Stability of Soil Aggregates Treated with Distillery Slops or Blackstrap Molasses

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INTRODUCTION

Many types of cementing agents are responsible for bonding and stabilizing soil particles into aggregates. Among these materials are: $CaCO_3$, hydrated oxides of Fe and Al, organic matter, and synthetic chemicals such as VAMA and many others.

Use of blackstrap molasses for this purpose has received some attention from various investigators, but no attempt has been made to determine how long soil aggregates persist in soils when stabilized by the use of either this material or distillery slops.

REVIEW OF LITERATURE

Vallance (*8*)[2] demonstrated through laboratory and field studies that molasses and chopped sweet sorghum additions to soils resulted in better and more aggregation in a heavy soil. The rates of molasses used were 3 and 12 tons an acre, and of chopped sorghum, 14 and 35 tons an acre. Soil-aggregation decreased with time on the treated plots, but aggregation was significantly higher on these plots than on the nontreated plots.

Novak, Watt, and Hiller (*5*) applied dextrinated molasses at a rate of 10 tons an acre to a heavy soil, and obtained excellent increases in soil aggregation. The dextrination of the molasses was accomplished by using certain strains of bacteria similar to Leuconostoc which often infest sugar factories. The authors claimed to have formed by this process a product similar in nature to the synthetic resins. This study has been responsible for the idea that blackstrap molasses should be subjected to a dextrin fermentation before applying it to soils.

In 1957, Beckman (*1*) reported a study in which increases in weights of nursery forest plants and an increase in the percentage of plants tubed was noted when blackstrap molasses was applied to soil at a rate of 30 tons to the acre. The best response obtained was with a soil containing an appreciable amount of clay of the montmorillonitic type. The results obtained were ascribed to improvements in soil aeration produced by an increase in aggregate stability.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 185.

MATERIALS AND METHODS

The soil used in this investigation was a Whippany clay of poor internal drainage characteristics. It is developed from glaciolacustrine or marine silt and clay sediments. The predominant minerals present in the soil colloidal fraction, as shown in figure 1, are vermiculite, quartz, and traces of kaolinite.

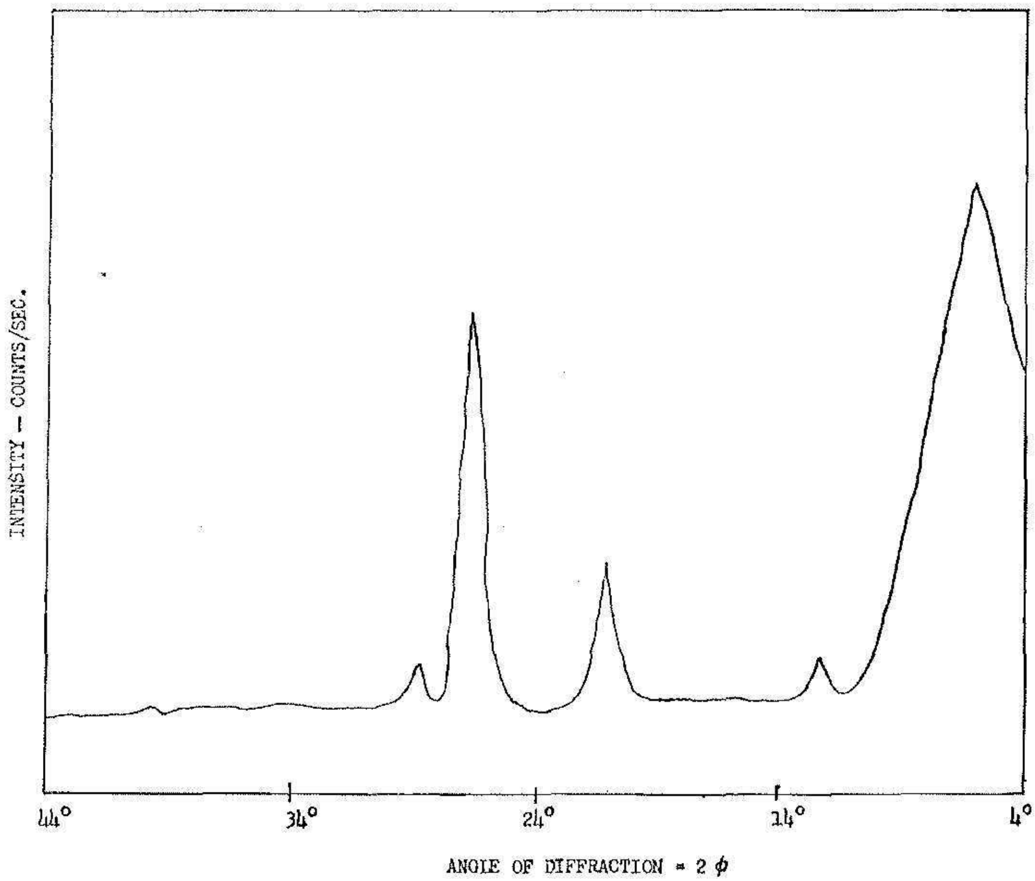

FIG. 1.—X-ray diffractogram of clay fraction of Whippany soil.

Air-dried field samples of this soil were crushed with a roller and passed through a 2-mm. sieve. Six pounds of the soil were placed in metal cans coated with horticultural asphalt and seeded to various test crops.

The following treatments were included in this experiment:

1. Check.
2. A fourth acre-inch of distillery slops.
3. A half acre-inch of distillery slops.
4. A fourth acre-inch of blackstrap molasses diluted to 11 percent by volume.

5. A half acre-inch of blackstrap molasses diluted to 11 percent by volume.

It was decided to use such low levels of slops and molasses since, if higher levels had been used, an undesirable fertility level would have been introduced which might have been reflected in the crops. The soil pH was brought from 4.6 to 6.8 with $CaCO_3$.

The treatments, replicated 12 times, were arranged in a randomized-block design. Wherever significant differences were found the sequential method (*7*) was used to make all comparisons.

Four successive crops, namely, snap beans (variety Bountiful), Sudan grass, wheat (variety Dual), and barley (variety Wong) were planted in this soil. Prior to seeding the successive three crops the pots received the equivalent of 1,000 pounds of 5-10-10 fertilizer an acre.

Soils were maintained at 80 percent of field capacity by weighing. Since the molasses and the slops supplied large amounts of plant nutrients, especially potassium and nitrogen, it was considered desirable, in order to minimize differences other than those that could have been brought by the treatments, to have the same amounts of nutrients in all plots. This was done by applying compensating cations and anions as C.P. salts. Germination counts were made several days after planting, depending upon the nature of the crop.

After each crop three replicates from each treatment were removed and the following treatments made: Hydraulic conductivity and percentage aggregate stability. To determine the effect of the treatments on the uptake of nutrient elements, nitrogen, phosphorus, potassium, and calcium contents were determined on each crop.

The nitrogen content of the various crops grown was determined by the standard Kjeldahl procedure. Phosphorous was measured colorimetrically, as the reduced form of ammonium phosphomolybdate, employing a Lumetron colorimeter and a 660 filter. Potassium and calcium were determined by flame photometric techniques, using LiCl as the internal standard. Soil organic matter was determined by the chromic acid-reduction method (*9*).

Cation-exchange capacity of the soil was measured by the barium acetate method (*6*). Particle-size distribution was determined by the pipette method, as modified by Kilmer and Alexander (*4*). Aggregate stability of the soil was determined by the technique developed by Bryant, Bendixen, and Slater (*3*). Hydraulic conductivity of the water-saturated cores was measured by a modified method of Bower (*2*).

The minerals present in the soil colloidal fraction were determined using an RCA-Leiments Crystalloflex IV X-ray diffractometer with an automatic recording device.

RESULTS AND DISCUSSION

The chemical and physical characterization of the soil is presented in the following tabulation:

pH	Organic matter Percent	Cation exchange capacity Meq./100 gm.	Sand Percent	Silt Percent	Clay Percent
4.6	2.84	24.0	4.2	33.1	62.7

The organic-matter content of the soil does not seem to be low, and one could perhaps explain thereby why the soil had a relatively low aggregate stability. It may be that the reduced forms of iron and manganese prevail because of the poor drainage conditions of the soil in the field. The oxidizing agent used in the organic-matter determination does not distinguish between reduced forms of minerals and the organic carbon. It is also to be noted that, even though the clay-size material is rather high, 62.7 percent, a good part of it was quartz, and this can explain why the cation-exchange capacity, 24 meq./100 gm., is not in accord with the cation-exchange capacity of vermiculite which ranges from 100 to 150 meq./100 gm.

Table 1 presents the germination percentages, dry-weight yields, and the uptake of N, K, P, and Ca by snap beans grown on the Whippany clay soil. Values for hydraulic conductivity and aggregate stability are also listed in this table. The treatment of a fourth of an acre-inch of slops resulted in the highest germination percentage, followed by the treatment of a half acre-inch of slops, which was also higher than the control. The two molasses treatments resulted in a higher germination percentage than on the untreated plots. The germination percentage was higher for the low-level slops than for the high-molasses-level treatment. Snap beans are known as a crop which requires proper air:water relations, particularly during germination. These conditions were present in the soils treated with slops and molasses.

Dry-weight yields did not, however, follow the trends noted in the germination data. The low levels of slops and molasses produced yields that were higher than those obtained in the high-level treatments of these materials, or in the check. It is believed that the lower yields produced on the high-treatment levels of slops and molasses resulted from a rapid loss of water from the soils, because of greater water-infiltration rates induced by these treatments.

As pointed out in discussing experimental procedure, in order to minimize differences other than those that could have been produced by the treatments, compensating cations and anions were supplied to the treatments as salts and acids. In treatments 3 and 5, phosphate and sulfate differences were balanced by using phosphoric and sulfuric acid, respectively. Use of these acids did not lower the soil pH appreciably, but, nevertheless, may have exerted some influence on the availability of minor elements to the plants.

TABLE 1. *Germination percentages, dry-weight yields, and nutrient uptake by snap beans, and hydraulic conductivity and percentages of water-stable soil aggregates in Whippany clay soil after harvest*[1]

Treatment	Germination	Dry-weight yields	Nutrient uptake				Hydraulic conductivity	Water-stable aggregates
			N	P	K	Ca		
	Percent	*Gm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*In./hr.*	*Percent*
1. Check	39	22.34	500	65	552	560	0.77	42.0
2. 1/4 acre-inch slops	76	25.63	768	83	740	683	2.30	65.3
3. 1/2 acre-inch slops	74	19.45	737	61	548	495	6.06	83.3
4. 1/4 acre-inch molasses	64	26.35	780	96	805	688	2.53	72.0
5. 1/2 acre-inch molasses	57	18.44	771	59	553	503	2.60	75.0

[1] *Level of significance*[2]

	5 percent	*1 percent*
Germination	2 3 4 5 1	2 3 4 5 1
Dry-weight yields	4 2 1 3 5	4 2 1 3 5
Nitrogen	n.s.	n.s.
Phosphorus	4 2 1 3 5	n.s.
Potassium	4 2 1 3 5	n.s.
Calcium	4 2 1 3 5	n.s.
Hydraulic conductivity	3 5 4 2 1	n.s.
Aggregate stability	3 5 4 2 1	3 5 4 2 1

[2] Any 2 means not underscored by the same line are different at the indicated level of significance.

The total amounts of N, P, K, and Ca removed from the complete tops of snap beans show that nitrogen uptake was not different in any of the treatments. It was observed during the third week of growth of the plants that those in the control series turned a pale green, indicating a possible nitrogen problem which may have resulted from poor soil drainage.

Phosphorus uptake was higher in the low-molasses treatment than in the high slops and high molasses treatments, and the control, but was not significantly higher than the low-slops treatment. Similar relations were observed with potassium and calcium uptake by the plants.

Hydraulic-conductivity values and the contents of water-stable soil aggregates present in the Whippany clay after the first crop of snap beans, show that the increase in the content of water-stable soil aggregates, and the effects of these aggregates are reflected in hydraulic-conductivity values because of the slops and molasses treatments.

The soil treated with the most slops contained 83.3 percent of water-stable soil aggregates. This value was found to be highly significant over the low slops and the control values.

When the soil in the pots was examined after the growth of the first bean crop, it was observed that the soil crumbs had maintained their stability, even though the soil had been heavily watered during the summer season. A blackish coating seemed to bind the primary soil particles together. This was noted in both the slops and molasses treatments.

The content of water stable aggregates in the check, although lower than in the slops and molasses treatments, cannot be considered as low. The values obtained, however, are in contrast with the observed behavior of the aggregates while watering was conducted. Breakdown of soil aggregates in the check treatment was obvious at the very start of the experiment. It is believed that alternate wetting and drying during the growth of the crop may have been responsible for soil-aggregate stabilization in this treatment.

The germination percentages, the dry-weight yields of Sudan grass, and the uptake of N, P, K, and Ca are presented in table 2; hydraulic-conductivity and aggregate stability values are also shown. In this second experiment, no difference in germination of Sudan grass were obtained between the treatments which were initially applied. Grasses, in general, are somewhat more tolerant of adverse soil conditions than are snap beans and this may have been responsible for the fact that no differences were obtained.

Dry-weight yields of Sudan grass obtained in the slops and molasses treatments were significantly higher than those obtained from the control treatment. There were no differences, however, between the various slops and molasses treatments.

The total amounts of N, P, K, and Ca removed in Sudan grass tops show that nitrogen uptake was significantly higher from the slops and molasses treatments than from the control. No differences in phosphorus uptake were found between the various treatments. Only the high-slops treatment yielded differences in K uptake over the control plots, but the Ca uptake was higher in both molasses and slops treatments, when compared with the check.

During the growth of Sudan grass it was observed that the control plants were pale in color, probably indicating a nitrogen problem.

The hydraulic conductivity of the Whippany clay treated with both levels of slops was higher than the check. The values for hydraulic conductivity in all slops and molasses treatments were higher, but the experimental error was of such magnitude that statistically significant differences were found only at the two levels of slops.

TABLE 2. *Germination percentages, dry-weight yields, and nutrient uptake by Sudan grass tops and hydraulic conductivity and percentages of water-stable soil aggregates in Whippany clay soil after harvest*[1]

Treatment	Germination	Dry-weight yields	Nutrient uptake				Hydraulic conductivity	Water-stable aggregates
			N	P	K	Ca		
	Percent	*Gm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*In./Hr.*	*Percent*
1. Check	88	18.67	108	49	368	32	1.63	31.3
2. ¼ acre-inch slops	89	22.06	163	52	445	57	3.97	86.3
3. ½ acre-inch slops	88	22.28	168	51	500	62	8.97	88.7
4. ¼ acre-inch molasses	88	22.04	165	51	390	64	2.30	84.7
5. ½ acre-inch molasses	91	22.45	203	53	385	61	1.97	87.0

[1] *Level of significance*[2]

	5 percent	*1 percent*
Germination	n.s.	n.s.
Dry-weight yields	5 3 2 4 1	5 3 2 4 1
Nitrogen	5 3 2 4 1	n.s.
Phosphorus	1 2 3 4 5	n.s.
Potassium	3 2 4 5 1	3 2 4 5 1
Calcium	4 3 5 2 1	4 3 5 2 1
Hydraulic conductivity	3 2 4 5 1	n.s.
Aggregate stability	3 5 2 4 1	3 5 2 4 1

[2] Any 2 means not underscored by the same line are different at the indicated level of significance.

The content of water-stable soil aggregates was higher in the slops and molasses treatments than in the control. The percentages of water-stable soil aggregates tended to increase in both slops and molasses treatments and to decrease slightly in the control.

The third crop planted in the Whippany clay was wheat. The germination percentages, dry-weight yields, nutrient uptake by wheat, as well as the hydraulic conductivity and percentages of water-stable soil aggregates after the crop are recorded in table 3. No differences in germination were obtained under the various treatments. In the third crop, yields of wheat were higher for the high-slops treatment when compared with the control, and the low- and high molasses treatments. Yields of wheat from the low level of slops and molasses treatments were, however, significantly higher than from the control.

As was the case with the first two crops, nitrogen uptake by wheat was higher from the treated than from the control plots. No differences existed, however, between the various treatments. This relation was also true for phosphorus and potassium, but not for calcium uptake which showed no differences.

Values for hydraulic conductivity were the highest for the high- and low-slops treatments. In the treatment with a half acre-inch of slops the value of 8.60 inches per hour was highly significant over the other treatments. Higher values than in the control were also obtained in the low-slops treatment. The values obtained in the molasses treatments, even though they appeared to be higher than the control, were not significantly different, because of extreme variation in replicate samples.

The content of water-stable soil aggregates in the slops and molasses treatments was consistently higher than in the control treatment. No difference, however, was apparent between the slops and molasses treatments.

Table 4 presents data concerned with germination, dry-weight yields, and N, P, K, and Ca uptake by barley grown as the fourth crop. In addition, hydraulic conductivity and content of water-stable soil aggregates in the soil after the removal of the barley crop, are also listed. Excellent germination of barley was obtained in the untreated check. Crop yields, however, were markedly higher in both slops and molasses treatments than in the control.

Except for the low level of molasses, the other treatments showed a marked increase in the uptake of nitrogen over the control. Calcium uptake was higher by plants grown at the two levels of slops, as well as at the two levels of molasses, than in the control. No difference in phosphorus or potassium uptake was apparent among the various treatments.

Hydraulic conductivities of all treatments seemed to be higher than the control, but statistical analysis of the data indicated no significant difference.

The content of water stable soil aggregates was slightly increased in all treatments, except at the low slops level.

After the removal of the fourth crop it was observed that the large soil aggregates that had persisted during the growth of the first three crops showed some signs of breakdown. The relatively high content of water-stable soil aggregates present in the soil at the time of removal of the fourth crop is indicative of the resistance to decomposition of the organic cementing, or bonding, agents which are present in the distillery slops, and are responsible for the formation of water-stable soil aggregates.

TABLE 3.—*Germination percentages, dry-weight yields, and nutrient uptake by wheat, and hydraulic conductivity and percentages of water-stable soil aggregates in Whippany clay soil after harvest*[1]

Treatment	Germination	Dry-weight yields	Nutrient uptake				Hydraulic conductivity	Water-stable aggregates
			N	P	K	Ca		
	Percent	*Gm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*In./hr.*	*Percent*
1. Check	85	2.52	52	15	81	11	2.07	33.7
2. 1/4 acre-inch slops	86	3.64	73	25	107	15	4.37	83.0
3. 1/2 acre-inch slops	78	4.04	84	29	125	17	8.60	85.3
4. 1/4 acre-inch molasses	81	3.19	71	24	108	14	2.83	85.3
5. 1/2 acre-inch molasses	91	3.28	73	27	108	16	3.13	90.7

[1] *Level of significance*[2]

	5 percent	*1 percent*
Germination	n.s.	n.s.
Dry-weight yields	3 2 5 4 1	3 2 5 4 1
Nitrogen	3 2 5 4 1	3 2 5 4 1
Phosphorus	3 5 2 4 1	3 5 2 4 1
Potassium	3 4 5 2 1	3 4 5 2 1
Calcium	n.s.	n.s.
Hydraulic conductivity	3 2 5 4 1	3 2 5 4 1
Aggregate stability	5 4 3 2 1	5 4 3 2 1

[2] Any 2 means not underscored by the same line are different at the indicated level of significance.

SUMMARY

Data are presented on the effect of the application of two levels of black-strap molasses and of rum distillery slops on some soil physical conditions,

and crop and nutrient yields of a poorly drained soil of New Jersey. A favorable lasting effect on soil aggregate stabilization with the application of a fourth of an acre-inch of distillery slops and blackstrap molasses was observed when these materials were applied to this soil. The effect persisted even after the growth of four consecutive crops (snap beans, Sudan grass,

TABLE 4.—*Germination percentages, dry-weight yields, and nutrient uptake by barley, and hydraulic conductivity and percentages of water-stable aggregates, in Whippany clay soil after harvest*[1]

Treatment	Germination	Dry-weight yields	Nutrient uptake				Hydraulic conductivity	Water-stable aggregates
			N	P	K	Ca		
	Percent	*Gm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*In./hr.*	*Percent*
1. Check	96	4.13	84	26	216	25	2.43	42.3
2. ¼ acre-inch slops	96	4.90	103	29	203	37	3.33	78.7
3. ½ acre-inch slops	96	5.01	103	28	270	35	4.20	90.3
4. ¼ acre-inch molasses	96	4.59	94	28	213	35	4.18	88.0
5. ½ acre-inch molasses	96	4.77	103	25	213	37	3.03	88.3

[1] *Level of significance*[2]

	5 percent	*1 percent*
Germination	n.s.	n.s.
Dry-weight yields	3 2 5 4 1	n.s.
Nitrogen	3 2 5 4 1	n.s.
Phosphorus	n.s.	n.s.
Potassium	n.s.	n.s.
Calcium	2 5 3 4 1	n.s.
Hydraulic conductivity	n.s.	n.s.
Aggregate stability	3 5 4 2 1	3 5 4 2 1

[2] Any 2 means not underscored by the same line are different at the indicated level of significance.

wheat, and barley). The emergence of snap bean seedlings was favorably affected by the slops and molasses treatments, but the emergence of other crops was not influenced by these treatments.

The uptake of P, K, and Ca by snap beans was increased by these treatments, as were the crop yields. Soil hydraulic-conductivity values also tended to increase with time in the check treatments. The values also tended to increase in the slops treatment, until the third crop, and slightly decreased after the removal of the fourth crop.

Two possible explanations are offered for the decrease in hydraulic conductivity in contrast to the slight increase in aggregate stability with time. These are: First, aggregate stability was determined using 0.5- to 2-mm.-size aggregates separated from the soil by sieving. Since a breakdown of the macroaggregate was observed to occur after the last crop, the 0.5- to 2-mm.-sized aggregates which formed from these larger aggregates were quite stable. Further, since the smaller aggregates tend to create finer pores which retard water movement, the hydraulic conductivity values were reduced. The second possible explanation is that, since roots had been accumulating in the soil because of the growth of four crops, these probably plugged the macro- and micropores, thus sealing, to a certain extent, the channels that would have been available for the movement of water.

The relatively high content of water-stable soil aggregates present in the soil at the time of removal of the fourth crop is indicative of the resistance to decomposition of the organic cementing or bonding agents which are present in the slops and molasses, and are responsible for the formation of water-stable soil aggregates.

RESUMEN

Se estudió el efecto que la aplicación de dos niveles de mieles finales y mostos de destilerías tuvo sobre algunas propiedades físicas, los rendimientos de cosechas y los nutrimentos, en un suelo de New Jersey, de desagüe deficiente. Se observó un efecto persistente sobre la estabilidad de los agregados de este suelo, después de una sola aplicación de un cuarto de acre-pulgada de mosto o miel final. El efecto persistió aún después de cuatro cosechas consecutivas. El efecto sobre la geminación de habichuelas fue favorable, pero no se observó efecto alguno sobre las otras tres cosechas. La absorción de P, K y Ca por las habichuelas aumentó significativamente con los tratamientos de mosto y miel. Los valores de conductividad hidráulica tendieron a subir según pasaba el tiempo, en el caso de las pruebas testigo. En las pruebas en que se aplicó el mosto también tendieron a subir estos valores, aunque sólo hasta la tercera cosecha, disminuyendo ligeramente después de la última. Se sugieren dos posibles razones para explicar esta disminución en la conductividad hidráulica, en contraste con el ligero aumento que hubo en la estabilidad de los agregados. La primera es que la estabilidad se determinó usando agregados de un tamaño de 0.5 a 2 mm. Estos agregados habían sido parte integrante de los macroagregados, los cuales no se desintegraron hasta después de la última cosecha. Esta desintegración dio lugar a que se formaran poros más finos que retardaron un poco el movimiento del agua. La segunda explicación es que las raíces acumuladas después de cuatro cosechas consecutivas puedan haber ocupado los espacios porosos tan necesarios para el movimiento libre del agua.

El alto contenido de agregados estables aún después de la última cosecha indica la persistente resistencia a la descomposición que poseen los agentes cohesivos que se hallan en los mostos y en las mieles finales.

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