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WATER-STABLE SOIL AGGREGATES STABILIZED
BY POLYELECTROLYTES¹

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Workers in agriculture have observed repeated situations in which crop yields have decreased because of the physical condition of the soil and not because of its lack of fertility (4, 5). The physical limitation invariably involves the breakdown of the good structural soil condition.

The soil structure, or arrangement of the primary particles, is important for many reasons. In general, a favorable structural condition is one in which the soil particles are aggregated into groups or clods of various sizes (1). This condition provides for a sufficient number of large soil pores to permit adequate aeration. At the same time, this structural condition will provide small pores within and between the clods, where water is held for use by the plant life. A proper balance is essential for the complete satisfaction of the requirements of the plant and the microorganisms within the soil.

It is well known that organic matter plays an essential role in securing the structural condition or tilth required for high productivity. The natural soil aggregating substances consist of three general types, polar organic substances of polysaccharides, polyuronides, and polyuronic groupings resulting from gradual decomposition of fresh organic matter, and a group consisting of hydrated oxides, fats, waxes, and resins, which are less efficient in aggregation. The soil organic matter is continually undergoing decomposition and thus it is destroyed about as fast as it is added. Structural decay of the soil clods results when the valuable organic substances are decomposed and not replaced.

Recently, artificial stabilization of the soil clods has received considerable attention (3). The purpose was to introduce a substance into the soil which would be similar to the polyuronic material naturally present. This substance would resist decomposition by microorganisms and at the same time take the important place of maintaining the structural soil condition indefinitely. The result was what is known widely as Soil Conditioners.

Materials currently being studied for soil stabilization are classed in three general groups: acrylic acid derivatives, cellulose gums, and silicate derivatives. This paper includes chemicals from the acrylic acid derivatives group only. The purpose of this study was to determine the effect of slaking and drying on soil stabilized with these conditioners and to determine the effect of these chemicals on Bolivar, Crowley, and Sharkey soil.

EXPERIMENTAL

In order to study the effect of the soil conditioners on the soil aggregates and to compare the effects of different materials, it was necessary to establish a standard procedure. The grain sizes of small aggregate particles in the soils were determined by means of sedimentation and Stoke's law. Separation for large aggregates was done by means of a nest of sieves. Thus, not only were the individual particles determined, but the sizes of the aggregates stabilized were determined and any differences in size distribution among soils were noted.

The two conditioner types involved in this study were hydrolized polyacrylonitrile (K-9 or HPAN) and a copolymer of vinyl acetate-maleic acid (K-6 or VAMA) both of which now are available commercially.²

The soil to be treated with conditioner was air dried and carefully crushed to pass a 40 mesh (.42 mm) screen. The calculated amount of conditioner was added to the weighed soil and thoroughly mixed. The amount of conditioner used was 0.15, 0.08, 0.04, 0.02, and 0.00 per cent by weight-active material. The

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² The chemicals were supplied by the Monsanto Chemical Company.

mixture was moistened and stirred under an atomizer spray until the moisture equivalent was reached. This process encouraged thorough mixing, adsorption of the electrolyte, and aggregate formation. The samples were allowed to stand 24 to 96 hours.

These samples were then carefully crushed through a 5 mm screen and then washed into a standard hydrometer jar. The suspension then was shaken end over end for one minute and the percentage of particles less than .05 mm in diameter was determined by use of the standard Bouyoucos soil hydrometer (2). No dispersing agent was added. The material which was used for the sedimentation study then was poured through a nest of screens. The per cent of aggregates on each screen was determined by a modified procedure of Yoder (6). The total aggregates >0.25 mm then were calculated. The data thus obtained gave aggregate grain size distribution of percentages greater than 0.05, 0.25, 0.42, 0.84, and 2.0 mm, respectively. Only the total aggregates greater than .05 mm and .25 mm, are reported in this paper, because these sizes are most indicative of stability and state of aggregation.

Alterations in the procedures were made in order to determine the slaking effect of water on the aggregates and the permanency of the cemented aggregate. The three treatment conditions thus imposed on the Bolivar soil were:

- A. Addition of conditioner, moistened and set 24 hours, determination of 0.05 mm aggregates by sedimentation, screening separation; all processes performed successively without time lag.
- B. Addition of conditioner, moistened and set 24 hours, determination of 0.05 mm aggregates by sedimentation, soak for six days, screening separation after the sixth day.
- C. Addition of conditioners, moistened and set four days, determination of .05 mm aggregates by sedimentation, screening separation immediately.

Data for additional soils in the study are given for aggregates greater than .05 mm in diameter which is the sand-size particle. Method A was used.

RESULTS AND DISCUSSION

Effect of slaking and drying on aggregates. The aggregate analysis of the Bolivar soil, according to the methods and modifications previously described, is shown in Figure 1 and Figure 2. Both of the conditioner types studied showed increases in percentage of water-stable aggregates greater than 0.05 mm diameter and 0.25 mm diameter size with increases in concentration. No differences among methods used can be shown for the 0.05 mm aggregates. Modification C showed significant increases in aggregation for large aggregates using K-6. K-9 did not produce a significant response by this modification.

A consideration of Figure 1 and Figure 2 indicates little difference in the relative position of the curves for the conditioners used. There is no significant difference between the location of the lines in the two figures for the same method modification, with the exception of modification C for K-6.

Modification C, employing a drying cycle for the treated soil, appears to show greater amounts of 0.25 mm aggregates at the higher concentrations. It appears that pretreatment by drying is most desirable for good results. This drying cycle serves to cement and fix the particles together by the binding action of the conditioners. Particles so held are highly resistant to dispersion. These larger aggregates were produced by stirring, indicating the importance of thorough incorporation of the chemicals with the soil. Concentrations above 0.08 per cent by weight appear to be of little importance in producing added amounts of stable aggregates.

Effect of conditioners on soils. Aggregate analysis showed little difference between the effect of K-9 and K-6 on Bolivar silt loam (see Table I). Increasing amounts of conditioner increased the amount of stable aggregates >0.05 mm formed. The greatest increases are found at the lower concentrations with linear, small increases at higher rates of added material. Little or no difference between the two types of conditioners was found or expected.

This soil is formed from the sandstone formations in Northwest Arkansas and while its textural class is that of silt loam, the grade tends to be on the sandy side of the tolerant range for this class.

In the case of the Crowley silt loam soil, differences between these conditioners can be noted (see Table I). The effect of the K-9 was to form aggregates larger than the 0.05 mm size at rather low concentrations. This effect was somewhat decreased where more than 0.04 per cent conditioner was used. Other data seem to indicate that at high concentrations these chemicals also may act as dispersing agents as well as aggregants (3). The K-6 (VAMA), however, showed a marked increase in aggregates of 0.05 mm through the entire range of concentrations used. The increase was greatest at 0.04 per cent. Further increases due to the added conditioner were minor.

The Crowley is a silt loam soil from the plains formed from the White River. Since its texture is one in which the silt and clay are high enough to place it on the clay side of the silt loam range, it appears that the clay content plays an important role in the aggregate formation with these conditioners. Also, it is shown that K-6 may have a slight superiority and greater stability than does K-9 on Crowley with the high silt and clay content. This also is shown in data elsewhere.

In the case of Sharkey clay, the effect of the conditioner is reported for K-6 only. It is apparent that a greater amount of conditioner may be needed in high clay soils to give appreciable effects. While the amount of 0.05 mm aggregates in this soil is high under the experimental conditions in the check treatment, Sharkey clay in the field becomes dispersed and puddled after long exposure to water. This is due in part to the relatively high amount of montmorillonite type clay present in this soil. Stabilizing effects on this soil may be highly important in the field.

When the effect of K-6 is considered on all of these soils and the conditions imposed, it can be seen that a concentration of greater than 0.08 per cent has little value in causing formation of, or maintaining aggregates of, these sizes as studied. High concentrations, however, tend to promote the larger size aggregates as previously discussed.

These data all indicate that while K-9 may be an effective aggregant, the K-6 produces larger aggregates which appear to be more stable in water if they have had an opportunity to become fixed.

Table I. Stabilization of Soil Aggregates Larger than 0.05 mm Size in Three Soils by Use of Synthetic Polyelectrolytes, K-9 (HPAN) and K-6 (VAMA) by Method A.

Rate (Pct.)	Per cent of total aggregates > 0.05 mm				
	Crowley silt loam		Bolivar silt loam		Sharkey clay
	K-9	K-6	K-9	K-6	K-6
Ck	36.7	40.0	44.1	45.0	55.2
.02	69.2	56.1	46.6	56.0	57.2
.04	73.7	73.4	54.1	56.0	60.2
.08	65.2	76.5	58.9	59.6	68.2
.15	54.2	79.4	64.2	64.0	71.7

SUMMARY

Increases in soil aggregation were brought about by HPAN (K-9) and VAMA (K-6), both of which are now commercially available. The effect of these aggregants was noticeable, and the results obtained with them give them an important place among agricultural chemicals.

Time is needed between the addition of the soil conditioning chemicals and an expression of their beneficial effects.

Generally the effect of the conditioners was to increase the proportion of the aggregates in the larger size groups. The greater the amount of conditioner used the greater was the tendency toward this effect.

The effect on the increasing increment of the soil aggregation appeared to be greatest at about 0.08 per cent by weight active ingredient.

Thorough incorporation into the soil mass is necessary for proper results to be obtained.

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