PRELIMINARY STUDIES ON HEATED SOILS

A fairly extensive amount of data has been accumulated upon the immediate changes induced in soils heated to temperatures between 50° C. and 500° C., with reference to the effect of such treatment upon seed germination and plant growth. The results appear to have some value in explaining the striking effects, injurious and beneficial, observed on sterilized or partially sterilized soils. The work of Russell[1] and his associates, Pickering[2] and Schreiner and Lathrop[3] have led in general to quite different conclusions as regards the nature of the injurious action. These and other workers have also maintained considerably different views regarding the nature of the beneficial action of sterilized soils. The difference in opinion is perhaps due in a large measure to the point of view from which the investigation has been undertaken, as well as to the manner in which the sterilization of the soil has been accomplished. The conclusions drawn here are considered to apply particularly to soils heated above 100° C., although it is believed that the same principles apply in soils heated to lower temperatures. An endeavor has been made to give due consideration to the several phases of the subject since these involve not only chemical, biological and physical changes in the soil, but also the physiological and pathological conditions of the seeds and plants grown in these soils.

The method of investigation by which the results presented in this paper were obtained has been largely that of attempting to correlate the chemical changes produced in the heated soils with their effect upon seed germination and plant growth. The amount of water-soluble material formed by heating has been measured by the lowering of the freezing point. For this the Beckmann thermometer was used. Ammonia was determined by the ordinary method of distilling in the presence of magnesium oxide. The nitrate was determined colorimetrically by the phenoldisulphonic acid method. Seed germination tests were made on the soil in Petri dishes. The seeds were placed on the surface of the soil, which was almost saturated with distilled water. Various kinds of seeds were employed, but especial use was made of cabbage.

The results in general were similar for the different seeds, though they varied much in their susceptibility to the injurious action. Lettuce and clover seeds, for instance, were very susceptible to the injurious action of highly heated soils, whereas rye and buckwheat were very resistant. Plant growth is affected in much the same manner, wheat, for example, recovering rapidly from the deleterious action of certain heated soils where tomatoes appeared to be permanently injured. Different soils give markedly different results upon heating to the same temperatures. The action appears to be dependent particularly upon the content of organic matter in the heated soil, as this influences both the amount of decomposition and the absorptive power of the soil for the substances produced upon heating. These results are in general confirmatory of the work of others upon this subject.

The temperature to which the soil is heated is seemingly the most important factor in determining the extent of the injurious or beneficial action. Approximately 250° C. was found to be the most critical temperature in all the soils used. At this temperature seed germination was most strikingly retarded. Early plant growth was usually checked for the longest period of time on soils heated to 250° C., although late plant growth, in the case of some crops at least, was most vigorous on these soils. Heating to temperatures of 300° C., or above, in all the soils used, again reduced the injurious action to seed germination and early plant growth, as well as the beneficial action to late plant growth.

Heating soils to 250° C. produced greater amounts of material extractable with water than heating to higher or lower temperatures. The ammonia content of the soil increased proportionally to the temperature of heating up to about 250° C., after which it rapidly

[1] Russell and Petherbridge, *Jour. Agr. Sci.*, 5: 248–287, 1913.

[2] Pickering, *Jour. Agr. Sci.*, 3: 277–284, 1910.

[3] Schreiner and Lathrop., U. S. Dept. Agr., Bur. Soils Bul. 89, pp. 7–37, 1912.

fell to a minimum. The increase in ammonia was accompanied by a decrease in nitrates, which were practically non-existent in the highly heated soils.

The ammonia produced on heating soil has been suggested by Russell as causing the injurious action, although no evidence on this point could be obtained. Pickering suggested that the injurious factor was volatile in nature, on account of its gradual disappearance from the soil, but Russell disagrees on this point. Russell, however, worked with low temperatures, usually not exceeding 100° C., and with volatile antiseptics. Under such treatment, only relatively small amounts of ammonia are produced directly, and seed germination and plant growth are not so strikingly affected as in soils heated to higher temperatures.

The percentage of seed germination has been found to be closely correlated with the amount of ammonia present in the heated soils studied. The amount of ammonia required to injure germination, however, appears to vary with the type of soil when comparisons of different heated soils are made. It appears that the absorptive power of the soil is a very important limiting factor in determining the extent of the injurious action.

The presenec of dihydroxystearic acid as described by Schreiner could not be demonstrated in the most toxic of the heated soils. That the toxic substance is of a volatile nature is evident by the fact that it is readily removed from the soil by aeration. If collected in water upon removal, its toxicity can be readily demonstrated. By collecting in a hydrochloric acid solution the chemical composition of the resultant salt has been shown to be ammonium chloride, containing ammonia in sufficient quantity to account for the toxic action of heated soils.

It is improbable that all the ammonia produced in heated soils exists as free ammonia. Large amounts of carbon dioxide are also produced when soils are heated, which possibly accounts for the increased acidity of heated soils. The evidence at hand points toward the formation and injurious action of ammonium carbonates particularly. These salts being unstable in the soil except when kept in a dry and unaerated condition, accounts for the gradual disappearance of the injurious action of heated soils. It also appears that other compounds of ammonia are formed which are more stable in character.

The beneficial action of heated soils on plant growth, especially of those heated between 150° C., and 250° C., is believed to be due in a large part to the direct assimilation of ammonia or ammonium compounds by the plants after the manner described by various workers. The increased growth follows in practically all cases after a period of injurious action to plant growth, and is no doubt dependent upon the reduction of the toxic substance to a point where it is stimulatory or acts as a plant food. The relative importance of increased plant food production as a result of bacterial activity, and of direct chemical action, in highly heated soils remains to be ascertained.

The writer will be pleased to obtain suggestions or criticisms on the point of view presented in this paper.

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NOTE ON THE INTERFERENCES OF PARALLEL AND CROSSED RAYS

After perfecting the design (Fig. 1) of my last article[1] thus obtaining an apparatus which is free from transmission through glass and in which all the rays are guided by reflection from metal surfaces only, I have secured definite evidence showing that the strands of interference patterns obtained are actually referable to the intersection of two grids, due to the two sodium lines, respectively. One of the grids is retarded in rotational phase with respect to the other. Why in the case of a transmitting grating, the nature of the phenomenon is so effectively concealed, I have not been able to make out; but with mercury light, but one set of striations is obtained, as anticipated.

With this definite understanding of the phenomenon, the resolving power works out as

[1] Science, February 25, p. 282.