THE RELATIVE SENSIBILITY OF PLANTS TO ACIDITY IN SOILS.

By Walter Maxwell.

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THE degree of acidity in soils is relative, and is largely controlled by climatic conditions. In temperate zones, due to the more moderate means in temperature and rainfall, this matter of acidity does not necessarily engage as much attention in agricultural considerations. In subtropical and tropical conditions, in which the writer is engaged, and where the mean annual temperature is over 21° C., and the yearly rainfall varies between twenty inches on the leeward side of the islands, and 200 inches (17.5 feet) on the windward uplands, the matter of soil acidity demands primary and careful consideration.

Our observations were made not only in order to obtain precise knowledge concerning the relative sensibility of various plants, and families of plants, to acid conditions, but also to indicate that the errors and confusion at present existing, concerning the forms in which plants assimilate nitrogen, may be in part due to this behavior of plants in relation to acidity.

In another publication[1] we selected, among others, as an example, a tropical wood fern, which was growing in conditions of extreme soil acidity, such as the sugar-cane could not exist in. We used the analysis of this fern, the green leaves of which contained four-tenths per cent. nitrogen, to show that "one of the two theories must be wrong, and that the nitrifying organisms in soils can carry on the nitrification of organic nitrogen in acid media, or that the fern must take up nitrogen in a non-nitrified form."

The conditions of the situation have obliged us to make examinations, the results of which show that certain common agricultural varieties of plants live and thrive in soils where others totally fail; and that the success or failure of the respective varieties can be due to the inability of given plants to withstand a degree of soil acidity in which other plants reach a considerable and even normal growth; and may be quite independent of the mode and elements of plant nutrition.

The experiments which furnished the given data were

[1] Reports of the Hawaiian Experiment Station, 1896.

arranged and conducted as follows: Two tubs having a diameter of twenty-four inches, and a depth of twenty inches, and perforated bottoms, which were covered with linen cloth, were each filled with 120 pounds of air-dried soil of moderate fertility, having a neutral behavior towards acid and alkaline tests. These tubs were placed in tin pans which were six inches deep, the perforated bottoms of the tubs being raised four inches above the bottoms of the tin pans. The tin pans were filled with water up to the level of the perforated bottoms, and the water was kept up to that level until the soil in the tubs had absorbed moisture to saturation, the water absorbed being 48.2 per cent. on the water-free weight of the soil. To tub No. 1 enough citric acid was added to make the whole volume of water absorbed a one-tenth per cent. solution. To tub No. 2 citric acid was added to make the absorbed water a one-fiftieth per cent. solution. In each of the tubs seventeen varieties of seeds were planted, these being planted in a circle, and equal distances apart. The seeds germinated quickly, were up within four days, and had a healthy appearance. After the plants were up, and one inch high, the mode of applying the acid was changed. When the acid was applied in the water absorbed by capillarity from the tin pans, it was not equally distributed through the mass of the soil, but was more or less fixed by the bases in the soil at the bottom of the tubs, and did not reach the plants. Therefore the acid was dissolved in water and applied around the plants at the surface. This was controlled by determining the loss of water from the tubs by evaporation, and replacing the lost water, with the weight of citric acid dissolved in it necessary to bring up the whole volume of water in the tubs to one-tenth per cent. and one-fiftieth per cent. solutions respectively. This was repeated every fourth day, the acid solution being applied by our field assistant, E. G. Clarke, with a pipette, and in strictly equal quantities to each plant. With this detailed description of the mode of applying the citric acid to the tubs, the results may be given, which are found in the following tables:

A. CRUCIFERA.

(Tub No. 1. Strength of Acid one-tenth per cent.)

Name of plant.	Planted.	Up.	Failed.	Development.
Black mustard.....	May 27	May 29	June 15	Three inches high
White mustard	"	" 29	" 15	"
Beet...............	"	" 31	" 11	"
Mangel wurzel.....	"	" 31	" 11	"
Rape..............	"	" 30	" 17	"
Carrot.............	"	June 3	" 17	Four "

(Tub No. 2. Strength of Acid one-fiftieth per cent.)

Name of plant.	Planted.	Up.	Failed.	Development.
Black mustard.....	May 27	May 29	June 15	Three inches high
White mustard	"	" 29	" 11	"
Beet...............	"	" 31	" 11	"
Mangel wurzel.....	"	" 31	" 11	"
Rape..............	"	" 30	" 11	"
Carrot.............	"	June 3	" 17	Five "

B. LEGUMINOSAE.

(Tub No. 1. Strength of Acid one-tenth per cent.)

Name of plants.	Planted.	Up.	Failed.	Development.
White lupine...	May 27	May 30	July 16	1 foot high
Cow bean.......	"	" 30	Aug. 31	7 feet 2 inches long (No seed)
Windsor bean ..	"	June 3	Aug. 12	3 feet long
Winter vetch...	"	May 31	July 9	2 feet long
Crimson clover.	"	" 30	June 17	3 inches high
Alfalfa.........	"	" 29	" 15	3 inches high

(Tub No. 2. Strength of Acid one-fiftieth per cent.)

Name of plants.	Planted.	Up.	Failed.	Development.
White lupine...	May 27	May 30	July 21	1 foot 2 inches long
Cow bean	"	" 30	Aug. 30	6 feet long (No seed)
Windsor bean ..	"	June 3	" 12	3 feet long
Winter vetch...	"	May 31	" 4	3 feet long
Crimson clover.	"	" 30	June 17	3 inches high
Alfalfa.........	"	" 29	" 11	3 inches high

C. GRAMINAE.

(Tub No. 1. Strength of Acid one-tenth per cent.)

Name of plants.	Planted.	Up.	Result.	Development.
Pearl millet....	May 27	May 30	Matured	4 feet 1 inch long and formed seed
Wheat.........	"	"	Failed	1 foot 3 inches high
Maize	"	"		3 feet 6 inches high Formed flowers but no seed
Oats...........	"	"	Failed	8 inches high
Barley	"	"	Failed	8 inches high

(*Tub No. 2. Strength of Acid one-fiftieth per cent.*)

Name of plant.	Planted.	Up.	Result.	Development.
Pearl millet....	May 27	May 30	Matured	5 feet 4 inches high and formed seed
Wheat.........	"	"	Failed	1 foot 2 inches high
Maize	"	"		Formed flowers but no seed
Oats...........	"	"	Failed	6 inches high
Barley.........	"	"	Failed	11 inches high

The crucifers succumbed almost immediately to the action of the acid, the one-fiftieth solution acting almost as effectually as the one-tenth solution. This behavior of the crucifers under artificial treatment with citric acid corresponds to certain general observations upon the growing of root crops in non-aerated and sour lands.

The lupine, bean, and vetch struggled hard and long against the acid action, but none of these fully matured, or formed seed. The crimson clover and alfalfa succumbed as rapidly as the crucifers. showing that the clovers cannot bear an acid soil, and explaining one cause of the extreme "hunger" of the clovers for lime.

The graminae showed a very variable behavior in relation to the acid. The wheat, barley, and oats failed almost completely, although none of these actually died. The maize grew well, had a strong and deep green-colored blade, and reached a moderate size, forming a full blossom, but no seed. The pearl millet distinguished itself from all the other varieties. Its growth was steady and quite normal, as compared with a plat of millet growing in the field near by, which it actually exceeded in development, reaching five feet five inches in height. Five large heads matured, which contained a finer grade of seed than was originally planted. A special test was made with the millet, in which the plant was treated every fourth day with a one per cent. solution of citric acid. This strength of solution kept the young plant, which was three inches high, at a standstill for three weeks. After that time the plant appeared to accommodate itself to the intense acidity, began a further growth, and was two feet high when the experiment was stopped. (A photograph was taken of this example.)

Considering the relation of these observations to common findings in the field, it may be said that maize is being planted with some success in our upland, acid soils, and millet will now be tried. The effects of acidity upon the crucifers and certain legumes, have been noted in soils notably less sour than most of the upland soils of these islands. The Director and Agriculturalist of the Rhode Island (U. S.) Experiment Station, Professor Flagg, in a communication concerning a sample of soil sent to the laboratories of the writer, says: "We found all this soil acid when tested with litmus paper; so much so that timothy and clover, barley, beets, spinach, lettuce, and a few other plants, failed to thrive without the use of air-slaked lime to correct the acidity."

These observations, which are only a part of extensive investigations that will be published shortly, show the extreme difference in degree of sensibility of the various agricultural plants to soil acidity. They also indicate with what ease a failure in growth of one plant can be attributed to some trouble in plant nutrition, when it may be wholly due to the inability of the plant to bear the acidity of the soil, which is illustrated, as has been shown, by the power of other plants to thrive in the same medium.

METHODS AND SOLVENTS FOR ESTIMATING THE ELEMENTS OF PLANT FOOD PROBABLY AVAILABLE IN SOILS.

BY WALTER MAXWELL.

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IN framing a method, and in the selection of solvents for estimating the proportion of plant food probably available in soils, it appears necessary to be wholly guided by a precise observance of the agencies by means of which the insoluble soil-materials are being daily changed by the processes of nature in the field, into forms in which they can be used by growing plants.

The processes by which the food elements are prepared in nature are altogether chemico-physiological; and for this reason the problem cannot be primarily considered from an analytical standpoint.

The solvent agents operating in nature's processes are, in addition to water, the acids moving in the sap of living organ-