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Walter F. Loehwing

University of Iowa

SAP HYDRION CONCENTRATION AS A FACTOR IN PLANT METABOLISM

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In poorly drained humid portions of the glacial drift area of the eastern half of the United States occur certain unproductive organic soils which superficially resemble fertile loams. Analyses of these unproductive types generally disclose high acidity and mineral deficiency, especially of potassium. In many instances, however, lime employed to correct acidity, and potash to increase the nutrient value of the soil have proven injurious instead of beneficial to grain crops. The present investigation was undertaken to determine the explanation of the anomalous response and the exact nature of the injury.

Four soils known to differ in their response to lime and potash fertilizers were employed. Analyses of the soils used are given in table I. Chemically pure salts were thoroughly mixed with each soil and 3200 gm. portions were placed in glazed earthenware crocks to which were added 800 c. c. of distilled water. Lime was added in slight excess of the indicated lime requirement to neutralize latent acidity and improve soil tilth. Victory oats were planted on treated soils and their growth under controlled greenhouse conditions compared with that of the same crop on untreated (check) soils. At the close of the tenth week the entire crop, including roots, was harvested and analyzed as shown in table II.

If plant yield (dry weight) be taken as a criterion, it may be stated that lime proved injurious on the first three soils, but was beneficial on the fourth. Potash applications were deleterious in the

Table I — Chemical Analyses of four untreated muck soils

	Percentage Dry Weight			
	Soil 1	Soil 2	Soil 3	Soil 4
Total calcium	1.67	0.08	3.44	3.54
Total magnesium	0.18	0.10	0.40	1.02
Total iron	0.10	2.02	1.21	2.22
Total potassium	0.30	1.52	0.29	1.05
Total phosphorus	0.34	0.08	0.19	0.20
Total sulphur	0.44	0.11	0.54	0.20
Total nitrogen	3.90	1.42	3.62	1.22
Volatile matter	83.00	42.61	48.10	47.78
Lime requirement ppm	2700.00	3500.00	2700.00	1200.00

Table II — Chemical Analyses of Victory Oats

Salt Added (ppm)	Percentage Dry Weight								Sap Extract		Dry
	Iron	Magnesium	Calcium	Potassium	Nitrate Nitrogen	Total Nitrogen	Total Sugars	Total Carbohydrates	Osmotic Pressure (atm)	pH	Weight Yield (gms)
Soil 1											
Check	0.067	0.16	0.40	0.47	0.18	2.25	4.51	13.80	5.40	6.0	5.70
400 KCl	0.080	0.08	0.31	0.82	0.26	2.01	5.09	11.41	5.80	5.1	4.12
4000 $CaCO_3$	0.089	0.28	0.57	0.30	0.69	1.70	4.40	10.07	4.25	6.5	3.78
Soil 2											
Check	0.120	0.27	0.35	0.75	0.38	1.74	5.20	9.60	6.30	5.2	4.73
400 KCl	0.140	0.12	0.14	0.90	0.09	1.13	5.69	9.02	6.65	5.0	2.76
4000 $CaCO_3$	0.090	0.30	0.49	0.37	0.97	0.90	5.31	7.52	6.52	5.9	4.20
Soil 3											
Check	0.046	0.33	0.32	0.91	0.21	1.80	3.77	10.32	3.85	4.9	4.88
400 KCl	0.053	0.21	0.42	1.19	0.07	2.33	5.26	12.41	4.81	4.5	5.71
4000 $CaCO_3$	0.082	0.38	0.58	0.46	0.92	1.67	5.20	8.75	3.00	6.2	2.90
Soil 4											
Check	0.081	0.22	0.29	0.74	0.61	1.75	6.46	11.94	4.26	4.7	3.70
400 KCl	0.097	0.20	0.19	0.95	0.40	1.94	7.00	12.49	5.70	4.4	5.10
4000 $CaCO_3$	0.061	0.29	0.26	0.57	0.30	2.07	8.11	13.40	4.92	5.8	4.37

case of the first two but helpful on the last two soils. The degree of injury varied and in a few cases was restricted to diminution of dry weight yield. Mature leaves of plants suffering noticeable injury following use of lime were elongate, flaccid, dull in color with wavy margins and puckered surfaces, while young leaves were more distinctly yellow than those of equal age on check plants. The external appearance of mature leaves suggested potash insufficiency as the cause of poor growth, an explanation which finds support in the observed depression in potassium content of tissues following use of lime. Marked suppression of potash intake was in all cases correlated with a decrease of sap hydrion concentration, carbohydrates, and total nitrogen of tissues. Nitrate increments in the tissues were probably attributable to the accumulation of nitrates in the soil in the presence of lime and their subsequent entry into the plant where these nitrates remained as such because the plant was unable to synthesize them into proteins in the absence of an adequate supply of carbohydrates.

Carbohydrate metabolism was also influenced by the diminished hydrion concentration of sap following lime additions. It was at first difficult to reconcile the chlorotic appearance of young leaves with the high iron content of the lime-injured plants but microchemical examinations disclosed that chlorosis was due to reduced sap acidity which led to precipitation of iron in roots and basal stem nodes. Had roots and tops been analyzed separately practically no iron would have been found in the tops. Paucity of iron in the leaves apparently retarded chlorophyll development and hence further diminished carbohydrate synthesis. Consequently the conclusion is inescapable that reduced sap acidity interferred not so much with iron intake as with mobility of iron within the plants.

On soil 4, which was relatively high in iron, lime proved beneficial by allaying iron toxicity. No chlorosis was noted following the use of lime and microchemical examination disclosed iron in foliar vessels and mesophyll. Among the plants from limed soils those of soil 4 had the most acid sap, a fact which probably explains their ability to transport sufficient iron to the leaves. The total iron supply, however, was less than in the check plants. Crops on soil 4, though slightly benefited by potash amendments, responded best to dressings of potash combined with moderate amounts of lime.

Plants in the check cultures of soil 1 developed small, yellowish, mottled leaves with irregular dark green patches near the midrib. These symptoms were accentuated by applications of potash. Increased sap acidity and augmented iron and potassium content of tissues were the invariable consequences of potassium amendments. These gains, however, appeared to be made at the expense of lime and magnesia, facts which suggest that basic exchange in colloidal soil complexes may also profoundly influence the mineral balance within the crops. Foliar discoloration and underdevelopment reflect the deficiency of magnesia and lime respectively. The effect of magnesium hunger was essentially localized in the leaves.

Plants on soil 2, relatively high in iron, were injured by applications of potash. Injured leaves displayed numerous minute spots and roots were discolored. Use of potassium chloride is known to result in ionic interchange in the soil, the effect of which is to increase soil acidity and hence the solubility of toxic iron salts. This explanation of the injury is suggested by the high acidity and iron content of this soil as well as by the analogous behavior of acid, mineral soils under similar conditions.

The response of crops to potash on soil 3 was very favorable, owing apparently to the fact that it increased iron availability without diminishing the intake of calcium or magnesium to the point of insufficiency. The rise in osmotic pressure of the sap in the plants on soils 3 and 4, following use of potash, was coupled with an increase in its ash content. This fact points to more effective absorption of soluble mineral nutrients from the soil.

From the foregoing data it appears that increased absorption of certain mineral nutrients by plants on unproductive muck soils involves diminished intake of others. Hence there may occur simultaneously the injury of excess with respect to one ion and of insufficiency with respect to another. Crop response to mineral fertilizers added to these soils is striking, a behavior which is due probably to disturbance of the critical internal nutrient balance. Shifts in the internal nutrient balance are correlated with marked changes in sap hydrion concentration. All these facts suggest profound alteration in the soil solution following use of lime or potash. Ionic replacement in the colloidal fraction of the soils and preferential absorption of certain ions by plants following additions of mineral fertilizers may render the soil solution toxic.

Potash amendments have been known to induce magnesium deficiency and iron toxicity on mineral soils. Many instances of lime-induced chlorosis are also on record. Hence, though crops grown on muck and mineral soils differ in their response to lime and potash applications, it appears that this difference is more in degree than in kind. The greater sensitivity of crops on muck soils is clearly associated with more critical nutrient and hydrion fluctuations in the soil and cell sap. Internally, lack of balance among mineral nutrients often interferes with adequate carbohydrate and protein synthesis. So clearly are certain phases of carbon and nitrogen metabolism linked with mineral balance in the tissues of plants grown on the above described muck soils that these soils acquire a scientific importance entirely apart from their agricultural value.

UNIVERSITY OF IOWA,
IOWA CITY.