polarity only when that factor is weakened by some such condition as unusual shortness of the piece.

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THE EFFECT OF DRYING UPON THE ACIDITY OF SOIL SAMPLES[1]

BURGESS[2] has recently reported a study of the effect of air and oven drying upon the H-ion concentration of soils, using samples of Miami silt loam from a series of plots at the Rhode Island Agricultural Experiment Station. He found that drying had little or no effect upon acid soils, but increased the H-ion concentration of alkaline soils.

In an investigation of the H-ion concentration of Minnesota soils that has been in progress for some time at this laboratory, numerous samples of soil from different parts of the state and from soil types of different genesis have been tested. Early in the investigation we tried to determine the proper conditions of moistness and freshness of the samples and have now satisfied ourselves that the determinations should be made with soil freshly taken from the field from which little or no moisture has been allowed to escape. Only then are the results a reliable indication of the conditions actually existing in the field.

In order to determine the effect of drying upon the H-ion concentration, we made determinations upon about 200 samples of soils in both the moist and the air-dry condition. With part of these oven-dried samples also were used. All the determinations were made by the gas chain electrometric method.

Comparing samples from five of our experimental fields, the soils of which are naturally acid, we find that samples from one field show marked changes upon being allowed to become air dry; those from two fields change somewhat less, but still appreciably, and those from the remaining two change only slightly. Generally the H-ion concentration increased, but in a few instances it decreased. With the samples from plots where sufficient lime or marl had been added to make the soil alkaline, some showed no change in H-ion concentration, some an increase and others a decrease upon air-drying.

A group of 92 glacial soils, partly acid and partly alkaline, were found after air-drying to be decidedly more acid than before, the alkaline soils, however, showing the more marked change. A group of loessial soils, on the whole more acid than the glacial soils, showed less change.

Oven-drying was found to increase the H-ion concentration more than air-drying. Samples moistened after air-drying became more acid than the original moist samples and usually more acid than the air-dried samples. Moist samples kept in air-tight glass containers generally become more acid on standing; out of 20 samples tested, 13 became more acid, five showed little change and two became less acid.

H-ION CONCENTRATIONS OF FRESH AND DRIED SOILS SHOWING VARIABLE EFFECT OF DRYING AND REMOISTENING

Sample No.	Formation	Fresh pH	Air-Dried pH	Oven-Dried pH	Remoistened pH
1	Glacial Outwash	5.53	5.79	.....	.....
2	" "	6.32	5.33	5.21	.....
3	" "	7.20	6.54	6.04	.....
4	" "	7.34	7.66	.....	.....
5	Till Plain	5.44	5.19	.....	5.28
6	"	5.60	5.46	.....	5.04
7	"	5.78	5.74	.....	.....
8	"	6.20	5.90	5.55	5.50
9	"	6.49	5.11	.....	.....
10	"	7.19	6.54	.....	6.15
11	"	8.00	7.39	7.79	.....
12	Loessial	5.87	5.80	5.31	.....
13	"	6.32	5.90	5.19	5.02
14	"	6.63	6.12	5.34	.....
15	"	7.51	7.13	.....	.....

Air-dried samples, when tested by the qualitative potassium thiocyanate method, gave a more acid reaction than moist ones freshly taken from the field. The full data are now being prepared for publication, but the accompanying few given in the table will serve to illustrate the magnitude of the changes we have found.

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THE BENEFICIAL EFFECT TO WHEAT GROWTH DUE TO DEPLETION OF AVAILABLE PHOSPHORUS IN THE CULTURE MEDIA

THE exceptionally good growth wheat seedlings, grown four weeks in complete nutrient solutions, make when transferred to aqueous culture media that contain all essential nutritive salt elements except phosphorus, presents a problem of great importance from the standpoint both of theory relating to fertilizer practice and of that pertaining to the physiology of the wheat plant. In experiments designed to test the effects of the absence of the commonly assumed essential elements in the culture media at various stages of growth on the development of wheat, it

[1] Published with the approval of the director as Paper No. 373 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] SCIENCE, 1922, N. S., 55, 647–648.

was found that eight weeks after the transfer above referred to was made, the cultures grown in media devoid of phosphorus far excelled those grown in complete nutrient solutions that were not allowed to be markedly depleted of any essential salt elements. The former set of cultures exceeded the latter in height, weight of plants and earliness of heading. Comparison as to height was 50 inches and 36 inches and that of the weight of green plants 700 grams and 480 grams. Wheat grown an equal length of time from the early seedling stage in nutrient solutions devoid of phosphorus made very little growth, the weight being approximately 30 grams. It appears, therefore, that while phosphorus is needed in the early growth period of wheat, it is not only useless, but relatively harmful, if present in appreciable quantities in physiologically available form in the culture media for the latter growth periods.

These results call for a marked revision of the theory underlying the use of phosphates as fertilizers. The fact that the absence of phosphorus in aqueous culture media during approximately three fourths of the entire growth period of wheat, which included the fruiting stage, is decidedly beneficial not only suggests but is inferential evidence that analogous conditions may prevail in soils, and that large yield of wheat (and presumably that of other crops) results from and is conditioned by the depletion of physiologically available phosphorus in the soil during certain periods of growth of the plants. If the thesis in ecological principle and plant adaptation is true, as it appears it must be, that whatever growth a plant makes under any given set of conditions is the best growth for that particular set of conditions, then the beneficial effect to plant growth of the absence of phosphorus in the nutrient solution, as compared with one that contains this element for the particular phase of growth to which it applies, is the expression of an ecological factor concerned in crop production, to which wheat has become adapted to produce maximum yield.

But is phosphorus in fertile soils generally physiologically unavailable to wheat plants during the later phases of their growth? Answer to this question involves consideration of several points. In the first place, while it is generally assumed that if phosphorus in the soil is in water-soluble form, it is therefore physiologically available, nevertheless results of physiological experimentation have neither satisfactorily proved nor disproved this assumption. As physiological availability of an element is determined by the measure of growth it has produced and not by the amount of that material absorbed by the plant, it follows that neither chemical analysis of plant nor of water extract of that soil can give the answer. However, as analyses of soil extracts show that the concentration of water soluble phosphorus is usually very low during the greater part of the growing period of cereal plants, it appears, therefore, that the mechanics in the soil that meet these particular physiological requirements of the plants to render phosphorus unavailable for the later growth phase of wheat, lies in the low rate of solution of this material.[1]

As already mentioned in a previous paper,[2] results obtained from this type of experimentation led the writer to define the crop-producing power of soils as a function of the rate of the temporary depletion of certain nutrients in physiologically available form. Because plant growth is improved by the seasonal depletion of certain nutritive elements in the growth media, therefore yield of crop can not be expressed as a function of the supply of available nutritive material either in aqueous culture media or in the soil. The supply of nutritive material is only one factor of the more comprehensive expression herein stated that defines crop-production as the correlated response of progressive and changing conditions in the soil.

The fact that for certain periods of growth of the plants the absence in the culture media of material extensively used as a fertilizer is decidedly beneficial to plants must necessarily call for a thorough study of the economy and use of fertilizers in general. In no way have the results of the experiments herein quoted invalidated the soundness and economy of the use of phosphates on land when needed. However, due to the fact that in innumerable experiments, no increase in production obtained where phosphates or other fertilizers were applied, it is quite obvious that some heretofore unaccounted for factor had been operative to negative anticipated or hoped for results. But in the light of this investigation, which shows certain nutritive elements may be required at certain phases of growth of plants and not at others, or are beneficial at certain phases of plant development and relatively harmful at others, it follows that a rational basis of fertilizer application can be founded only on the knowledge of nutritive requirements of plants at various phases of growth and on that of the progressive changes that take place in the supply of physiologically available nutritive material in the soil.

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[1] Burd, J. S., and Martin, J. C. "Secular and seasonal changes in the soil solution" (in preparation).

[2] "The beneficial effect to plant growth of the temporary depletion of some of the essential elements in the soil," W. F. Gericke, SCIENCE, April 4, 1924, Vol. LIX: 1527.