 Mol. (1/500 N.)	1/40-1/400 g. mol. wt.
$MgCl_2$	" " (")	1/40-1/200 " "	1/2000-1/10000 Mol. (1/1000-1/5000 N.)	1/200-1/400 " "
$CaCl_2$	" " (")	1/200 " "	" " " (")	1/400-1/2000 " "
Na_2SO_4	1/100 " (1/50 N.)	1/40-1/200 " "	1/100-1/200 Mol. (1/50-1/100 N.)	" " " "
NaCl	" " (1/100 N.)	1/40 " "	1/100 Mol. (1/100 N).	1/200-1/400 " "
Na_2CO_3	1/200 " (")	1/40 " "	1/200-1/1000 Mol. (1/100-1/500 N.)	1/200-1/2000 " "
$NaHCO_3$	1/100 " (1/50 N.)	1/20 " "	" " " (")	1/200-1/400 " "

D. Summary.

Taking all of the above results into consideration we may safely conclude as follows:

1) The alkali salts under examination act as an agent both toxic and stimulating upon the germination and growth of rice plants, according to their amount.

2) The amount which is toxic and that which is stimulating, varies with the kind of salts.

3) The toxic effect of each salt, except magnesium sulphate and sodium bicarbonate, upon the germination capacity of rice seeds appears in concentration greater than about 1/5 normal, while those two salts are toxic in 1/2 normal concentration. But, until the dilutions of the salts, except sodium bicarbonate, reach 1/10 normal, they seem to possess a delaying action on the germination; for sodium bicarbonate this point is reached at 1/5 normal. When the dilutions of salts are greater than 1/50 or 1/100 normal, there are indications of a beneficial action on the germination. The highest stimulation of magnesium sulphate and chloride appears in concentration of 1/500 normal while that of sodium sulphate and chloride appears in concentration of 1/1000 normal. Calcium chloride shows its maximum stimulation at 1/5000 normal while sodium carbonate

and bicarbonate show in concentration of 1/500–1/1000 and 1/100 normal respectively.

4) The toxicity on the growth of rice seedlings appears in the case of magnesium sulphate and chloride, calcium chloride, sodium chloride and carbonate in concentration greater than 1/100 normal, while sodium sulphate and bicarbonate each in concentration greater than 1/50 normal. The maximum stimulation point of these salts is attained in the dilution of 1/500 normal for magnesium sulphate, 1/1000–1/5000 normal for magnesium and calcium chlorides, 1/50– 1/100 normal for sodium sulphate, 1/100 normal for sodium chloride, 1/100–1/500 normal for sodium carbonate and bicarbonate.

5) The toxic and highest stimulating effects of the salts upon the growth of rice plants in the experiment with the soil we used are shown in the following amounts:

Salts	Amount of salt added to 2000 g. of soil	
	Toxic amount	Highest stimulating amount
	g. mol wt.	g. mol. wt.
$MgSO_4$	$\frac{1}{10}$	$\frac{1}{20}-\frac{1}{200}$
$MgCl_2$	$\frac{1}{20}-\frac{1}{100}$	$\frac{1}{100}-\frac{1}{200}$
$CaCl_2$	$\frac{1}{100}$	$\frac{1}{200}-\frac{1}{1000}$
Na_2SO_4	$\frac{1}{20}-\frac{1}{100}$	$\frac{1}{200}-\frac{1}{1000}$
$NaCl$	$\frac{1}{20}$	$\frac{1}{100}-\frac{1}{200}$
Na_2CO_3	$\frac{1}{20}$	$\frac{1}{100}-\frac{1}{1000}$
$NaHCO_3$	$\frac{1}{10}$	$\frac{1}{100}-\frac{1}{200}$

6) The amount of toxic and highest stimulation of the salts upon the growth of rice plants varies with the nature of the culture media. It is generally higher in soils than in pure solution.

7) The resistant power of rice toward these salts seems to be almost equal to that of wheat and weaker than maize, but stronger than oats and sorghum.

II. On the Antagonism between two Salts relating to their toxic Effect upon the Growth of Rice Seedlings.

The results of the experiments with single salt solutions have been described in the preceding chapter, but it can not be correlated with our knowledge of alkali soils, since as Kearney and Cameron[1] pointed out, in nature we have always to do with a mixture of salts and never with single solutions. They found in connection with Loeb's striking results with marine animals that by adding sodium salts to the solution of magnesium salts the critical concentrations of the latter could be raised considerably and in the case of *Lupinus albus* and *Medicago sativa*, the neutralizing effect became enormous when salts of calcium were added to the solutions of sulphates and chlorides of magnesium and sodium.

The physiology of the decreasing toxicity of a salt due to the presence of a second salt in the solution, was specially discussed by Osterhout[2] from the view point of Loeb's conception of a "physiologically balanced salts solution". As the result of investigations, it has been shown that marine plants as well as marine animals are very sensitive to pure salt solutions, but thrive well in solutions containing a mixture of salts, even though each component is present in an amount that is toxic in pure solution. A mixture of the more important salts present in sea water, each at about the concentration at which it occurs in the sea, was found to be the best medium for the growth of marine algea. Moreover, the same phenomenon has been observed in the case of land plants.

Kearney and Harter[3] also investigated the neutralizing effect of calcium sulphate upon the toxicity of magnecium and sodium salts with

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1). Kearney and Cameron,—l. c.

2). Osterhaut,—Jour. Biol. Chem., **1**, pp. 363–369 (1906); Bot. Gaz., **42**, pp. 127–134 (1906); Univ. Cal. Pubs. Bot., **2**, p. 317 (1907); Jahrb. f. Wissensch. Bot., **46**, p. 121 (1908); Bot. Gaz., **45**, p. 117 (1908); Univ. Cal. Pubs. Bot., **3**, pp. 331–337 (1908); Bot. Gaz., **48**, pp. 98–104 (1909).

3). Kearney, and Harter,—l. c.

eight different land plants and found that the presence of calcium sulphate tends very greatly to diminish, not only the differences between different species as to their tolerance of magnesium and sodium salts, but also the differences between the latter in their toxicity to the same species, and the neutralizing effect of calcium sulphate is generally much more marked with the magnesium than with the sodium salts.

In 1907, Benecke[1] also studied the poisonous action of various salts upon the growth of spirogyra. The result of his investigation was summarized as follows: chloride, nitrate, sulphate and phosphate of sodium potassium, magnesium and iron are more or less poisonous, and among these cations iron and magnesium are more poisonous than potassium, sodium is less poisonous than potassium; among the anions, chlorine is least poisonous. The toxicity of these anions and cations can be neutralized or decreased by the addition of calcium iron. Loew and Aso[2] also studied the same subject in relation to spirogyra and observed that calcium salts can prevent the toxic effects of magnesium salts while potassium salts can retard but not entirely prevent the injurious action of the same.

Takeuchi[3] pointed out, at the end of his investigation of the behavior of algae in relation to salts at certain concentration, that the injurious action of magnesium salts can only completely be overcome by calcium salts, and not by sodium or potassium salts, which has been observed not only with algae, but also with young plants of barley and maize which were deprived of their endosperm.

Hansteen[4] has recently investigated the antagonism between cations upon the growth of wheat seedlings and shown that the pure solution of potassium, sodium and magnesium salts are more or less injurious according to their concentrations. But in combination with calcium salts, their injurious effect on the growth of leaves, roots and root-hairs is greatly

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1). Benecke,—Ber. D. bot. Ges., **25**, p. 322 (1907).

2). Loew and Aso,—Bull. Coll. Agric., Tokyo Imp. Univ., **7**, pp. 395–409 (1906–1908).

3). Takeuchi,—Bull. Coll. Agric., Tokyo Imp. Univ., **7**, p. 628 (1906–1908).

4). Hansteen,—Nyt. Mag. Naturvidensk., **47**, pp. 181–192 (1909); ref. Exp. Sta. Rec., U. S. Dept. of Agriculture, **23**, p. 28 (1910).

decreased and especially calcium has a strong antagonistic action which served as protection of root growth.

Toxic and antagonistic effects of salts as related to ammonification by *Bacillus subtilis* were also studied by Lipman[1] and the following conclusions were reported: "1. Each of the four chlorides ($CaCl_2$, $MgCl_2$, KCl, NaCl) is toxic for *Bacillus subtilis*, in the order given, the first being the most toxic and the fourth the least. This is quite different from the results with higher plants, where magnesium is the most toxic and calcium the least. 2. A marked antagonism exists between calcium and potassium, magnesium and sodium, potassium and sodium. 3. No antagonism exsists between magnesium and calcium, but the toxic effect of each is increased by combination with the other. This is just the opposite of what has hitherto been found for plants".

As yet no investigation has been made regarding the antagonistic effects of salts upon the growth of rice plants, we have selected the chlorides of sodium, potassium, magnesium and calcium, and the sulphates of sodium, potassium and magnesium, the nitrates of sodium and potassium, as the salts to be tested and examined the respective antagonisms between these two salts in different combinations by one of the following methods.

Method A. Eight beakers of about 5.5 cm. diameter and 7 cm. deep, each containing 30 cc. of culture fluids, served for the experiment. Seven beakers received 1/10 N. A[2] solution 30 cc., 1/10 N. A solution 25 cc. + 1/10 N. B[2] solution 5 cc., 1/10 N. A solution 20 cc. + 1/10 N. B solution 10 cc., 1/10 N. A solution 15 cc. + 1/10 N. B solution 15 cc., 1/10 N. A solution 10 cc. + 1/10 N. B solution 20 cc., 1/10 N. A solution 5 cc. + 1/10 N. B solution 25 cc. and 1/10 N. B solution 30 cc. respectively, while 1 beaker containing distilled water served as control. The young rice seedlings which were grown in distilled water from seeds of almost uniform size and specific gravity (1.185–1.200), were transplanted into the beakers, each receiving five healthy individuals of uniform size (about 10–

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1). Lipman,—Bot. Gaz., **48**, pp. 105–124 (1909).

2). A and B denote the salts to be tested in the experiment. As already proved in the previous chapter, a pure solution of the salts under test is very injurious upon the growth of rice seedlings in the concentration of 1/10 normal.

25 mm. high) and kept in a green house. The evaporated water was supplemented with distilled water from time to time to keep solutions always in their initial concentrations. The measurement was made when the difference in development in the respective cultures was strikingly noticeable.

Method B. The experiment was carried out in the same manner as in method A excepting the sowing of 25 seeds in place of the transplanting of 5 seedlings. The plants were grown in a room of ordinary temperature.

In carying out the experiments described beyond the method A has been adopted unless otherwise stated.

A. The Antagonism between two Salts with different Cation but same Anion.

The antagonism between two salts with different cation and same anion was tested in nine combinations with the following results:

1. Result with NaCl and KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. NaCl 30 cc.	35	35	2×
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. KCl 5 cc.	60	45	6×
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. KCl 10 cc.	55	45	6×
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. KCl 15 cc.	55	40	6×
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. KCl 20 cc.	42	45	7×
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. KCl 25 cc.	50	35	6×
$\frac{1}{10}$ N. KCl 30 cc.	40	25	6×
Distilled water 30 cc.	68	43	7

× Only one root (primary root) was well developed.

Culture period.................... Feb. 1st—Feb. 18th (1913).

Initial length of seedlings.......... 20 mm.

2. Resutlt with Na_2SO_4 and K_2SO_4.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	35	35	2×
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. K_2SO_4 5 cc.	67	43	6×
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. K_2SO_4 10 cc.	47	37	6×
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. K_2SO_4 15 cc.	47	37	6×
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. K_2SO_4 20 cc.	47	35	6×
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. K_2SO_4 25 cc.	50	43	7×
$\frac{1}{10}$ N. K_2SO_4 30 cc.	40	37	6×
Distilled water 30 cc.	68	43	7

Culture period ………………… Feb. 1st—Feb. 18th (1913).
Initial length of seedlings ……… 20 mm.

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3. Result with $NaNO_3$ and KNO_3.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $NaNO_3$ 30 cc.	35	35	2×
$\frac{1}{10}$ N. $NaNO_3$ 25 cc. + $\frac{1}{10}$ N. KNO_3 5 cc.	60	37	7×
$\frac{1}{10}$ N. $NaNO_3$ 20 cc. + $\frac{1}{10}$ N. KNO_3 10 cc.	50	40	6×
$\frac{1}{10}$ N. $NaNO_3$ 15 cc. + $\frac{1}{10}$ N. KNO_3 15 cc.	50	35	7×
$\frac{1}{10}$ N. $NaNO_3$ 10 cc. + $\frac{1}{10}$ N. KNO_3 20 cc.	43	35	7×
$\frac{1}{10}$ N. $NaNO_3$ 5 cc. + $\frac{1}{10}$ N. KNO_3 25 cc.	50	35	7×
$\frac{1}{10}$ N. KNO_3 30 cc.	40	35	4×
Distilled water 30 cc.	68	43	7

Culture period ………………… Feb. 1st—Feb. 18th (1913).
Initial length of seedlings ……… 20 mm.

4. Resul with NaCl and $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. NaCl 30 cc.	38	25	1
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc.	57	40	$6^{\times}$
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc.	53	30	$4^{\times}$
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc.	50	32	$3^{\times}$
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc.	45	28	$2^{\times}$
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc.	45	20	1
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	42	20	1
Distilled water 30 cc.	50	80	6

Culture period···················Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ········10 mm.

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5. Result with Na_2SO_4 and $MgSO_4$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	35	1
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. $MgSO_4$ 5 cc.	60	40	$5^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. $MgSO_4$ 10 cc.	55	30	$5^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. $MgSO_4$ 15 cc.	55	35	$4^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. $MgSO_4$ 20 cc.	55	40	$3^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. $MgSO_4$ 25 cc.	50	33	1
$\frac{1}{10}$ N. $MgSO_4$ 30 cc.	40	20	1
Distilled water 30 cc.	80	50	7

Culture period···················Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ········20 mm.

6. Result with NaCl and CaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. NaCl 30 cc.	38	25	1
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	69	60	9
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	55	50	7
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	47	35	5
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	47	40	5
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc.	47	35	3
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	40	35	1
Distilled water 30 cc.	50	80	6

Culture period····················Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ·········10 mm.

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7. Result with KCl and $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. KCl 30 cc.	40	17	3
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc.	60	16	4
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc.	58	15	6
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc.	55	15	7
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc.	55	15	5
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc.	56	21	4
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	43	23	3
Distilled water 30 cc.	63	47	11

Culture period····················March 7th—March 24th (1913).
Initial length of seedlings ········25 mm.

8. Result with KCl and $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. KCl 30 cc.	40	17	3
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	68	51	10
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	65	25	8
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	65	25	8
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	65	25	8
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc.	64	20	8
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	35	18	3
Distilled water 30 cc.	63	47	11

Culture period ·················· March 7th—March 24th (1913).
Initial length of seedlings ·········· 25 mm.

9. Result with $MgCl_2$ and $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	35	8	1
$\frac{1}{10}$ N. $CaCl_2$ 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc.	55	5	2
$\frac{1}{10}$ N. $CaCl_2$ 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc.	80	6	5
$\frac{1}{10}$ N. $CaCl_2$ 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc.	95	25	4
$\frac{1}{10}$ N. $CaCl_2$ 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc.	105	22	5
$\frac{1}{10}$ N. $CaCl_2$ 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc.	110	40	8
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	45	5	1

Method ························ B.
Culture period ··················· July 30th—August 20th (1912).

From the results, it is clear that the poisonous effects of these salts more or less completely disappear when we mix the two salts, specially in faboravle proportions, this phenomenon being due to the antagonism between two different cations, since the anions were the same in all the combinations.

In a favorable mixture of sodium and potassium, sodium and magnesium, potassium and magnesium ions, the length of leaf became almost equal to that of control plant, but the growth and the number of roots were invariably poor. It is evident, therefore, that the toxic effect of sodium, potassium and magnesium ions was mutually counteracted by combination of each other, but not completely neutralized. The curve of antagonism between sodium and potassium ions shows two maxima and the location of these maxima is almost constant, occurring at the point of the proportion of 5 : 25. It is also seen that the potassium ion has superior efficacy over the sodium ion in neutralizing the toxic effect of each other. The neutralizing power of magnesium ion toward the toxic effect of sodium or potassium ion was greater than that of sodium or potassium to magnesium as in the case of 1/10 N. NaCl 25 cc. + 1/10 N. $MgCl_2$ 5 cc., 1/10 N. Na_2SO_4 25 cc. + 1/10 N. $MgSO_4$ 5 cc. or 1/10 N. KCl 25 cc. + 1/10 N. $MgCl_2$ 5 cc., when the highest development of the seedlings was really observed.

On the other hand, in a mixture of sodium and calcium, potassium and calcium, magnesium and calcium ions in proper proportions, the toxic effect of these ions is almost mutually counteracted and a medium is produced in which the plant may grow almost perfectly. The toxic effect of sodium, potassium and magnesium ions almost completely disappeared when a little calcium ion is added; on the contrary, the poisonous effect of calcium ion was excluded only by the addition of a large amount of other ions.

B. The Antagonism between two Salts with different Anion but same Cation.

In the above nine combinations, we examined the antagonisms between the metallic ions in regard to their toxic effects upon the growth of rice seedlings. We then undertook to investigate the question of the mutual power of counteracting the injurious effects of anions upon the development of rice plants. The following seven culture fluids which were composed of two salts with different anion but same cation, were used to be examined. The results obtained were as follows:

1. Result with NaCl and Na_2SO_4.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. NaCl 30 cc.	42	30	1
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. Na_2SO_4 5 cc.	60	40	1
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. Na_2SO_4 10 cc.	53	30	1
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. Na_2SO_4 15 cc.	42	30	1
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. Na_2SO_4 20 cc.	52	30	1
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. Na_2SO_4 25 cc.	55	30	1
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	35	1
Distilled water 30 cc.	80	50	7

Culture period………………… Nov. 19th—Oct. 1st (1912).
Initial length of seedlings……… 20 mm.

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2. Result with KCl and K_2SO_4.

Solutions used	Legnth of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. KCl 30 cc.	40	35	6×
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. K_2SO_4 5 cc.	47	43	7×
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. K_2SO_4 10 cc.	47	35	6×
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. K_2SO_4 15 cc.	40	32	6×
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. K_2SO_4 20 cc.	50	50	7×
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. K_2SO_4 25 cc.	47	35	7×
$\frac{1}{10}$ N. K_2SO_4 30 cc.	35	25	6×
Distilled water 30 cc.	58	43	7

Culture period………………… Feb. 1st.—Feb. 18th (1913).
Initial length of seedlings………… 20 mm.

3. Result with $MgCl_2$ and $MgSO_4$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	45	35	1
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $MgSO_4$ 5 cc.	60	40	1
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $MgSO_4$ 10 cc.	55	30	1
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $MgSO_4$ 15 cc.	48	30	1
$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $MgSO_4$ 20 cc.	50	25	1
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $MgSO_4$ 25 cc.	55	25	1
$\frac{1}{10}$ N. $MgSO_4$ 30 cc.	40	25	1
Distilled water 30 cc.	80	50	7

Culture period ···················· Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ·········· 20 mm.

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4. Result with $NaNO_3$ and NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $NaNO_3$ 30 cc.	43	25	1
$\frac{1}{10}$ N. $NaNO_3$ 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc.	63	35	$7^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 20 cc. + $\frac{1}{10}$ N. NaCl 10 cc.	59	30	$6^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 15 cc. + $\frac{1}{10}$ N. NaCl 15 cc.	55	35	$6^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 10 cc. + $\frac{1}{10}$ N. NaCl 20 cc.	50	25	$5^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 5 cc. + $\frac{1}{10}$ N. NaCl 25 cc.	57	30	$6^{\times}$
$\frac{1}{10}$ N. NaCl 30 cc.	46	25	$3^{\times}$
Distilled water 30 cc.	78	58	7

Culture period ···················· Feb. 20th—March 5th (1913).
Initial length of seedlings ·········· 25 mm.

5. Result with KNO_3 and KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. KNO_3 30 cc.	45	25	3×
$\frac{1}{10}$ N. KNO_3 25 cc. + $\frac{1}{10}$ N. KCl 5 cc.	60	35	6×
$\frac{1}{10}$ N. KNO_3 20 cc. + $\frac{1}{10}$ N. KCl 10 cc.	50	35	6×
$\frac{1}{10}$ N. KNO_3 15 cc. + $\frac{1}{10}$ N. KCl 15 cc.	48	30	6×
$\frac{1}{10}$ N. KNO_3 10 cc. + $\frac{1}{10}$ N. KCl 20 cc.	50	40	7×
$\frac{1}{10}$ N. KNO_3 5 cc. + $\frac{1}{10}$ N. KCl 25 cc.	72	40	7×
$\frac{1}{10}$ N. KCl 30 cc.	50	25	7×
Distilled water 30 cc.	78	58	7

Culture period··············· ·····Feb. 20th—March 5th (1913).
Initial length of seedlings ·········25 mm.

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6. Result with Na_2SO_4 and $NaNO_3$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	35	35	2×
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. $NaNO_3$ 5 cc.	52	35	5×
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. $NaNO_3$ 10 cc.	52	35	5×
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. $NaNO_3$ 15 cc.	40	35	5×
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. $NaNO_3$ 20 cc.	50	35	5×
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. $NaNO_3$ 25 cc.	45	30	5×
$\frac{1}{10}$ N. $NaNO_3$ 30 cc.	35	35	2×
Distilled water 30 cc.	68	43	7

Culture period····················Feb. 1st—Feb. 18th (1913).
Initial length of seedlings···· ····20 mm.

7. Result with K_2SO_4 and KNO_3.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. K_2SO_4 30 cc.	40	35	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 25 cc. + $\frac{1}{10}$ N. KNO_3 5 cc.	58	45	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 20 cc. + $\frac{1}{10}$ N. KNO_3 10 cc.	53	38	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 15 cc. + $\frac{1}{10}$ N. KNO_3 15 cc.	45	38	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 10 cc. + $\frac{1}{10}$ N. KNO_3 20 cc.	50	42	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 5 cc. + $\frac{1}{10}$ N. KNO_3 25 cc.	40	35	$6^{\times}$
$\frac{1}{10}$ N. KNO_3 30 cc.	40	35	$4^{\times}$
Distilled water 30 cc.	68	43	7

Culture period···················Feb. 1st—Feb. 18th (1913).
Initial length of seedlings··········20 mm.

From the results, we observe that in a mixture of these salts the toxic effects ef each salt is mutually counteracted, though not completely. The counteraction observed is doubtless due to the actions between the anions (Cl' and SO_4'', Cl' and NO_3', NO_3' and SO_4'') present in the culture media since the cations in both salts are the same in all combinations. It is also observed that the mutual counteraction between these anions is less than in case of cations as already described. The curve of antagonism between these anions shows two maxima as in the case of the antagonism between sodium and potassium, and the location of these maxima is almost constant, occurring at the point of the proportion of 5 : 25 while that of antagonization of SO_4'' toward the toxic effect of NO_3' appeared in proportion of 10 : 20. The neutralizing power of SO_4'' toward the toxic effect of Cl' seems to be greater than that of Cl' to SO_4''. It seems also that NO_3' has superior efficacy over SO_4'' in neutralizing the toxic effect of the other.

C. The Antagonism between two Salts with different Cation and different Anion.

The antagonism between two salts with different cation and different anion was examined in ten combinations with the following results:

1. Result with K_2SO_4 and NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. K_2SO_4 30 cc.	47	35	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc.	68	35	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 20 cc. + $\frac{1}{10}$ N. NaCl 10 cc.	59	35	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 15 cc. + $\frac{1}{10}$ N. NaCl 15 cc.	52	30	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 10 cc. + $\frac{1}{10}$ N. NaCl 20 cc.	60	33	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 5 cc. + $\frac{1}{10}$ N. NaCl 25 cc.	65	35	$6^{\times}$
$\frac{1}{10}$ N. NaCl 30 cc.	46	25	$3^{\times}$
Distilled water 30 cc.	78	58	7

Culture period ·········· Feb. 20th—March 5th (1913).
Initial length of seedlings ·········· 25 mm.

2. Result with Na_2SO_4 and KC l.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	20	$2^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. KCl 5 cc.	72	25	$7^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. KCl 10 cc.	65	26	$7^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. KCl 15 cc.	60	18	$6^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. KCl 20 cc.	64	25	$7^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. KCl 25 cc.	71	28	$5^{\times}$
$\frac{1}{10}$ N. KCl 30 cc.	50	25	$7^{\times}$
Distilled water 30 cc.	78	58	7

Culture period ·········· Feb. 20th—March 5th (1913).
Initial length of seedlings ·········· 25 mm.

3. Result with KNO_3 and NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. KNO_3 30 cc.	45	25	$3^{\times}$
$\frac{1}{10}$ N. KNO_3 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc.	65	30	$5^{\times}$
$\frac{1}{10}$ N. KNO_3 20 cc. + $\frac{1}{10}$ N. NaCl 10 cc.	62	30	$5^{\times}$
$\frac{1}{10}$ N. KNO_3 15 cc. + $\frac{1}{10}$ N. NaCl 15 cc.	60	25	$4^{\times}$
$\frac{1}{10}$ N. KNO_3 10 cc. + $\frac{1}{10}$ N. NaCl 20 cc.	63	25	$5^{\times}$
$\frac{1}{10}$ N. KNO_3 5 cc. + $\frac{1}{10}$ N. NaCl 25 cc.	75	35	$7^{\times}$
$\frac{1}{10}$ N. NaCl 30 cc.	46	25	1
Distilled water 30 cc.	78	58	1

Culture period····················Feb. 20th—March 5th (1913).
Initial length of seedlings ·········25 mm.

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4. Result with $NaNO_3$ and KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $NaNO_3$ 30 cc.	43	20	1
$\frac{1}{10}$ N. $NaNO_3$ 25 cc. + $\frac{1}{10}$ KCl 5 cc.	75	30	$7^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 20 cc. + $\frac{1}{10}$ KCl 10 cc.	65	35	$6^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 15 cc. + $\frac{1}{10}$ KCl 15 cc.	62	35	$6^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 10 cc. + $\frac{1}{10}$ KCl 20 cc.	64	25	$4^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 5 cc. + $\frac{1}{10}$ KCl 25 cc.	70	25	$7^{\times}$
$\frac{1}{10}$ N. KCl 30 cc.	50	25	$7^{\times}$
Distilled water 30 cc.	78	58	7

Culture period····················Feb. 20th—March 5th (1913).
Initial length of seedlings ···· ····25 mm.

5. Result with Na_2SO_4 and KNO_3.

Solutions used	Length of leaf mm	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	20	$2^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. KNO_3 5 cc.	65	35	$6^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. KNO_3 10 cc.	70	30	$7^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. KNO_3 15 cc.	60	30	$3^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. KNO_3 20 cc.	77	30	$7^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. KNO_3 25 cc.	60	35	$4^{\times}$
$\frac{1}{10}$ N. KNO_3 30 cc.	45	25	$3^{\times}$
Distilled water 30 cc.	78	58	7

Culture period ····················Feb. 20th—March 5th (1913).
Initial length of seedlings ·········25 mm.

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6. Result with K_2SO_4 and $NaNO_3$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. K_2SO_4 30 cc.	47	35	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 25 cc. + $\frac{1}{10}$ N. $NaNO_3$ 5 cc.	73	30	$7^{\times}$
$\frac{1}{10}$ N. K_2SO_4 20 cc. + $\frac{1}{10}$ N. $NaNO_3$ 10 cc.	60	20	$5^{\times}$
$\frac{1}{10}$ N. K_2SO_4 15 cc. + $\frac{1}{10}$ N. $NaNO_3$ 15 cc.	60	25	$5^{\times}$
$\frac{1}{10}$ N. K_2SO_4 10 cc. + $\frac{1}{10}$ N. $NaNO_3$ 20 cc.	60	35	$6^{\times}$
$\frac{1}{10}$ N. K_2SO_4 5 cc. + $\frac{1}{10}$ N. $NaNO_3$ 25 cc.	72	40	$5^{\times}$
$\frac{1}{10}$ N. $NaNO_3$ 30 cc.	43	20	1
Distilled water 30 cc.	78	58	7

Culture period····················Feb. 20th—March 5th (1913).
Initial length of seedlings ··········25 mm.

7. Result with NaCl and $MgSO_4$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. NaCl 30 cc.	38	25	1
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $MgSO_4$ 5 cc.	55	37	$6^{\times}$
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $MgSO_4$ 10 cc.	50	33	$4^{\times}$
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $MgSO_4$ 15 cc.	45	30	$3^{\times}$
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $MgSO_4$ 20 cc.	48	31	1
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $MgSO_4$ 25 cc.	48	32	1
$\frac{1}{10}$ N. $MgSO_4$ 30 cc.	30	35	1
Distilled water 30 cc.	50	80	6

Culture period ···················· Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ·········· 10 mm.

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8. Result with Na_2SO_4 and $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	35	1
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc.	80	40	$6^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc.	80	38	$6^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc.	65	45	$4^{\times}$
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc.	50	30	1
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc.	60	25	1
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	55	40	1
Distilled water 30 cc.	80	50	7

Culture period ···················· Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ·········· 20 mm.

9. Result with Na_2SO_4 and $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. Na_2SO_4 30 cc.	45	35	1
$\frac{1}{10}$ N. Na_2SO_4 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	80	90	9
$\frac{1}{10}$ N. Na_2SO_4 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	80	90	7
$\frac{1}{10}$ N. Na_2SO_4 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	70	50	7
$\frac{1}{10}$ N. Na_2SO_4 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	57	30	5
$\frac{1}{10}$ N. Na_2SO_4 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc.	50	38	4
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	45	25	1
Distilled water 30 cc.	80	50	7

Culture period ···················· Nov. 19th—Oct. 1st (1912).
Initial length of seedlings ········· 20 mm.

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10. Result with $MgSO_4$ and $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
$\frac{1}{10}$ N. $MgSO_4$ 30 cc.	50	23	1
$\frac{1}{10}$ N. $MgSO_4$ 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	135	55	4
$\frac{1}{10}$ N. $MgSO_4$ 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	135	50	6
$\frac{1}{10}$ N. $MgSO_4$ 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	120	45	6
$\frac{1}{10}$ N. $MgSO_4$ 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	85	25	4
$\frac{1}{10}$ N. $MgSO_4$ 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25cc.	80	18	3
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	35	8	1

Method ······················· B.
Culture period ················· July 20th—August 29th (1912).

As will be seen in the above results, in a suitable mixture of these salts, except calcium salt, their toxic effects disappear largely but not completely while in a mixture with calcium salt in a favorable proportion, the toxic effect of each salt completely disappears and a medium is produced in which the plant may grow almost perfectly as in the case of the antagonism between cations already observed. The presence of calcium ion in a culture medium seems to be a most important factor for the growth of plants and especially for root growth.

It is also observed that the combined antagonistic actions of cations and anions have a more favorable effect than that of either one of them, though the antagonism between anions in such case seems to be overcome to a large extent by that between cations.

D. Summary.

From the above results, we may summarize as follows:

1) The salts under examination, used separately, are very poisonous in 1/10 normal concentration upon the growth of rice plants, but when the two salts are mixed with each other in a suitable proportion, the toxic effect of each salt more or less completely disappears. The result is of great importance in alkali soil investigations and forms an important factor in the question of soil fertility.

2) The antagonistic action of salts is due to that of the ions formed by the dissociation of the salt.

3) The antagonism between anions is weak in comparison with that between cations.

4) Among cations, divalent cations are markedly antagonistic to monovalent, but on the contrary, monovalent cations do not strongly antagonize divalent cations.

5) The monovalent cations, sodium and potassium, are antagonized by each other. Consequently, the curve of antagonism between these ions shows two maxima, but the antagonistic power of potassium to neutralize the toxic effect of sodium is greater than that of sodium to potassium.

6) Among the divalent cations, calcium shows a more marked antagonism than magnesium. The presence of calcium in a culture medium is an essential factor for the growth of plants especially for root growth and only in such case, toxic effect of other ions is completely disappeared.

7) The anions are almost equally antagonized by each other. The curve of antagonism between the anions shows, therefore, two maxima as in the case of sodium and potassium.

8) The neutralizing power of SO_4'' toward the toxic effect of Cl' seems to be greater than that of Cl' to SO_4''. Again, NO_3' seems to have superior efficacy over SO_4'' in neutralizing the toxic effect of the other.

9) The combined antagonistic actions of cations and anions have a more favorable effect than that of one of them, though the antagonism between anions in such case seems to be overcome to a large extent by that between cations.

III. Can Barium or Strontium replace Calcium in its antagonistic Action?

In the previous chapter, it was pointed out that the injurious action of the metallic ions upon the growth of rice seedlings is perfectly neutralized by the presence of calcium ion. Whether or not barium and strontium which are so similar in chemical properties with calcium, can exert the same beneficial action as calcium in counteracting the toxic effect of other metallic ions forms an important subject of study. For the solution of this problem the following experiments were made.

A. Experiment with $MgCl_2$.

Twenty beakers of about 5.5 cm. diameter and 7 cm. deep, served for the experiment. While 1 beaker which contained 30 cc. of distilled water, served as check, the other 19 beakers received 1/10 N. $MgCl_2$ 30 cc., 1/10 N. $MgCl_2$ 25 cc. + 1/10 N. $CaCl_2$ 5 cc., 1/10 N. $MgCl_2$ 20 cc.

+ 1/10 N. $CaCl_2$ 10 cc., 1/10 N. $MgCl_2$ 15 cc. + 1/10 N. $CaCl_2$ 15 cc., 1/10 N. $MgCl_2$ 10 cc. + 1/10 N. $CaCl_2$ 20 cc., 1/10 N. $MgCl_2$ 5 cc. + 1/10 N. $CaCl_2$ 25 cc., 1/10 N. $CaCl_2$ 30 cc., 1/10 N. $MgCl_2$ 25 cc. + 1/10 N. $BaCl_2$ 5 cc., 1/10 N. $MgCl_2$ 20 cc. + 1/10 N. $BaCl_2$ 10 cc., 1/10 N. $MgCl_2$ 15 cc. + 1/10 N. $BaCl_2$ 15 cc., 1/10 N. $MgCl_2$ 10 cc. + 1/10 N. $BaCl_2$ 20 cc., 1/10 N. $MgCl_2$ 5 cc. + 1/10 N. $BaCl_2$ 25 cc., 1/10 N. $BaCl_2$ 30 cc., 1/10 N. $MgCl_2$ 25 cc. + 1/10 N. $SrCl_2$ 5 cc., 1/10 N. $MgCl_2$ 20 cc. + 1/10 N. $SrCl_2$ 10 cc., 1/10 N. $MgCl_2$ 15 cc. + 1/10 N. $SrCl_2$ 15 cc., 1/10 N. $MgCl_2$ 10 cc. + 1/10 N. $SrCl_2$ 20 cc., 1/10 N. $MgCl_2$ 5 cc. + 1/10 N. $SrCl_2$ 25 cc. and 1/10 N. $SrCl_2$ 30 cc. respectively. Five seedlings, about 25 mm. high, which were grown in distilled water from seeds of almost uniform size and specific gravity (1.185–1.200), were transplanted in each beaker on February 25th (1913) and kept in a green house. The evaporated water was supplemented with distilled water from time to time so as to keep the culture solutions always in their initial concentration. On March 14th, the difference in development in the respective culture was very striking, when the measurement was made with the following result:

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	68	60	8
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	53	12	1
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	68	50	9
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	65	40	10
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	62	35	8
$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	60	20	8
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc.	52	15	6
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	44	12	8
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $BaCl_2$ 5 cc.	40	12	1
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $BaCl_2$ 10 cc.	33	10	1
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $BaCl_2$ 15 cc.	28	8	1

$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $BaCl_2$ 20 cc.	28	7	1
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $BaCl_2$ 25 cc.	28	5	1
$\frac{1}{10}$ N. $BaCl_2$ 30 cc.	24	8	1
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $SrCl_2$ 5 cc.	60	12	3
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $SrCl_2$ 10 cc.	45	8	3
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $SrCl_2$ 15 cc.	40	5	2
$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $SrCl_2$ 20 cc.	35	7	1
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $SrCl_2$ 25 cc.	30	9	1
$\frac{1}{10}$ N. $SrCl_2$ 30 cc.	22	8	1

The result shows that the presence of calcium in proper proportion can exert a beneficial action, while in the case of barium, on the contrary, a depression resulted. Although strontium in suitable proportion retarded the toxic action of magnesium, it is far inferior to calcium.

B. Experiment with NaCl.

Twenty beakers, each containing 30 cc. of culture fluids, served for the experiment. The culture solutions were prepared in the same proportion as in experiment A, excepting the use of sodium chloride in place of magnesium chloride.

Five seedlings, about 20 mm. high, were transplanted in each beaker on March 7th (1913) and kept in a green house. The evaporated water was supplemented with distilled water from time to time as in the preceding experiment. The plants had developed very well with remarkable differences in growth. The plants were measured on March 24th with the following result which coincides with that of the preceding experiment.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	65	50	9
$\frac{1}{10}$ N. NaCl 30 cc.	44	13	1

$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc.	70	40	9
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc.	70	40	9
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc.	60	25	8
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc.	56	20	8
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc.	50	20	6
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	44	22	6
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $BaCl_2$ 5 cc.	40	20	3
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $BaCl_2$ 10 cc.	41	18	5
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $BaCl_2$ 15 cc.	30	15	3
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $BaCl_2$ 20 cc.	30	20	3
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $BaCl_2$ 25 cc.	28	17	3
$\frac{1}{10}$ N. $BaCl_2$ 30 cc.	29	10	3
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $SrCl_2$ 5 cc.	50	22	6
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $SrCl_2$ 10 cc.	47	20	4
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $SrCl_2$ 15 cc.	45	16	5
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $SrCl_2$ 20 cc.	40	10	4
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $SrCl_2$ 25 cc.	36	16	4
$\frac{1}{10}$ N. $SrCl_2$ 30 cc.	28	15	3

C. Summary.

The injurious effect of the metallic ions upon the growth of rice seedlings is perfectly counteracted only by the presence of calcium ion while strontium ion can exert but a slight influence in neutralizing the toxicity of the other cations. Barium ion not only has no beneficial action, but rather a depressing effect is observed. It is tbus seen that barium or strontium in the concentration used can not replace calcium in its antagonistic action.

IV. A most favorable Ratio of Calcium to Magnesium or Sodium for the Neutralization of the Toxicity.

It was shown in previous chapter that the toxicity of various salts common in alkali soils is a specific property of the ions. It has also been shown that a mixture of two salts, both of which are toxic in pure solution, is much less injurious than either one alone, or that there is an antagonistic action of the salts. The strength of the antagonism varies between the different cations. The presence of calcium in a culture medium is an essential factor for the growth of plants, especially for root growth and only in such case, toxic effect of other cations is almost completely neutralized.

Without further consideration it will be easily seen that the significance of an antagonism between two salts, specially calcium and other cations, is very great in the proper management of alkali soils. In view of this consideration, it will be of vast interest to find a suitable ratio between calcium and other cations, at which the plant can grow most favorably, under varying concentrations. To determine this, calcium chloride was added to the solution of the chloride of magnesium or of sodium in such amount that all the culture solutions in a series would contain the same amount of chlorine, with but varying ratios of calcium to magnesium or sodium. Fifteen different ratios were tried, namely 15 : 15, 14 : 16, 13 : 17, 12 : 18, 11 : 19, 10 : 20, 9 : 21, 8 : 22, 7 : 23, 6 : 24, 5 : 25, 4 : 26, 3 : 27, 2 : 28, 1 : 29; each series being under three different concentrations of 1/20, 1/10 and 1/5 normal of the salts tested.

The experiments were conducted in beakers of about 5.5 cm. in diameter and 7 cm. deep, each containing 30 cc. of the solutions as noted in the following tables. The seeds of almost uniform size and specific gravity were germinated in glass dishes containing distilled water. When the plumules were about 20 mm. long four seedlings were transferred to each of the beakers. Seedlings were selected with the greatest care, so that those in each solution in a series should be as equal as possible in length of plumule and radicle. The beakers were then covered with glass plates and kept in a green house. The evaporated water was supplemented with distilled water from time to time to keep the solutions always in their initial concentrations. After ten days, the difference in development in the respective cultures was very remarkable, when the measurements were made with the following results.

1. Results with $CaCl_2$ versus NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	60	55	6
$\frac{1}{20}$ N. $CaCl_2$ 30 cc.	45	40	5×
$\frac{1}{20}$ N. $CaCl_2$ 15 cc. + $\frac{1}{20}$ N. NaCl 15 cc.	68	70	6
$\frac{1}{20}$ N. $CaCl_2$ 14 cc. + $\frac{1}{20}$ N. NaCl 16 cc.	70	60	6
$\frac{1}{20}$ N. $CaCl_2$ 13 cc. + $\frac{1}{20}$ N. NaCl 17 cc.	65	70	6
$\frac{1}{20}$ N. $CaCl_2$ 12 cc. + $\frac{1}{20}$ N. NaCl 18 cc.	68	80	6
$\frac{1}{20}$ N. $CaCl_2$ 11 cc. + $\frac{1}{20}$ N. NaCl 19 cc.	73	75	7
$\frac{1}{20}$ N. $CaCl_2$ 10 cc. + $\frac{1}{20}$ N. NaCl 20 cc.	73	78	7
$\frac{1}{20}$ N. $CaCl_2$ 9 cc. + $\frac{1}{20}$ N. NaCl 21 cc.	68	75	6
$\frac{1}{20}$ N. $CaCl_2$ 8 cc. + $\frac{1}{20}$ N. NaCl 22 cc.	68	75	6
$\frac{1}{20}$ N. $CaCl_2$ 7 cc. + $\frac{1}{20}$ N. NaCl 23 cc.	68	79	6
$\frac{1}{20}$ N. $CaCl_2$ 6 cc. + $\frac{1}{20}$ N. NaCl 24 cc.	70	85	7
$\frac{1}{20}$ N. $CaCl_2$ 5 cc. + $\frac{1}{20}$ N. NaCl 25 cc.	73	85	8
$\frac{1}{20}$ N. $CaCl_2$ 4 cc. + $\frac{1}{20}$ N. NaCl 26 cc.	70	80	7
$\frac{1}{20}$ N. $CaCl_2$ 3 cc. + $\frac{1}{20}$ N. NaCl 27 cc.	70	90	5
$\frac{1}{20}$ N. $CaCl_2$ 2 cc. + $\frac{1}{20}$ N. NaCl 28 cc.	65	80	5
$\frac{1}{20}$ N. $CaCl_2$ 1 cc. + $\frac{1}{20}$ N. NaCl 29 cc.	68	70	6
$\frac{1}{20}$ N. NaCl 30 cc.	57	20	1

$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	42	25	$5^{\times}$
$\frac{1}{10}$ N. $CaCl_2$ 15 cc. + $\frac{1}{10}$ N. NaCl 15 cc.	55	25	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 14 cc. + $\frac{1}{10}$ N. NaCl 16 cc.	65	40	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 13 cc. + $\frac{1}{10}$ N. NaCl 17 cc.	65	40	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 12 cc. + $\frac{1}{10}$ N. NaCl 18 cc.	48	35	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 11 cc. + $\frac{1}{10}$ N. NaCl 19 cc.	50	35	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 10 cc. + $\frac{1}{10}$ N. NaCl 20 cc.	50	30	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 9 cc. + $\frac{1}{10}$ N. NaCl 21 cc.	50	40	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 8 cc. + $\frac{1}{10}$ N. NaCl 22 cc.	50	40	6^{o}
$\frac{1}{10}$ N. $CaCl_2$ 7 cc. + $\frac{1}{10}$ N. NaCl 23 cc.	55	45	6
$\frac{1}{10}$ N. $CaCl_2$ 6 cc. + $\frac{1}{10}$ N. NaCl 24 cc.	65	45	6
$\frac{1}{10}$ N. $CaCl_2$ 5 cc. + $\frac{1}{10}$ N. NaCl 25 cc.	68	45	7
$\frac{1}{10}$ N. $CaCl_2$ 4 cc. + $\frac{1}{10}$ N. NaCl 26 cc.	68	45	6
$\frac{1}{10}$ N. $CaCl_2$ 3 cc. + $\frac{1}{10}$ N. NaCl 27 cc.	60	45	6
$\frac{1}{10}$ N. $CaCl_2$ 2 cc. + $\frac{1}{10}$ N. NaCl 28 cc.	63	45	6
$\frac{1}{10}$ N. $CaCl_2$ 1 cc. + $\frac{1}{10}$ N. NaCl 29 cc.	68	55	7
$\frac{1}{10}$ N. NaCl 30 cc.	45	15	1
$\frac{1}{5}$ N. $CaCl_2$ 30 cc.	27	20	$3^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 15 cc. + $\frac{1}{5}$ N. NaCl 15 cc.	35	20	$4^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 14 cc. + $\frac{1}{5}$ N. NaCl 16 cc.	35	20	$4^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 13 cc. + $\frac{1}{5}$ N. NaCl 17 cc.	37	20	$4^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 12 cc. + $\frac{1}{5}$ N. NaCl 18 cc.	35	20	$4^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 11 cc. + $\frac{1}{5}$ N. NaCl 19 cc.	38	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 10 cc. + $\frac{1}{5}$ N. NaCl 20 cc.	38	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 9 cc. + $\frac{1}{5}$ N. NaCl 21 cc.	38	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 8 cc. + $\frac{1}{5}$ N. NaCl 22 cc.	38	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 7 cc. + $\frac{1}{5}$ N. NaCl 23 cc.	38	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 6 cc. + $\frac{1}{5}$ N. NaCl 24 cc.	40	30	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 5 cc. + $\frac{1}{5}$ N. NaCl 25 cc.	48	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 4 cc. + $\frac{1}{5}$ N. NaCl 26 cc.	45	25	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 3 cc. + $\frac{1}{5}$ N. NaCl 27 cc.	40	20	$5^{\times}$
$\frac{1}{5}$ N. $CaCl_2$ 2 cc. + $\frac{1}{5}$ N. NaCl 28 cc.	38	25	$5^{\times}$

$\frac{1}{5}$ N. $CaCl_2$ 1 cc. + $\frac{1}{5}$ N. NaCl 29 cc.	30	20	3×
$\frac{1}{5}$ N. NaCl 30 cc.	30	10	1

2. Results with $CaCl_2$ versus $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	60	55	6
$\frac{1}{20}$ N. $CaCl_2$ 30 cc.	45	40	5×
$\frac{1}{20}$ N. $CaCl_2$ 15 cc. + $\frac{1}{20}$ N. $MgCl_2$ 15 cc.	70	45	6
$\frac{1}{20}$ N. $CaCl_2$ 14 cc. + $\frac{1}{20}$ N. $MgCl_2$ 16 cc.	75	45	6
$\frac{1}{20}$ N. $CaCl_2$ 13 cc. + $\frac{1}{20}$ N. $MgCl_2$ 17 cc.	68	40	6°
$\frac{1}{20}$ N. $CaCl_2$ 12 cc. + $\frac{1}{20}$ N. $MgCl_2$ 18 cc.	70	40	6°
$\frac{1}{20}$ N. $CaCl_2$ 11 cc. + $\frac{1}{20}$ N. $MgCl_2$ 19 cc.	75	45	7
$\frac{1}{20}$ N. $CaCl_2$ 10 cc. + $\frac{1}{20}$ N. $MgCl_2$ 20 cc.	75	45	7
$\frac{1}{20}$ N. $CaCl_2$ 9 cc. + $\frac{1}{20}$ N. $MgCl_2$ 21 cc.	70	45	7
$\frac{1}{20}$ N. $CaCl_2$ 8 cc. + $\frac{1}{20}$ N. $MgCl_2$ 22 cc.	68	45	7°
$\frac{1}{20}$ N. $CaCl_2$ 7 cc. + $\frac{1}{20}$ N. $MgCl_2$ 23 cc.	68	40	7°
$\frac{1}{20}$ N. $CaCl_2$ 6 cc. + $\frac{1}{20}$ N. $MgCl_2$ 24 cc.	70	45	7
$\frac{1}{20}$ N. $CaCl_2$ 5 cc. + $\frac{1}{20}$ N. $MgCl_2$ 25 cc.	75	55	7
$\frac{1}{20}$ N. $CaCl_2$ 4 cc. + $\frac{1}{20}$ N. $MgCl_2$ 26 cc.	72	40	7
$\frac{1}{20}$ N. $CaCl_2$ 3 cc. + $\frac{1}{20}$ N. $MgCl_2$ 27 cc.	68	40	7°
$\frac{1}{20}$ N. $CaCl_2$ 2 cc. + $\frac{1}{20}$ N. $MgCl_2$ 28 cc.	70	40	6°
$\frac{1}{20}$ N. $CaCl_2$ 1 cc. + $\frac{1}{20}$ N. $MgCl_2$ 29 cc.	70	40	6°
$\frac{1}{20}$ N. $MgCl_2$ 30 cc.	65	30	3×
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	42	25	5×
$\frac{1}{10}$ N. $CaCl_2$ 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc.	60	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 14 cc. + $\frac{1}{10}$ N. $MgCl_2$ 16 cc.	70	45	7°
$\frac{1}{10}$ N. $CaCl_2$ 13 cc. + $\frac{1}{10}$ N. $MgCl_2$ 17 cc.	65	40	6°
$\frac{1}{10}$ N. $CaCl_2$ 12 cc. + $\frac{1}{10}$ N. $MgCl_2$ 18 cc.	68	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 11 cc. + $\frac{1}{10}$ N. $MgCl_2$ 19 cc.	65	30	7°
$\frac{1}{10}$ N. $CaCl_2$ 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc.	65	30	7°

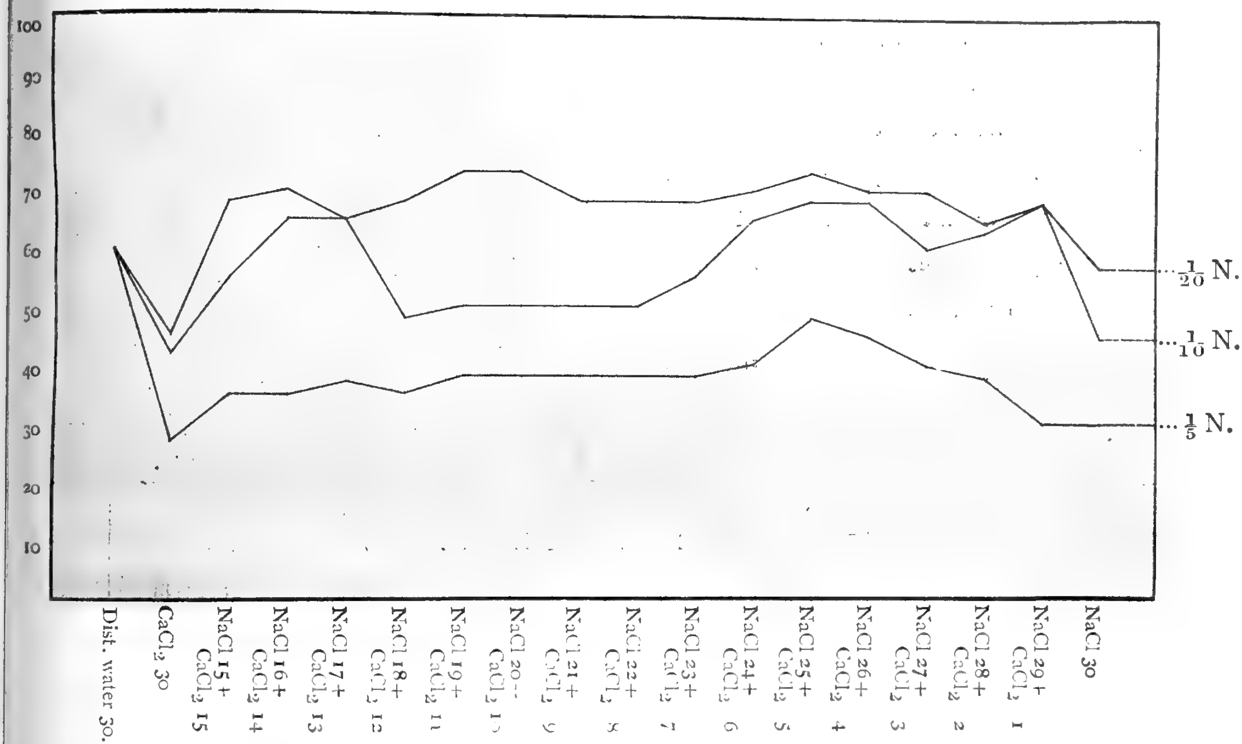
$\frac{1}{10}$ N. $CaCl_2$ 9 cc. + $\frac{1}{10}$ N. $MgCl_2$ 21 cc.	60	35	6°
$\frac{1}{10}$ N. $CaCl_2$ 8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 22 cc.	60	35	6°
$\frac{1}{10}$ N. $CaCl_2$ 7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 23 cc.	65	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 6 cc. + $\frac{1}{10}$ N. $MgCl_2$ 24 cc.	68	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc.	72	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 4 cc. + $\frac{1}{10}$ N. $MgCl_2$ 26 cc.	68	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 27 cc.	65	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 28 cc.	68	40	7°
$\frac{1}{10}$ N. $CaCl_2$ 1 cc. + $\frac{1}{10}$ N. $MgCl_2$ 29 cc.	72	35	7°
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	55	25	3×
$\frac{1}{5}$ N. $CaCl_2$ 30 cc.	27	20	3×
$\frac{1}{5}$ N. $CaCl_2$ 15 cc. + $\frac{1}{5}$ N. $MgCl_2$ 15 cc.	32	25	5×
$\frac{1}{5}$ N. $CaCl_2$ 14 cc. + $\frac{1}{5}$ N. $MgCl_2$ 16 cc.	40	25	5×
$\frac{1}{5}$ N. $CaCl_2$ 13 cc. + $\frac{1}{5}$ N. $MgCl_2$ 17 cc.	50	25	5×
$\frac{1}{5}$ N. $CaCl_2$ 12 cc. + $\frac{1}{5}$ N. $MgCl_2$ 18 cc.	46	25	5×
$\frac{1}{5}$ N. $CaCl_2$ 11 cc. + $\frac{1}{5}$ N. $MgCl_2$ 19 cc.	46	25	5×
$\frac{1}{5}$ N. $CaCl_2$ 10 cc. + $\frac{1}{5}$ N. $MgCl_2$ 20 cc.	50	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 9 cc. + $\frac{1}{5}$ N. $MgCl_2$ 21 cc.	50	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 8 cc. + $\frac{1}{5}$ N. $MgCl_2$ 22 cc.	45	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 7 cc. + $\frac{1}{5}$ N. $MgCl_2$ 23 cc.	50	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 6 cc. + $\frac{1}{5}$ N. $MgCl_2$ 24 cc.	55	35	5×
$\frac{1}{5}$ N. $CaCl_2$ 5 cc. + $\frac{1}{5}$ N. $MgCl_2$ 25 cc.	58	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 4 cc. + $\frac{1}{5}$ N. $MgCl_2$ 26 cc.	53	30	5×
$\frac{1}{5}$ N. $CaCl_2$ 3 cc. + $\frac{1}{5}$ N. $MgCl_2$ 27 cc.	50	20	5×
$\frac{1}{5}$ N. $CaCl_2$ 2 cc. + $\frac{1}{5}$ N. $MgCl_2$ 28 cc.	48	25	4×
$\frac{1}{5}$ N. $CaCl_2$ 1 cc. + $\frac{1}{5}$ N. $MgCl_2$ 29 cc.	55	20	4×
$\frac{1}{5}$ N. $MgCl_2$ 30 cc.	40	25	1

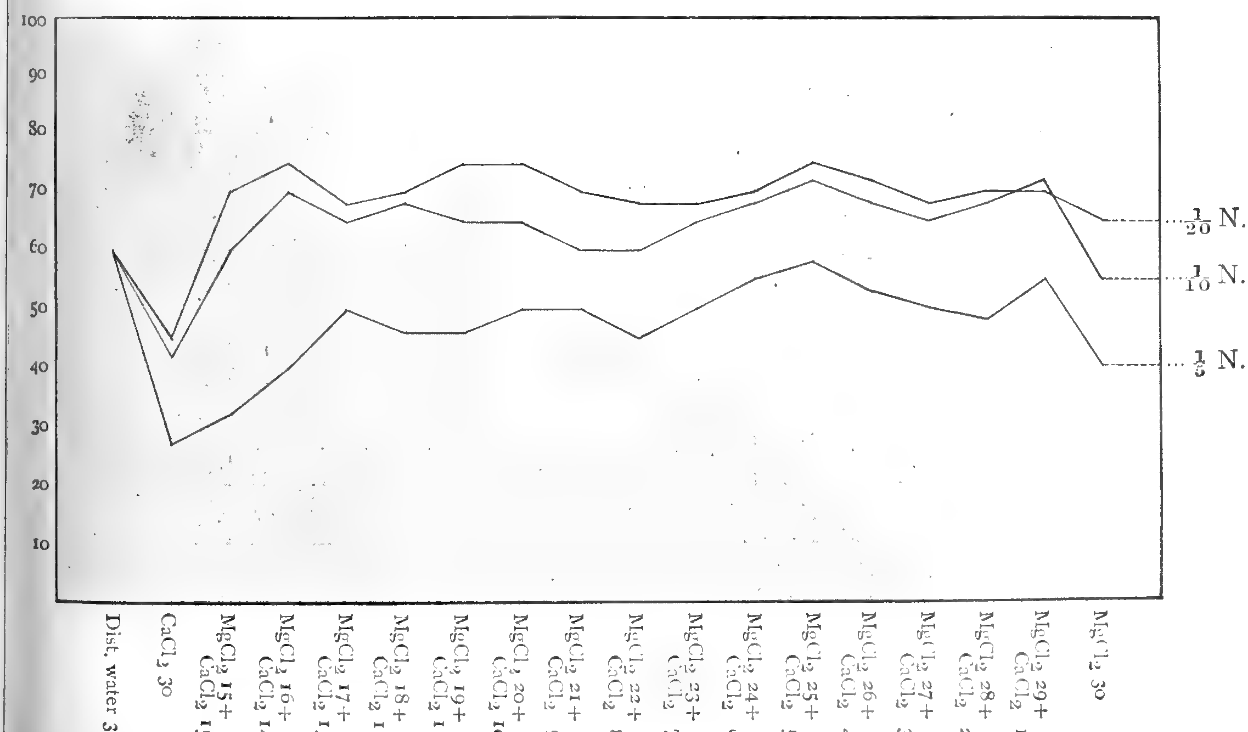
× Only one root (primary root) was well developed.

° The several rootlets were not equally developed. The devclopment of root, therefore, was far inferior to that of control plant.

Culture period ....Feb. 6th—Feb. 16th (1914).

The marginal units are in millimeter.





The results show that in all the concentrations tried, the suitable ratio of the cations, calcium and magnesium or calcium and sodium had a favorable effect upon the growth of the plants. The plants did much better where calcium and magnesium or calcium and sodium were present in the ratio 5 : 25.[1] The more concentrated the solution the greater was the difference in effect between the ratio 5 : 25 and the other ratios. In higher concentrations than dicinormal, however, the plants did not grow so well as in distilled water even in the most favorable ratio.

V. Influence of a third Salt upon the Growth of Rice Seedlings in a Mixture of two Salts.

Some years ago Loeb[2] and Ostwald[3] found from the study of marine and freshwater animals that as the toxicity of a pure solution is diminished by the addition of a second salt, so is the toxicity of certain mixtures diminished by the addition of a third or fourth salt, and by addition of various salts a mixture known as balanced solution (i. e., one which is no more injurious than distilled water) can finally be obtained. In view of this fact, Osterhout[4] made a number of experiments with the salts which are contained in sea water with marine, freshwater as well as land plants and proved that facts similar to those mentioned above are also observed even in plants. According to him, the order of

1) Some years ago Loew advanced the theory that plants made their maximum growth-other conditions, of course, being favorable—when the available lime and magnesia are present in a certain ratio to each other, the optimum ratio for rice plants being to $\frac{CaO}{MgO} = 1$. But, this ratio of lime to magnesia seems to apply only in a medium in which a sufficient amount of other nutritive salts is present.

2) Loeb,—Pflüger's Archiv, **107** P. 252 (1905).

3) Ostwald,—Ibid., **106** P. 568 (1905).

4) Osterhout,—Bot. Gaz., **42**, p. 127 (1906); **44**, p. 259 (1907).

the decreasing toxicity of the mixtures[1] upon the duration of life of *Ruppia maritima* is as follows:

1. NaCl
2. NaCl + KCl
3. NaCl + $MgCl_2$
4. NaCl + $CaCl_2$
5. NaCl + KCl + $CaCl_2$
6. NaCl + KCl + $CaCl_2$ + $MgCl_2$ + $MgSO_4$
7. Sea water.

The subject seemed to us to be of much importance as well as of interest for the solution of the question of alkali soils. We have therefore selected chloride of sodium, potassium, magnesium and calcium as the salts to be tested and the experiments were conducted as follows.

Thirty four beakers of about 5.5 cm diamenter and 7 cm. deep, each containing 30 cc of culture fluids, served for the experiment. Thirty three beakers received the solutions noted in the tables below while one beaker containing distilled water served as control. The seed of almost uniform size and specific gravity were germinated in glass dishes holding distilled water. When the plumules were about 10–20 mm. long five seedlings, after being washed several times with distilled water, were transferred to each of the culture beakers and kept in a green house. The beakers were then covered with glass plates to exclude dust and retard evaporation as much as possible. The evaporated water was supplemented with distilled water from time to time to keep the solutions always in their initial concentrations. The measurement was made when the difference in development in the respective culture was strikingly noticeable. The results were as follows.

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1) Each salt in the mixtures was mixed according to the amount of Van't Hoff's formula of artificial sea water as follows: 1000 cc. NaCl 3m/8; 78 cc. $MgCl_2$ 3m/8; 38 cc. $MgSO_4$ 3m/8; 22 cc. KCl 3m/8; 10 cc. $CaCl_2$ 3m/8.

1. **Results with NaCl + KCl + $MgCl_2$.**

A. **NaCl + KCl versus $MgCl_2$.**

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**63**	**40**	**7**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. = A	62	29	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	**75**	**40**	**7**
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	72	35	7
,, 15 cc. + ,, 15 ɔc. (,, 12.5 + ,, 2.5 + ,, 15.0)	63	33	$6^{\times}$
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	65	30	$6^{\times}$
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	72	35	$4^{\times}$
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. KCl 10 cc. = B	59	30	$5^{\times}$
B 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	72	35	6°
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	70	30	6°
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	67	30	$6^{\times}$
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	65	30	$6^{\times}$
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	65	30	$5^{\times}$
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. KCl 15 cc. = C	53	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	65	20	7°
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	75	38	7°

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	72	27	6×
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	63	27	5×
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	70	30	5×
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. KCl 20 cc. = D	48	23	5×
D 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	66	35	7°
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	73	38	7°
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	66	30	7×
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	70	30	6×
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	75	35	5×
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. KCl 25 cc. = E	50	27	3×
E 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	67	27	5°
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	76	38	7°
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	63	37	7×
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	65	30	5×
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	77	30	5×
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	44	20	1

× Only one root (primary root) was well developed.

° The several rootlets were not equally developed. The development of root, therefore, was far inferior to that of control plants.

Culture period ………………Oct. 18th—Dec. 4th (1913).

Initial length of seedlings ………20 mm.

B. $NaCl + MgCl_2$ versus KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**47**	**27**	**5**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. = A	56	20	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	62	20	6°
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	67	15	6°
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	48	19	$5^{\times}$
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	48	14	$5^{\times}$
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	56	15	$6^{\times}$
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc. = B	56	20	$3^{\times}$
B 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	73	20	6°
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	60	20	6°
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	47	16	$5^{\times}$
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	48	20	$4^{\times}$
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	55	20	$5^{\times}$
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc. = C	51	15	$3^{\times}$
C 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	57	20	$5^{\times}$
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	60	18	$6^{\times}$

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	48	15	$6^{\times}$
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	55	23	$5^{\times}$
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	60	18	$4^{\times}$
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc = D	45	15	1
D 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	55	15	$5^{\times}$
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	70	20	6°
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	47	20	$4^{\times}$
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	55	20	5°
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	53	15	$4^{\times}$
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc. = E	46	15	1
E 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20.8 cc + $\frac{1}{10}$ N. KCl 5.0 cc.)	58	20	$5^{\times}$
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	61	26	6°
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	48	15	$5^{\times}$
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	45	18	$6^{\times}$
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	55	17	$5^{\times}$
$\frac{1}{10}$ N. KCl 30 cc.	45	15	$4^{\times}$

Culture period · ······· ······· Dec. 19th (1913)—Jan. 7th (1914).
Initial length of seedlings·· · ·····10 mm.

C. $KCl + MgCl_2$ versus NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**47**	**27**	**5**
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. = A	50	20	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	58	20	$5^{\times}$
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	53	23	$5^{\times}$
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	50	17	$6^{\times}$
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	52	20	$5^{\times}$
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	43	19	$5^{\times}$
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc. = B	44	19	$5^{\times}$
B 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	46	18	$5^{\times}$
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	55	25	$6^{\times}$
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	53	19	$6^{\times}$
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	50	19	$5^{\times}$
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	52	15	$4^{\times}$
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc. = C	46	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	60	20	7°
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	60	20	$6^{\times}$

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	55	20	5×
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	60	15	5×
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	60	20	6×
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc. = D	48	19	5×
D 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	60	20	6×
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	60	23	6×
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	60	25	5×
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	52	20	6×
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	62	20	6×
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc. = E	50	15	4×
E 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20.8 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	62	22	5×
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	60	20	4×
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	60	25	5×
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	65	25	5×
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	60	25	6×
$\frac{1}{10}$ N. NaCl 30 cc.	39	9	1

Culture period .... Dec. 19th (1913)—Jan. 7th (1914).

Initial length of seedlings .... 10 mm.

2. Results with NaCl + KCl + $CaCl_2$.

A. NaCl + KCl versus $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**63**	**40**	**7**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. = A	62	29	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**80**	**70**	**8**
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	**68**	**50**	**7**
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	65	40	7°
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	73	50	7°
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	65	50	6°
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. KCl 10 cc. = B	59	30	$5^{\times}$
B 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $NaCl_2$ 5.0 cc.)	**80**	**60**	**7**
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	**63**	**40**	**7**
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	65	35	5°
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	73	45	6°
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	63	40	5°
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. KCl 15 cc. = C	53	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**80**	**60**	**7**
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	**67**	**60**	**6**

„ 15 cc. + „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	65	48	7
„ 10 cc. + „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	**75**	**48**	**7**
„ 5 cc. + „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	65	38	7°
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. KCl 20 cc. = D	48	23	$5^{\times}$
D 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**80**	**60**	**7**
„ 20 cc. + „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	**70**	**43**	**7**
„ 15 cc. + „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	68	33	6°
„ 10 cc. + „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	73	50	7°
„ 5 cc. + „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	70	35	7°
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. KCl 25 cc. = E	50	27	$3^{\times}$
E 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**80**	**60**	**7**
„ 20 cc. + „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	**68**	**48**	**6**
„ 15 cc. + „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	60	40	7°
„ 10 cc. + „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	68	35	7°
„ 5 cc. + „ 25 cc („ 0.8 + „ 4.2 + „ 25.0)	68	40	7°
$\frac{1}{10}$ $CaCl_2$ 30 cc.	43	30	$5^{\times}$

Culture period ··············· Oct. 18th—Dec. 4th (1913).

Initial length of seedlings ········· 20 mm.

B. $NaCl + CaCl_2$ versus KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**50**	**37**	**4**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	52	47	5
A 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	**62**	**50**	**6**
" 20 cc. + " 10 cc. (" 16.7 + " 3.3 + " 10.0)	**58**	**40**	**6**
" 15 cc. + " 15 cc. (" 12.5 + " 2.5 + " 15.0)	**57**	**40**	**5**
" 10 cc. + " 20 cc. (" 8.3 + " 1.7 + " 20.0)	**53**	**45**	**4**
" 5 cc. + " 25 cc. (" 4.2 + " 0.8 + " 25.0)	**60**	**37**	**5**
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	56	40	5
B 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	62	60	5°
" 20 cc. + " 10 cc. (" 13.3 + " 6.7 + " 10.0)	53	42	5°
" 15 cc. + " 15 cc. (" 10.0 + " 5.0 + " 15.0)	50	40	4°
" 10 cc. + " 20 cc. (" 6.7 + " 3.3 + " 20.0)	**60**	**50**	**6**
" 5 cc. + " 25 cc. (" 3.3 + " 1.7 + " 25.0)	**65**	**60**	**6**
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	53	40	4°
C 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	53	40	4°
" 20 cc. + " 10 cc. (" 10.0 + " 10.0 + " 10.0)	55	42	4°

„ 15 cc.+ „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	**65**	**50**	**5**
„ 10 cc.+ „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	**60**	**45**	**6**
„ 5 cc.+ „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	**60**	**50**	**6**
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	47	40	$4^{\times}$
D 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	48	38	$4^{\times}$
„ 20 cc.+ „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	63	45	5°
„ 15 cc.+ „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	**67**	**55**	**6**
„ 10 cc.+ „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	**53**	**40**	**5**
„ 5 cc.+ „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	**55**	**55**	**5**
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	38	30	$4^{\times}$
E 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	52	43	$4^{\times}$
„ 20 cc.+ „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	55	45	$4^{\times}$
„ 15 cc.+ „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	60	40	5°
„ 10 cc.+ „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	53	35	$4^{\times}$
„ 5 cc.+ „ 25 cc. („ 0.8 + „ 4.2 + „ 25.0)	45	40	$4^{\times}$
$\frac{1}{10}$ N. KCl 30 cc.	48	35	$4^{\times}$

Culture period ························ Dec. 25th (1913)–Jan. 14th (1914).
Initial length of seedlings ···· ···· 10 mm.

C. KCl + $CaCl_2$ versus NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	50	35	6
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	58	40	5
A 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	75	55	8
„ 20 cc. + „ 10 cc. („ 16.7 + „ 3.3 + „ 10.0)	70	50	8
„ 15 cc. + „ 15 cc. („ 12.5 + „ 2.5 + „ 15.0)	60	45	7
„ 10 cc. + „ 20 cc. („ 8.3 + „ 1.7 + „ 20.0)	61	40	7
„ 5 cc. + „ 25 cc. („ 4.2 + „ 0.8 + „ 25.0)	68	45	8
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	58	25	6
B 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc)	65	35	6
„ 20 cc. + „ 10 cc. („ 13.3 + „ 6.7 + „ 10.0)	55	35	6
„ 15 cc. + „ 15 cc. („ 10.0 + „ 5.0 + „ 15.0)	53	35	6
„ 10 cc. + „ 20 cc. („ 6.7 + „ 3.3 + „ 20.0)	70	40	8
„ 5 cc. + „ 25 cc. („ 3.3 + „ 1.7 + „ 25.0)	75	55	7
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	55	20	6
C 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	57	20	$5^{\times}$
„ 20 cc. + „ 10 cc. („ 10.0 + „ 10.0 + „ 10.0)	55	20	$4^{\times}$

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	60	30	6
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	**63**	**38**	**6**
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	52	30	6
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	55	28	6°
D 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	63	20	6°
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	63	22	8°
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	55	30	7°
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	**60**	**35**	**7**
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	48	25	5
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	58	15	6°
E 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	68	22	7°
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	65	30	6°
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	**60**	**35**	**6**
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	**58**	**35**	**6**
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	**70**	**60**	**7**
$\frac{1}{10}$ N. NaCl 30 cc.	45	18	1

Culture period .... Jan. 12th—Jan. 29th (1914).

Initial length of seedlings .... 10 mm.

3. Results with NaCl + $MgCl_2$ + $CaCl_2$.

A. NaCl + $MgCl_2$ versus $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**47**	**27**	**5**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. = A	56	20	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**58**	**30**	**8**
„ 20 cc. + „ 10 cc. („ 16.7 + „ 3.3 + „ 10.9)	**54**	**30**	**6**
„ 15 cc. + „ 15 cc. („ 12.5 + „ 2.5 + „ 15.0)	50	25	5°
„ 10 cc. + „ 20 cc. („ 8.3 + „ 1.7 + „ 20.0)	52	17	5°
„ 5 cc. + „ 25 cc. („ 4.2 + „ 0.8 + „ 25.0)	48	14	5°
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc. = B	56	20	$3^{\times}$
B 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	46	25	6
„ 20 cc. + „ 10 cc. („ 13.3 + „ 6.7 + „ 10.0)	47	22	4°
„ 15 cc. + „ 15 cc. („ 10.0 + „ 5.0 + „ 15.0)	46	10	4°
„ 10 cc. + „ 20 cc. („ 6.7 + „ 3.3 + „ 20.0)	48	20	6°
„ 5 cc. + „ 25 cc. („ 3.3 + „ 1.7 + „ 25.0)	48	20	5°
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc. = C	51	15	$3^{\times}$
C 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	**50**	**30**	**5**
„ 20 cc. + „ 10 cc. („ 10.0 + „ 10.0 + „ 10.0)	47	20	6°

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	54	25	5°
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	45	15	5°
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	49	22	$6^{\times}$
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc. = D	45	15	1
D 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	58	25	6°
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	53	25	6°
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	47	22	$5^{\times}$
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	46	26	$5^{\times}$
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	42	15	$5^{\times}$
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc. = E	46	15	1
E 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	63	28	7°
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	45	20	$5^{\times}$
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	45	20	$5^{\times}$
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	46	20	$6^{\times}$
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	40	20	$5^{\times}$
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	35	20	$5^{\times}$

Culture period ………………… Dec. 19th (1913)—Jan. 7th (1914).

Initial length of seedlings ……… 10 mm.

B. $NaCl + CaCl_2$ versus $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**50**	**37**	**4**
$\frac{1}{10}$ N. NaCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	57	47	5
A 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	60	25	5
„ 20 cc. + „ 10 cc. („ 16.7 + „ 3.3 + „ 10.0)	54	20	4°
„ 15 cc. + „ 15 cc. („ 12.5 + „ 2.5 + „ 15.0)	52	30	$3^{\times}$
„ 10 cc. + „ 20 cc. („ 8.3 + „ 1.7 + „ 20.0)	50	30	$3^{\times}$
„ 5 cc. + „ 25 cc. („ 4.2 + „ 0.8 + „ 25.0)	56	40	$3^{\times}$
$\frac{1}{10}$ N. NaCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	56	40	5
B 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	**60**	**45**	**5**
„ 20 cc. + „ 10 cc. („ 13.3 + „ 6.7 + „ 10.0)	54	35	$4^{\times}$
„ 15 cc. + „ 15 cc. („ 10.0 + „ 5.0 + „ 15.0)	48	30	$4^{\times}$
„ 10 cc. + „ 20 cc. („ 6.7 + „ 3.3 + „ 20.0)	58	55	$5^{\times}$
„ 5 cc. + „ 25 cc. („ 3.3 + „ 1.7 + „ 25.0)	56	58	$2^{\times}$
$\frac{1}{10}$ N. NaCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	53	45	4°
C 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	50	40	$4^{\times}$
„ 20 cc. + „ 10 cc. („ 10.0 + „ 10.0 + „ 10.0)	48	45	$4^{\times}$

„ 15 cc. + „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	50	45	$5^{\times}$
„ 10 cc. + „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	55	42	$3^{\times}$
„ 5 cc. + „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	55	42	$3^{\times}$
$\frac{1}{10}$ N. NaCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	47	40	$4^{\times}$
D 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	45	35	$4^{\times}$
„ 20 cc. + „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	51	45	$4^{\times}$
„ 15 cc. + „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	53	45	$4^{\times}$
„ 10 cc. + „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	51	40	$4^{\times}$
„ 5 cc. + „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	50	45	$3^{\times}$
$\frac{1}{10}$ N. NaCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	38	30	$4^{\times}$
E 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. NaCl 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	50	50	$4^{\times}$
„ 20 cc. + „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	59	43	$4^{\times}$
„ 15 cc. + „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	51	42	$4^{\times}$
„ 10 cc. + „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	50	45	$3^{\times}$
„ 5 cc. + „ 25 cc. („ 0.8 + „ 4.2 + „ 25.0)	50	45	$3^{\times}$
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	45	35	$3^{\times}$

Culture period………………… Dec. 25th (1913)–Jan. 14th (1914).
Initial length of seedlings………… 10 mm.

C. $MgCl_2$ + $CaCl_2$ versus NaCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**50**	**35**	**6**
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	62	30	6°
A 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	65	30	6°
„ 20 cc. + „ 10 cc. („ 16.7 + „ 3.3 + „ 10.0)	55	25	6°
„ 15 cc. + „ 15 cc. („ 12.5 + „ 2.5 + „ 15.0)	68	35	7°
„ 10 cc. + „ 20 cc. („ 8.3 + „ 1.7 + „ 20.0)	**70**	**45**	**10**
„ 5 cc. + „ 25 cc. („ 4.2 + „ 0.8 + „ 25.0)	**65**	**35**	**7**
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	46	22	$6^{\times}$
B 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	50	20	6°
„ 20 cc. + „ 10 cc. („ 13.3 + „ 6.7 + „ 10.0)	70	30	7
„ 15 cc. + „ 15 cc. („ 10.0 + „ 5.0 + „ 15.0)	70	30	7
„ 10 cc. + „ 20 cc. („ 6.7 + „ 3.3 + „ 20.0)	**65**	**35**	**7**
„ 5 cc. + „ 25 cc. („ 3.3 + „ 1.7 + „ 25.0)	**50**	**40**	**6**
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	45	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	58	25	6°
„ 20 cc. + „ 10 cc. („ 10.0 + „ 10.0 + „ 10.0)	55	25	6°

„ 15 cc. + „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	55	30	6
„ 10 cc. + „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	52	25	7
„ 5 cc. + „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	48	30	7
$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	48	22	$6^{\times}$
D 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	63	25	7°
„ 20 cc. + „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	50	25	6°
„ 15 cc. + „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	57	30	6°
„ 10 cc. + „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	**67**	**40**	**8**
„ 5 cc. + „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	**70**	**45**	**8**
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	45	20	$5^{\times}$
E 25 cc. + $\frac{1}{10}$ N. NaCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. NaCl 5.0 cc.)	50	20	$5^{\times}$
„ 20 cc. + „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	53	20	$5^{\times}$
„ 15 cc. + „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	65	30	7°
„ 10 cc. + „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	60	30	7
„ 5 cc. + „ 25 cc. („ 0.8 + „ 4.2 + „ 25.0)	**58**	**45**	**8**
$\frac{1}{10}$ N. NaCl 30 cc.	45	18	1

Culture period ···················· Jan. 12th—Jan. 29th (1914).
Initial length of seedlings ········· 10 mm.

4. Results with $KCl + MgCl_2 + CaCl_2$.

A. $KCl + MgCl_2$ versus $CaCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**47**	**27**	**5**
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. = A	50	20	$5^{\times}$
A 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	62	20	7°
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	57	25	5°
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	60	30	6°
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	65	25	6°
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	56	20	6°
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $MgCl_2$ 10 cc. = B	44	19	$5^{\times}$
B 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	49	18	5°
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	54	20	6°
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	64	35	7°
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	52	17	6°
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	50	18	$5^{\times}$
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $MgCl_2$ 15 cc. = C	46	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	65	25	7°
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	63	20	6°

„ 15 cc. + „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	50	18	6°
„ 10 cc. + „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	63	25	6°
„ 5 cc. + „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	56	20	6°
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20 cc. = D	48	19	$5^{\times}$
D 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	62	15	$6^{\times}$
„ 20 cc. + „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	47	18	$5^{\times}$
„ 15 cc. + „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	47	15	$5^{\times}$
„ 10 cc. + „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	60	20	$6^{\times}$
„ 5 cc. + „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	62	20	$6^{\times}$
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 25 cc. = E	50	15	$4^{\times}$
E 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5.0 cc.)	49	20	$5^{\times}$
„ 20 cc. + „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	47	20	$5^{\times}$
„ 15 cc. + „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	51	15	$6^{\times}$
„ 10 cc. + „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	58	15	$5^{\times}$
„ 5 cc. + „ 25 cc. („ 0.8 + „ 4.2 + „ 25.0)	55	15	$5^{\times}$
$\frac{1}{10}$ N. $CaCl_2$ 30 cc.	35	20	$5^{\times}$

Culture period··················Dec. 19th (1913)—Jan. 7th (1914).
Initial length of seedlings···· ····10 mm.

B. KCl + $CaCl_2$ versus $MgCl_2$.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**50**	**35**	**6**
$\frac{1}{10}$ N. KCl 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	58	40	5
A 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	**65**	**40**	**7**
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	70	30	7
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	58	25	6°
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	62	25	6°
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	65	30	7°
$\frac{1}{10}$ N. KCl 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	58	25	6
B 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	60	30	6
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	60	28	6
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	58	23	6°
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	68	25	8°
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	72	27	9°
$\frac{1}{10}$ N. KCl 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	55	20	6
C 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	58	18	5
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	62	18	5

„ 15 cc. + „ 15 cc. („ 7.5 + „ 7.5 + „ 15.0)	67	18	6
„ 10 cc. + „ 20 cc. („ 5.0 + „ 5.0 + „ 20.0)	70	20	7
„ 5 cc. + „ 25 cc. („ 2.5 + „ 2.5 + „ 25.0)	68	20	$6^{\times}$
$\frac{1}{10}$ N. KCl 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	55	28	6°
D 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	58	15	6
„ 20 cc + „ 10 cc. („ 6.7 + „ 13.3 + „ 10.0)	73	22	8
„ 15 cc. + „ 15 cc. („ 5.0 + „ 10.0 + „ 15.0)	65	15	7°
„ 10 cc. + „ 20 cc. („ 3.3 + „ 6.7 + „ 20.0)	63	15	6°
„ 5 cc. + „ 25 cc. („ 1.7 + „ 3.3 + „ 25.0)	60	15	6°
$\frac{1}{10}$ N. KCl 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	58	15	6°
E 25 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5 cc. ($\frac{1}{10}$ N. KCl 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $MgCl_2$ 5.0 cc.)	75	15	6
„ 10 cc. + „ 10 cc. („ 3.3 + „ 16.7 + „ 10.0)	60	25	$5^{\times}$
„ 15 cc. + „ 15 cc. („ 2.5 + „ 12.5 + „ 15.0)	50	17	$5^{\times}$
„ 10 cc. + „ 20 cc. („ 1.7 + „ 8.3 + „ 20.0)	52	22	$5^{\times}$
„ 4 cc. + „ 25 cc. („ 0.8 + „ 4.2 + „ 25.0)	72	30	7°
$\frac{1}{10}$ N. $MgCl_2$ 30 cc.	48	18	1

Culture period .... Jan. 12th—Jan. 29th (1914).

Initial length of seedlings .... 10 mm.

C. $MgCl_2$ + $CaCl_2$ versus KCl.

Solutions used	Length of leaf mm.	Length of root mm.	Number of roots
Distilled water 30 cc.	**50**	**35**	**6**
$\frac{1}{10}$ N. $MgCl_2$ 25 cc. + $\frac{1}{10}$ N. $CaCl_2$ 5 cc. = A	62	30	6°
A 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 20.8 cc. + $\frac{1}{10}$ N. $CaCl_2$ 4.2 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	64	30	6°
,, 20 cc. + ,, 10 cc. (,, 16.7 + ,, 3.3 + ,, 10.0)	70	30	6°
,, 15 cc. + ,, 15 cc. (,, 12.5 + ,, 2.5 + ,, 15.0)	63	30	6°
,, 10 cc. + ,, 20 cc. (,, 8.3 + ,, 1.7 + ,, 20.0)	**70**	**35**	**7**
,, 5 cc. + ,, 25 cc. (,, 4.2 + ,, 0.8 + ,, 25.0)	**75**	**40**	**7**
$\frac{1}{10}$ N. $MgCl_2$ 20 cc. + $\frac{1}{10}$ N. $CaCl_2$ 10 cc. = B	46	22	$6^{\times}$
B 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 16.7 cc. + $\frac{1}{10}$ N. $CaCl_2$ 8.3 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	60	22	$6^{\times}$
,, 20 cc. + ,, 10 cc. (,, 13.3 + ,, 6.7 + ,, 10.0)	70	20	7°
,, 15 cc. + ,, 15 cc. (,, 10.0 + ,, 5.0 + ,, 15.0)	73	23	8
,, 10 cc. + ,, 20 cc. (,, 6.7 + ,, 3.3 + ,, 20.0)	**68**	**35**	**7**
,, 5 cc. + ,, 25 cc. (,, 3.3 + ,, 1.7 + ,, 25.0)	62	27	6
$\frac{1}{10}$ N. $MgCl_2$ 15 cc. + $\frac{1}{10}$ N. $CaCl_2$ 15 cc. = C	45	20	$5^{\times}$
C 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 12.5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 12.5 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	65	30	7°
,, 20 cc. + ,, 10 cc. (,, 10.0 + ,, 10.0 + ,, 10.0)	63	30	7°

,, 15 cc. + ,, 15 cc. (,, 7.5 + ,, 7.5 + ,, 15.0)	65	30	7°
,, 10 cc. + ,, 20 cc. (,, 5.0 + ,, 5.0 + ,, 20.0)	**69**	**35**	**7**
,, 5 cc. + ,, 25 cc. (,, 2.5 + ,, 2.5 + ,, 25.0)	50	20	6×
$\frac{1}{10}$ N. $MgCl_2$ 10 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20 cc. = D	48	22	6×
D 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 8.3 cc. + $\frac{1}{10}$ N. $CaCl_2$ 16.7 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	65	30	6×
,, 20 cc. + ,, 10 cc. (,, 6.7 + ,, 13.3 + ,, 10.0)	60	30	6×
,, 15 cc. + ,, 15 cc. (,, 5.0 + ,, 10.0 + ,, 15.0)	60	30	6
,, 10 cc. + ,, 20 cc. (,, 3.3 + ,, 6.7 + ,, 20.0)	68	30	8
,, 5 cc. + ,, 25 cc. (,, 1.7 + ,, 3.3 + ,, 25.0)	**70**	**40**	**8**
$\frac{1}{10}$ N. $MgCl_2$ 5 cc. + $\frac{1}{10}$ N. $CaCl_2$ 25 cc. = E	45	20	5×
E 25 cc. + $\frac{1}{10}$ N. KCl 5 cc. ($\frac{1}{10}$ N. $MgCl_2$ 4.2 cc. + $\frac{1}{10}$ N. $CaCl_2$ 20.8 cc. + $\frac{1}{10}$ N. KCl 5.0 cc.)	60	25	5×
,, 20 cc. + ,, 10 cc. (,, 3.3 + ,, 16.7 + ,, 10.0)	65	25	6°
,, 15 cc. + ,, 15 cc. (,, 2.5 + ,, 12.5 + ,, 15.0)	75	25	7°
,, 10 cc. + ,, 20 cc. (,, 1.7 + ,, 8.3 + ,, 20.0)	68	30	7
,, 5 cc. + ,, 25 cc. (,, 0.8 + ,, 4.2 + ,, 25.0)	67	30	7
$\frac{1}{10}$ N. KCl 30 cc.	48	18	1

Culture period ·················· Jan. 12th—Jan. 29th (1914).

Initial length of seedlings ·········· 10 mm.

Summary.

From a consideration of the results above tabulated, we may summarize as follows.

1) A mixture of three salts which are individually poisonous in like concentration produces generally a medium in which the plants grow more favorably than in that of two salts. This might be attributed to the fact that a mixture so formed approaches nearer to a balanced solution than a mixture of two salts.

2) In a mixture of three salts, the growth of the plants varies with the kind of salts. The combination ($NaCl + KCl + CaCl_2$) seems to be superior to ($NaCl + MgCl_2 + CaCl_2$) or ($KCl + MgCl_2 + CaCl_2$), while the latter two, in turn, appear to be better than ($NaCl + KCl + MgCl_2$).

3) The effect of the addition of a third salt seems to be great in the case in which the valency of its cation is different from that of the two salts already present in solution. On the contrary, the effect seems to be little when the valency of the cation of the third salt is similar to that of either of the two salts already present. For example, in the case of the combination ($NaCl + MgCl_2 + CaCl_2$), when we add NaCl to the mixture of ($MgCl_2 + CaCl_2$) the effect of the addition of a third salt (NaCl) is great, but on the other hand, when we add $MgCl_2$ or $CaCl_2$ to the mixture of ($NaCl + CaCl_2$) or ($NaCl + MgCl_2$) the effect of the addition of a third salt is little. Similarly, in combination ($NaCl + KCl + MgCl_2$) the effect of the addition of a third salt is great when we add $MgCl_2$ to the mixture of ($NaCl + KCl$), while a marked effect is not observed when we add NaCl or KCl to the mixture of ($MgCl_2 + KCl$) or ($MgCl_2 + NaCl$).

4) Each salt in a mixture of three salts must be present in certain suitable proportion for the most favorable growth of the plants. In general, in combinations of ($NaCl + KCl$) and $MgCl_2$ or $CaCl_2$ the growth of the plants is most favorable in the mixtures with large amount of NaCl and KCl and small amount of $MgCl_2$ or $CaCl_2$. So also in combinations of

NaCl or KCl and ($MgCl_2 + CaCl_2$), it is noted that by decreasing the amount of ($MgCl_2 + CaCl_2$) and increasing the amount of NaCl or KCl a favorable condition for the growth of the plants is produced.

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