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Soil Structure Linked to Microbial Activity

Role of microorganisms and organic materials weighed against physicochemical forces in aggregate stabilization

WEST LAFAYETTE, IND.—Widespread use of soil conditioners may eventually eliminate many expensive and time-consuming "soil-building" practices, but vast amounts of additional information about the physical, chemical, and biological properties of soil must first be collected. Thus, according to J. B. Page of Texas A&M College, speaking at the Soil Microbiology Conference held here June 21 through 24, the interrelationships among these factors must be more intensively studied to permit maximum efficiency in soil utilization.

For the superficially simple phenomenon of soil aggregation, for instance, there is as yet no simple explanation, Page commented, before the conference sponsored by the American Society of Agronomy, the Soil Science Society of America, and Purdue University. Maintaining high levels of microbial activity in the soil is important over the short term, he said, but it remains to be seen how much lasting improvement can be thus effected. In a plea for more practical study, Page urged that greater effort be directed toward determining the mechanisms involved in forming and stabilizing agricultural soil aggregates in the field, rather than in laboratory study of conditions under which aggregates can be produced. Lack of complete understanding of the forces affecting aggregation, and of the nature of processes which cause aggregates to remain in the soil, has so far prevented the development even of adequate means for measuring relative stability, Page observed.

Possible Mechanisms. Proposing three possible mechanisms for aggregate formation, Page suggested that all three may operate in different degrees in various soils. Page thinks the first of these, the effect of living bacteria and fungi binding particles together, may have been over-emphasized. There is strong evidence that the second factor, the presence of gelatinous organics—gums, resins, waxes—which cement clay particles together, may be of greater importance. Organic products formed during decomposition of other organic materials may play a major role here; chief attention currently is on the polysaccharides, of which uronic acid derivatives are being most intensively studied. Page suggested that the chief bonding influence, however, might be the third, that of clay particles themselves adhering one to another and entrapping, or bridging between, large sand and soil grains. If this were the case, the chief role of organic materials in the soil would be to modify the forces by which the clay particles are attracted one to another. Principal force contributing to adhesion of clay particles, said Page, would in most cases be cross bridging and sharing of intercrystalline ionic forces, abetted by interactions of exchangeable cations between oriented clay plates.

A. G. Norman of University of Michigan discusses objectives of the soil microbiology conference with L. W. Erdman of USDA. Erdman was chairman of the committee which organized the conference; Norman set stage for conference with opening paper on the place of microbiology in soil science

Microbial Activity. Dealing in detail with the interrelationship between microbial activity and soil aggregation, and differing in some degree with the theories set forth by Page, W. P. Martin of Ohio State compared effects of soil conditioners and microbial activities in conferring desirable physical properties on soil. In the best aggregated soils of the world, Martin said, a considerable percentage of binding materials appears to be organic, formed as a result of the activities of soil microorganisms. The practice of turning under green manure crops and crop residues aids soil tilth, he said, provided microbial activity is permitted to proceed normally. Under ordinary conditions, soil microorganisms attack these organic materials immediately; during decomposition, waste products of microbial metabolism, synthesized materials, and cells and filaments of the organisms involved may all act to combine soil particles together, increasing soil granulation. Materials resistant to decomposition take longer to exert their maximum binding effect, but remain effective over longer periods. Well-composted materials, certain lignified wood by-products, and some peats not readily decomposed have very little effect on soil aggregation. The level of aggregation, said Martin, is proportional to the amount of organic matter applied, and additional active material must be applied periodically to prevent a decline in the number of stable aggregates.

Three categories of substances, said Martin, account for the binding effects produced by microorganisms: decomposition products of organic matter dissimulation, microbial cells and colloidal gums and mucilages formed as secretory products, and synthesized polysaccharides. Uronide-type polysaccharides are very effective, Martin said, but cannot alone account for the aggregation observed in field tests. The discovery that naturally-produced polysaccharides could stabilize soil aggregation led to the search for synthetics that would do the same job, but last longer by resisting metabolism by soil microorganisms.

Organic Matter and Nitrogen. Organic matter in agronomic practices is largely a problem of proper handling of residues and nitrogen fertilization, in the opinion of S. W. Melsted, University of Illinois. No system of management or crop rotation, he declared, can be expected to maintain or build up soil organic matter if the amount of nitrogen removed in harvesting crops and other soil losses exceeds the amount of nitrogen being returned to the soil by legumes, manures, and commercial fertilizers. Nitrogen alone will not maintain soil organic matter, but must be accompanied by crop residues. Low nitrogen residues such as corn stover or grain straw accompanied by commercial nitrogen can supply a source of actively decomposible material in the soil which tends to promote good physical properties. Such conditions can be achieved for most soil, said Melsted, if the nitrogen program is adequate to meet the yield potential of the average season and if the normal crop residues are returned to the soil.

In discussing observations on the famous Morrow plots, he said that cultivation appeared to retard the formation of soil organic matter in some experiments, while adding nitrogen in excess of crop residues increased the amount of both carbon and nitrogen in the soil. Residues alone were not enough and nitrogen had to be added in order to form organic matter faster than it was being destroyed. It was indicated that normal quantities of crop residues obtainable under high fertility and a nitrogen maintenance program probably can maintain soil organic matter levels in soils which have lost considerable quantities of their inactive organic matter but which still have fairly good physical properties.

R. Bradfield of Cornell University in discussing the maintenance of organic matter emphasized the importance of considering the nature of the soil, the requirements of the individual crop as well as the climatic conditions in attempting to evaluate the importance, desirability, and feasibility of the maintenance of organic matter.

J. S. Joffe, Rutgers University, in a discussion session emphasized that the accumulation of humus varies with geographical zones as does the rate of breakdown of organic matter. He urged the study of known favorable areas and consideration of analogy in the study of organic matter maintenance. We should inquire as to the critical level, he said, and the factors which set that level as well as means of obtaining it.

Soil Conditioner Tests Show Improvement

Western soil scientists continue search for quantitative results, evolve several new methods

PULLMAN, WASH.—Just exactly a year ago, when AG AND FOOD reported on the American Association for the Advancement of Science Pacific Division's meeting (June 24, 1953, page 495), western soil conditioner researchers expressed considerable regret over lack of adequate tests. This year, western soil scientists, meeting in conjunction with Pacific Division, AAAS, here June 21 through 26, express the same need: more and better ways to evaluate soil structure.

In contrast to 1953, however, some glimmerings of light show through. Wet sieving and modulus of rupture still remain the most widespread methods for checking soil aggregation, but several new methods have promise for the future.

For instance, to check aggregate stability, James Engibous says he and his coworkers at Monsanto use what might be termed a "ball mill" approach. Ten grams of soil in 100 ml. of water is placed in a 200-ml. bottle. This bottle is then rotated (much like a ball mill, hence the name) at either 2 or 4 revolutions per second. At the end of a specified rotation period, turbidity of the sample is measured with a spectrophotometer (the higher the light transmission, the more stable the aggregate), and various conditioners and treatment practices are thus rated.

W. H. Gardner, State College of Washington, approaches aggregate stability from still another tack. He prepares a series of standard alcohol-water solutions with varying concentrations of alcohol, treats his aggregates with these standards, finds he can distinguish aggregate stability rather precisely (aggregate stable in 50%, for instance, unstable in 55%) by visual inspection of the aggregates. Using this method, he has so far been able to detect differences between 0.001% and 0.005% treatments of IBMA (the half-ammonia, half-amide salt of isobutylene maleic acid). The method,

S. J. Richards (left), University of California, Riverside, describes for Sterling A. Taylor, Utah State Agricultural College, and H. W. Gardner, State College of Washington, the apparatus he has devised to assure reproductive compacting of soils for soil conditioner tests. Formulas on blackboard are ones Dr. Gardner uses in attempts to evaluate conditioners quantitatively