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THE MINOR ELEMENTS IN OREGON SOIL FERTILITY AND PLANT NUTRITION

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Manuring to improve yield and quality of crops in former times was largely done with stable or crop refuse. In the past two decades replacement of animal power by farm tractors, production of pure synthetic fertilizers and intensive specialized agriculture on leachy humid-climate soils have contributed to manifestation of some deficiency diseases of crop plants. Most of the sulphur, iodine and boron may have been roasted out of the basaltic lava which is a major soil-forming material in the Pacific Northwest.

During the past twenty-five years the essential nature of very small amounts of several of the so-called minor or trace elements has gradually become apparent. Various obscure types of unhealthiness in plants are prevented or corrected by the presence of traces of such elements as boron, manganese, zinc, copper, molybdenum, or others for which essentiality is not so well established. Sulphur, iron, and magnesium are included by Willis in his review of minor elements.

For the past twelve years the Oregon Station Soils Department has done exploratory work with minor elements on Oregon soils including an intensive study of iodine. In order to determine the essentiality of a trace element it may be necessary to grow large numbers of plants under carefully controlled conditions in solution culture built up from purified chemicals in re-distilled water, and perhaps from successive generations of seed. Most of these trace elements are helpful only at concentrations of the order of one-fourth part per million, while two parts per million in solution may be toxic; so great care is needed in their use.

Possible Functions of the Rarer Elements

Response of plants to the presence of minor elements varies with different plants and with different soil environments. Functions that these elements may perform are the following:

(1) They may be essential nutrients for life and growth.
(2) They may serve as substitutes for other elements.
    Example: Calcium by strontium.
(3) They may help form enzymes or vitamins.

(4) They may antidote toxicity. Example: Sodium injury is reduced by a trace of zinc.
(5) One element may aid in keeping another reduced or oxidized.
(6) One element may liberate another element.
(7) They may increase resistance to disease.
(8) The addition of, or presence of, one element may precipitate ions of another element.
(9) An indirect effect may occur from effect on reaction or action of an element upon microorganisms or antidote bacterially formed toxin.
(10) They may have stimulative effects.
(11) They may have possible colloidal effects.

1. Sulphur

Sulphur is used in the Pacific Northwest for two very different purposes; namely, (1) as a fertilizer for legumes, and (2) for the reclamation of alkaline land.

The value of sulphur as a fertilizer was discovered by the Oregon Agricultural Experiment Station in 1912, as a result of experiments, in Southern Oregon by F. C.Reimer, and in Eastern Oregon by W. L. Powers. The explanation of the results obtained from sulphates was perhaps first suggested by Herman V. Tartar, at that time Agricultural Chemist at the Station.

The value of sulphur as a fertilizer appears to be most marked with the calcareous basaltic soils of the Pacific Northwest, extending from the vicinity of Gerber Junction, Northern California, to Western Montana. Perhaps 80 per cent of the alfalfa land in Oregon will respond to sulphur application, giving an increase of from one-half to two tons an acre a year, with a cost of about one dollar an acre for the treatment.

Sulphur was perhaps first used in reclamation of alkali land in Klamath Basin in 1917 by W. L. Powers. At the Vale, Oregon, Alkali Reclamation Experiment Field, permanent plats were established in 1921, and there less sulphur is needed if used in conjunction with nitrogenous organic manures. Applications of from 500 to 3000 pounds of sulphur have been made on the Vale Experiment Field. Good yields of alfalfa have been obtained on what was hard waste greasewood land where as little as 500 to 1000 pounds of sulphur per acre have been used with manure. Fertilizer acidified with sulphur liberates needed iron and manganese on calcareous soils. In studying the value of minor elements for Oregon soils, it has been customary to include plats or jars to which sulphur and calcium sulphate were added to check off possible sulphur effect. The minor elements have usually been applied as sulphates.

2. Manganese

Manganese applied to peat land as a sulphate in 1929 by the writer gave 30 per cent increase in yield of tomatoes and 15 per cent increase in peas. Manganese increased the yield of tomatoes 82 per cent on acid peat land near Warrenton and doubled the yield of table beets on Lake Labish land during the 1938 season. Manganese resulted in an increase in potassium in berry leaves. Manganese sulphate of technical grade costs about five cents a pound, and 20 to 40 pounds an acre may be tried. The first commercial applications in Oregon have been made the past spring in the Lower Columbia Valley.

3. Zinc

Zinc was shown to be essential to development of corn some 25 years ago by Mazé in France. It has been extensively used in California for control of leaf mottling or "littleleaf" or "rosette" of citrus. In the minor elements trial with six Oregon soils in 1928 and 1929, zinc gave an increase in the yield of peas of 21 per cent on Willamette silty clay loam, 51 per cent on Chehalis loam, and 6 per cent on Labish peat. The increase on sulphur alone in these trials was small. This treatment was used successfully in Oregon beginning in 1933 by O. T. McWhorter and W. W. Lawrence to control littleleaf in stone fruits near The Dalles, Cove, and Milton. The use of injections or zinc tacks has been replaced by an early-season application of a zinc sulphate spray, using 20 pounds or less per 100 gallons of water, applied after 4 p.m. Zinc content of leaves from three affected kinds of stone fruit trees is lower than for leaves of healthy trees. Zinc has increased the yield of Cuthbert raspberries (12.5 per cent) and of vetch and oat cover crop on Powell silt loam, and a three-acre yard there has been treated by the owner this season.

4. Boron

Boron was shown to be essential to normal development of broadbeans by Warington in England in 1923. Boron has been used in Oregon to control "corky-core" and "drought-spot" in apples; "yellow-top" in alfalfa; celery "stem-crack"; "beet-canker"; discoloration of broccoli and asters and "growth-strain" of potatoes. Frequently marked increase in yield and quality has resulted from the treatment. Old soils, leachy soils, peaty soils, or those derived from igneous rocks seem most apt to be deficient in boron. Soil reaction or lime and moisture contents, and perhaps also temperature, may affect availability.

In Oregon, experiments by the writer in 1936 demonstrated that yellow-top of alfalfa can be controlled on various soils by use of as little as 10 to 20 pounds of boric acid an acre applied in solution with a sprinkler. Normal color was restored in the field within 10 to 30 days and with controlled conditions in the greenhouse within a few days. Boric acid has been used periodically in our experimental culture solutions for a dozen years to overcome a certain type of chlorosis or yellowing of foliage. One-half part per million has proved sufficient and may safely be used. Chemical analyses show unfavorably low boron content in soils, waters, and alfalfa from affected areas. Use of boron in such areas has increased the boron content of plants and raised the chlorophyll and the vitamin A contents approximately 50 per cent. Deficiency of boron causes blighting of terminal buds, leaves, and blossoms, while excess results in spotting and loss of lower leaves.

During the past four seasons in three dozen trials, use of boron on Northwestern Oregon soils has controlled yellow top of alfalfa and trebled the yield for dry-weather cuttings. Boron promises to be as profitable for Willamette Valley alfalfa land as sulphur has been in Eastern Oregon. Similar symptoms have been observed and corrected on clovers and grasses.

Surface canker of table beets was controlled in the plant house and in the field in our experiments, started in 1937, perhaps for the first time. Canker has caused rejection of whole fields of the crop. Like results had been secured with sugar beet seed plants. Even application of 30 to 50 pounds of borax with control of soil moisture and with faintly acid soil, and perhaps use of resistant varieties, may be expected to aid in canker control.

Celery crack-stem has been more completely controlled in field trials by Professor A. G. B. Bouquet and the writer where early applications of boron were made. Assistance was given in starting commercial applications.

While chemically pure boric acid was applied in dilute solution with a garden sprinkler in early, controlled experiments, the use of borax is usually cheaper for field use and will give similar results if applied evenly and very early in the season. The boron treatment has been found to carry over for two or three years. Granular borax may be sown like clover seed with a cyclone type of hand seeder. Slight temporary toxicity has followed application of 40 pounds boric acid an acre to grass. Two pounds boric acid contain approximately as much of the element boron as does three pounds of borax. Borax may be obtained from wholesale druggists or certain fertilizer dealers in Portland at about $3.25 per 100-pound bag or $2.40 per cwt. in ton lots. Twenty tons were used in 1939 and 100 tons to April 10 for 1940.

5. Copper

Copper sulphate has been found to be very helpful in preventing "reclamation disease" or in increasing yield and quality in Florida and Holland. Negative results have been obtained with Oregon peats. There is some evidence that a little copper sulphate will increase yield on certain soils of the John Day, lower Willamette and Illinois Valleys.

6. Iodine

Iodine increases the iodine content of plants and may increase yield. Iodine may stimulate germination and growth. Increases in yields of head lettuce were obtained in 1929 by the writer in water culture solutions, and subsequently with alfalfa and corn. Mr. Waldo Carlson, who extended these studies in association with Dr. J. R. Haag and the writer on an Adams fund project, found good evidence that the effect of iodine is indirect and that microorganisms are involved with the potassium iodide added, perhaps changing to organic form before it is effective. Positive evidence of stimulation of activity of azotobacter has very recently been obtained in our soils laboratory by Dr. J. C. Lewis. Baumann in 1895 found that the absence of iodine in plants affects thyroid. Aso (1903) recommended seaweed as manure due to its iodine content. Fish by-products also carry iodine.

Using a modified Harvey Method, the iodine is found to be low in the waters, soils, and vegetation of much of Oregon. Iodine in our soils may run from .5 to 15 parts per million; in Oregon water .01 to 20 parts per billion. Relation is sharpest between water content of iodine and goiter. Soil iodine seems to associate with organic matter and sedimentary soil.

Significant increases in growth have been obtained from two to four pounds KI per acre on Aiken and Deschutes soil series. Applications of iodine have increased iodine content of plants up to 16 fold.

In general, deficiency diseases may actually be more prevalent than formerly; they are somewhat better understood and more promptly recognized. In the future, as we learn to recognize symptoms, foliary diagnosis will be increasingly useful. Frequently the needs of the plant may be more readily detected by appearance and analysis of the plant leaves than of the soil. Early recognition of the cause of trouble may avoid economic loss. Because only traces of the minor elements may be needed and more than a trace may be extremely toxic, applications should be made only where they are known to be needed and in carefully determined amounts.

"Fool-proof" methods of commercialization of "complete" water cultures are not yet provided. It seems inadvisable to include trace elements in fertilizers for general use. These should still be purchased on the basis of cost per unit of the readily available nitrogen, phosphoric acid, and potash that they contain.