

## Modification of Infiltration Rates in an Organic-Amended Irrigated Soil

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### ABSTRACT

Slow water infiltration in some California soils results in considerable irrigation water loss through increased runoff and evaporation. This 25-mo study was conducted to evaluate the effects of different organic amendments on soil physical parameters and water infiltration rates on an irrigated soil. Incorporation of three loadings (25 Mg ha<sup>-1</sup> each) of poultry manure, sewage sludge, barley straw (*Hordeum vulgare* L.), and alfalfa (*Medicago sativa* L.) to an Arlington soil (coarse-loamy, mixed, thermic Haplic Durixeralf) for 2 yr increased soil respiration rates (139-290%), soil aggregate stability (22-59%), organic C content (13-84%), soil saccharide content (25-41%), soil moisture content (3-25%), and decreased soil bulk density (7-11%). The change in soil physical properties resulted in significantly increased cumulative water infiltration rates (18-25%) in the organic-amended plots as compared with the unamended plots. Although additions of poultry manure and sewage sludge contributed to higher soil organic matter compared with straw and alfalfa, the straw amendment was statistically more effective in increasing soil aggregate stability, total saccharide content, infiltration rates, and soil respiration rates and in decreasing bulk density in the tillage zone. The increase in cumulative infiltration rates measured with the first organic addition (April 1987-January 1988) were significantly correlated with increased soil aggregation ( $P \leq 0.01$ ). Cumulative infiltration rates during the second (February 1988-September 1988) and third (October 1988-May 1989) organic incorporation were significantly correlated with decreased bulk density ( $P \leq 0.01$ ), but not with aggregate stability. Multiple linear regression analyses indicated that water infiltration rates in the organic-amended soils were initially increased by stimulation of microbial activity, which increased the stability of soil aggregates. Cumulative infiltration rates were further increased by a decrease in soil bulk density with additional organic treatments to the tillage zone.

**S**LOW WATER INFILTRATION is a serious problem in some irrigated soils and can result in plant injury, inefficient water use, and increased runoff and erosion. Infiltration rates in areas on the east side of the San Joaquin Valley, California, are low during the irrigation season with rates as low as 1 mm h<sup>-1</sup> (Oster and Singer, 1984). The formation of a soil surface crust and/or the reduction in hydraulic conductivity of the bulk soil has reportedly caused reduced infiltration rates (Ben-Hur et al., 1985). The impact energy of water drops and water surface stream compacts the upper soil layer and can cause clogging of the pores immediately beneath the surface (Morin and Benyamini, 1977; Agassi et al., 1981).

The ability of soil to transmit water depends on the arrangement and stability of the soil particles. Soil application of animal wastes, plant residues, and green manures has long been employed to induce favorable soil conditions (Khaleel et al., 1981; MacRae and Mehuys, 1985; Boyle et al., 1989). The mechanism by which organic amendments improve the physical structure of soil is not completely understood, al-

though the effects of organic additions are universally recognized (Jenny, 1980). The application of organic amendments often increases the C content of soil (Khaleel et al., 1981). An increase in the C content often leads to an increase in aggregate stability and water-holding capacity, and a decrease in bulk density (Gupta et al., 1977; Webber, 1978; Weil and Kroontje, 1979).

Several chemical fractions of the organic C component have been suggested to be responsible for increased aggregation. Chaney and Swift (1984) reported significant correlations between aggregate stability and the total soil organic matter content, total saccharide content, and humic material extracted from 120 soils. Other researchers have suggested that bacterial saccharides (Geoghegan and Brian, 1948; Rennie et al., 1954), fatty acids (Dormaar, 1983), and humic materials (Chaney and Swift, 1986) may be responsible for improvement in soil aggregation. Periodate oxidation of soils has provided indirect evidence that the microbial saccharides (mannose, fucose, and rhamnose) play a major role in soil aggregation in grasslands and arable soils (Cheshire et al., 1983, 1984). In addition, earlier work (Waksman and Martin, 1939; Peele, 1940; Gilmour et al., 1948) revealed that microbial activity promotes soil aggregation upon the addition of organic materials. In review of these processes, Chesters et al. (1957) postulated that stable aggregate formation under natural conditions is a gradual process influenced by physical, chemical, and biological agents. Despite the volumes of work evaluating the effects of organic amendments on bulk density, soil aggregation, and water-holding capacity, there is little work on the influence of organic amendments on infiltration rates of soils, particularly on a long-term scale (Smith et al., 1937; Johnson, 1957; Cross and Fishbach, 1972).

The objective of this 2-yr field study was to quantify the change in soil physical conditions and water infiltration rates in an irrigated soil receiving various organic amendments. The premise was that the addition of organic amendments would increase the soil polysaccharide content with a concomitant increase in soil aggregate stability and infiltration rates.

### MATERIALS AND METHODS

Infiltration experiments in replicated (5x) field plots (2 by 2 m) amended with poultry manure (pH, 8.8; C/N, 5.3), sewage sludge (pH, 6.9; C/N, 5.0) (Riverside, CA, Municipal Sewage Treatment Plant), barley straw (pH, 6.4; C/N, 48.5), and green alfalfa (pH, 6.1; C/N, 7.0) were conducted at the Citrus Research Center, Agricultural Experiment Station, Riverside, CA. Organic applications (25 Mg ha<sup>-1</sup> each) were made in April 1987, February 1988, and October 1988 to an Arlington coarse-loamy, mixed, thermic Haplic Durixeralf (pH, 7.9; 670 g sand, 250 g clay kg<sup>-1</sup> soil; 10 g organic C kg<sup>-1</sup> soil; 1.1 g N kg<sup>-1</sup> soil). The application rates for the four amendments (25 Mg ha<sup>-1</sup>) were based on the amounts of composted sewage sludge (Riverside, CA) that could be added to soil accounting for the metal content of the sludge as suggested by guidelines

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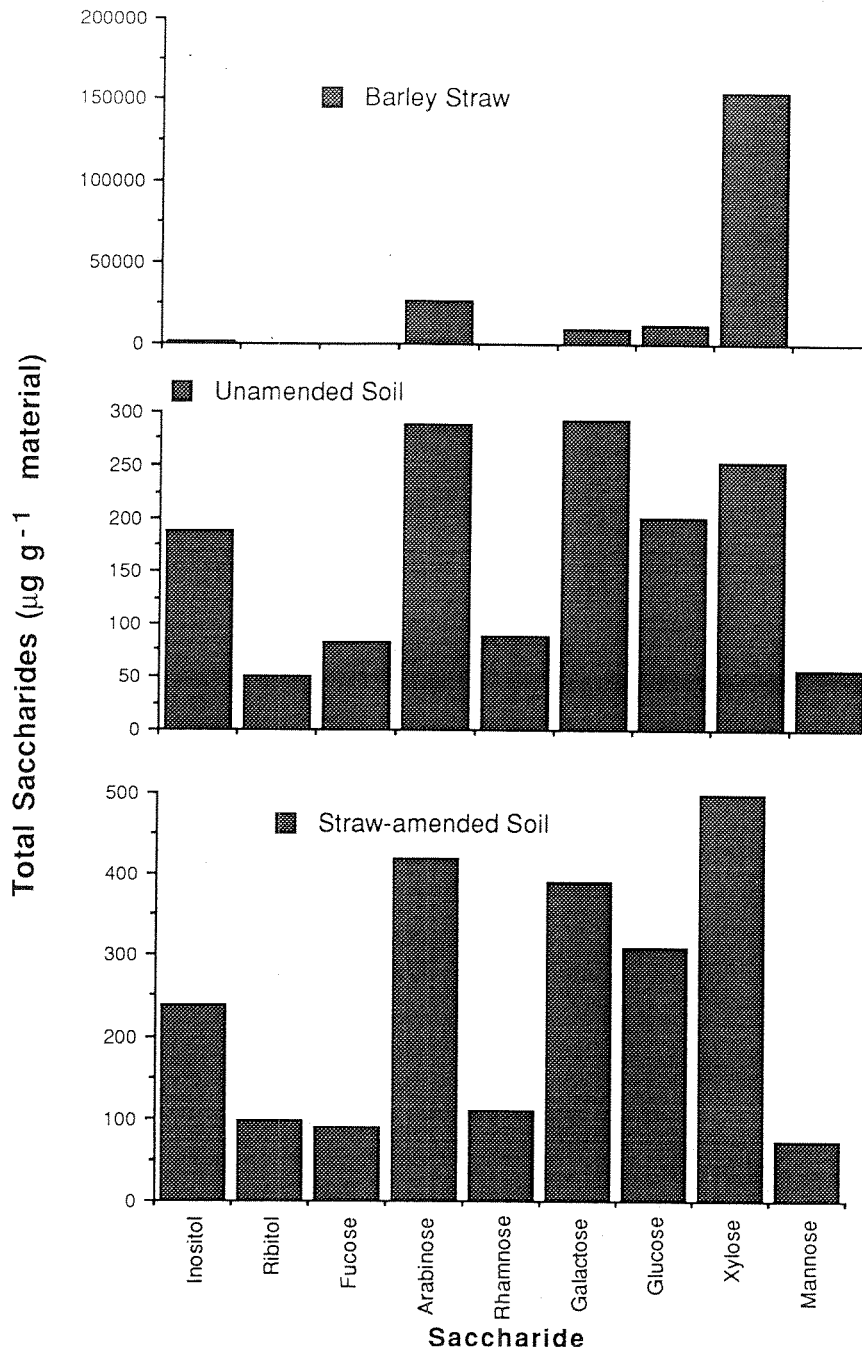


Fig. 1. Saccharide composition of barley straw, the unamended soil, and barley straw-amended soil at 7 mo after application.

of Chaney (1973) and Chaney and Giordano (1977). The amendments were mechanically incorporated by a single pass with a tractor-driven rotary tiller into the upper 15 cm of soil and sprinkler irrigated (100 mm water day<sup>-1</sup>; EC, 0.67 dS m<sup>-1</sup>; SAR, 1.3 meq L<sup>-1</sup>; pH, 7.1) weekly. The plots were maintained in a fallow state by frequent hand cultivation. The same tillage and organic incorporation practices were employed for all plots, including check plots, for the three organic applications.

Water infiltration rates were measured in the field utilizing a constant-head, double-ring infiltrometer with infiltration measurements taken at times ranging from 1 to 240 min (Bouwer, 1986). A 290 mm inner ring, equipped with a hook gauge and connected to a 1200 mm deep by 150-mm diam constant head cylinder, was placed inside a 1000-

mm outer ring. The water levels in the inner and outer rings were kept constant by use of floats. Water of the same quality used for the weekly irrigations was used in the infiltrometer study. Irrigation was stopped during infiltration measurements and one measurement was made per plot per time period. Infiltration measurements were made at approximately the same location for each determination and the rings removed from the plot after the measurement.

The soil bulk density was measured at the 25 to 100-mm depth in triplicate for each plot by use of a thin-walled metal cylinder with removable sample cylinders (Blake and Hartge, 1986). Soil moisture percentage was determined on the sample cores by the gravimetric method as described by Gardner (1986). Soil aggregate stability was determined by wet-sieving in a modified Yoder apparatus (Kemper and

Rosenau, 1986) as follows: 5 g of air-dry soil (1 to 2-mm aggregates) were placed on a single screen (0.4mm) and rewetted to approximately  $-0.034$  MPa by a gentle aerosol misting. The samples (5x) were wet-sieved in deaired water at a stroke length of 1.3 cm and at a frequency of 60 cycles  $\text{min}^{-1}$ . Samples were then removed at 2, 4, 6, 8, and 10 min and a linear regression equation was employed to predict aggregate stability at a time = 5 min. When infiltration rates were determined, soil samples were taken just before infiltration measurements.

Soil polysaccharides were determined by the method of Martens and Frankenberg (1990a). The method involved treating 1-g soil samples with 0.4 mL 6 M sulfuric acid for 2 h at room temperature and refluxing the sample for 16 h with 0.25 M sulfuric acid. The extracts were passed through a strong anion and strong cation resin column for removal of ionic interferences and the saccharides were determined by high performance anion chromatography with pulsed amperometric detection (Dionex, Sunnyvale, CA). Organic C was determined by a modified Mebius procedure described by Nelson and Sommers (1982) and total N was determined by the permanganate method of Bremner and Mulvaney (1982).

Soil respiration ( $\text{CO}_2$  evolution) was measured by incubating 100-g soil samples under field conditions for 10 d in a 250-mL flask equipped with a Suba Seal (Aldrich Chemical Co., Milwaukee, WI) gas septum (Anderson, 1982). A 1-mL headspace sample was separated on a Porapak Q column (Alltech Assoc., Inc., Deerfield, IL). The constituent peaks were detected by thermal conductivity on a gas chromatograph (Varian Assoc., Inc., Model 3700) with a He flow rate of 30 mL  $\text{min}^{-1}$ , a column temperature of 70 °C, an injector temperature of 70 °C, and a detector temperature of 110 °C. Constituent peaks ( $\text{CO}_2$ ) were confirmed through use of external standards.

The bulk density, soil moisture percentage, aggregate stability, organic C content, respiration rates, and soil saccharide contents were determined every 60 d. Temperature measurements were provided by the Citrus Experimental Station.

The statistical analyses used in this study included determination of correlation coefficients and multiple linear regressions in accordance with the SAS procedure (SAS Inst., Inc., 1985).

## RESULTS AND DISCUSSION

### Amendment Saccharide Composition and Fate in Soil

Among the saccharides in each of the amendments incorporated into the Arlington soil, the predominant sugars in poultry manure were xylose (6570 mg  $\text{kg}^{-1}$ ), arabinose (5200), glucose (3080), and galactose (2300). Sewage sludge was composed of arabinose (10 500 mg  $\text{kg}^{-1}$ ), galactose (4410), glucose (3340), mannose (2930), and xylose (2600). The barley straw contained mainly arabinose (26 410 mg  $\text{kg}^{-1}$ ) and xylose (154 040) (Fig. 1). The dominant saccharides found in alfalfa included xylose (58 050 mg  $\text{kg}^{-1}$ ), arabinose (40 950), glucose (31 340), galactose (20 220), and inositol (11 840). Other saccharides found in minor quantities in these amendments have been reported by Martens and Frankenberg (1990a). The total amount of saccharides applied to the soil plots in each of the three applications were as follows: 19.2 mg  $\text{g}^{-1}$  of poultry manure, 27.7 mg  $\text{g}^{-1}$  of sewage sludge, 203 mg  $\text{g}^{-1}$  of barley straw, and 163 mg  $\text{g}^{-1}$  of alfalfa. Once these amendments were applied to soil, samples were taken to monitor the composition and

quantity of saccharides upon each treatment. The composition and quantity of the monosaccharides determined for the four amended plots were very similar (Martens and Frankenberg, 1990a) in spite of the large variation in amounts of added individual saccharides in the amendments.

The saccharides extracted from the barley straw plot and the check plot are graphically illustrated in Fig. 1. The primary saccharides extracted from the amended and unamended soil were arabinose, galactose, glucose, and xylose. Much of the saccharides present in the amendments was decomposed within several months after the amendment was applied to the soil. The total extractable saccharide content determined at various seasons of the year in the organic-amended plots is shown in Fig. 2. During the study, less saccharide was extracted from the alfalfa-treated plots when compared with the other organic treatments (Table 1). This suggests that the alfalfa polysaccharides were metabolized at a greater rate than were the polysaccharides from the other organic amendments. Increased levels of total saccharides extracted from the treated plots were correlated with increased soil respiration ( $r = 0.39^{***}$ —significant at  $P = 0.001$ ) and soil organic matter content ( $r = 0.35^{***}$ —significant at  $P = 0.001$ ). The four organic amendments significantly increased the total extractable saccharide content in soil during the 25-mo study by 37, 31, 41, and 25% with the poultry manure, sewage sludge, barley straw, and alfalfa additions, respectively, compared with the unamended plots.

The addition of the four organic amendments significantly increased the extractable soil saccharide content in the soil; however, this increase did not reflect the levels of saccharides that were initially added with the amendments. Studies with  $^{14}\text{C}$ -labelled monosaccharides added to laboratory-incubated soils have shown that monosaccharides are rapidly metabolized and the majority of the added  $^{14}\text{C}$  is recovered as  $\text{CO}_2$  (Oades and Wagner, 1970, 1971; Cheshire et al., 1971; Sorensen and Paul, 1971). Cheshire et al. (1973) reported that when  $^{14}\text{C}$ -labelled rye straw was added to laboratory soils, approximately 50% of the straw was decomposed and respired as  $^{14}\text{CO}_2$ . Fractionation of the soil after incubation for 7.5 mo indicated that most of the  $^{14}\text{C}$  remaining was in the form of unchanged plant material. Incorporation of undecomposed organic amendments into soil humus may explain why saccharides of predominantly plant origin (arabinose, xylose, and glucose) can remain in soil for long periods of time. Martens and Frankenberg (1990b) evaluated several saccharide extraction procedures and found that heat in conjunction with sulfuric acid was necessary for efficient extraction of saccharides from soil. This suggests that the majority of the polysaccharides present in the Arlington soil exist as acid-labile hexopyranosyl glycosidic linkages of plant origin.

### Respiration Rates and Organic Matter Content

Soil respiration rates more than doubled with additions of the four organic amendments (Fig. 3). The greatest respiration flux was observed with the barley straw addition during the summer months of 1988.

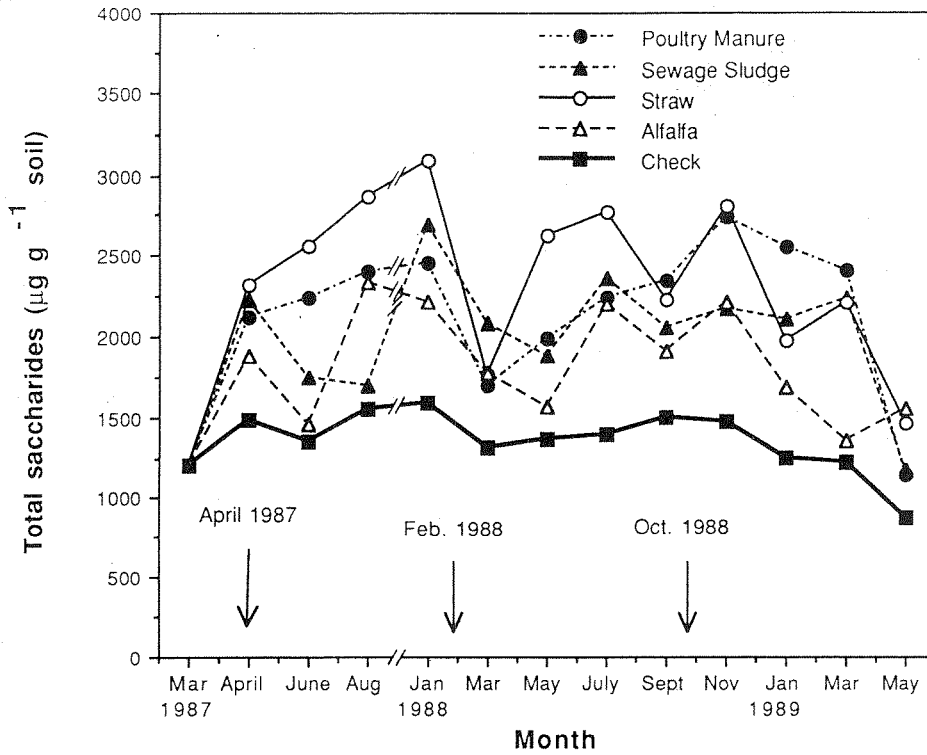


Fig. 2. Influence of organic amendment on total extractable soil saccharide content.  $LSD_{(0.05)} = 0.30$ . Arrows indicate addition of organic amendments.

Increased soil respiration rates in the organic-amended plots were not correlated with evapotranspiration rates or minimum temperatures but were related to the maximum soil temperatures ( $r = 0.82^{**}$  —significant at

$P = 0.01$  [poultry manure],  $0.79^{**}$  —significant at  $P = 0.01$  [barley straw], and  $0.74^*$  —significant at  $P = 0.05$  [alfalfa]). During the 25-mo study, the organic amendments significantly increased soil respi-

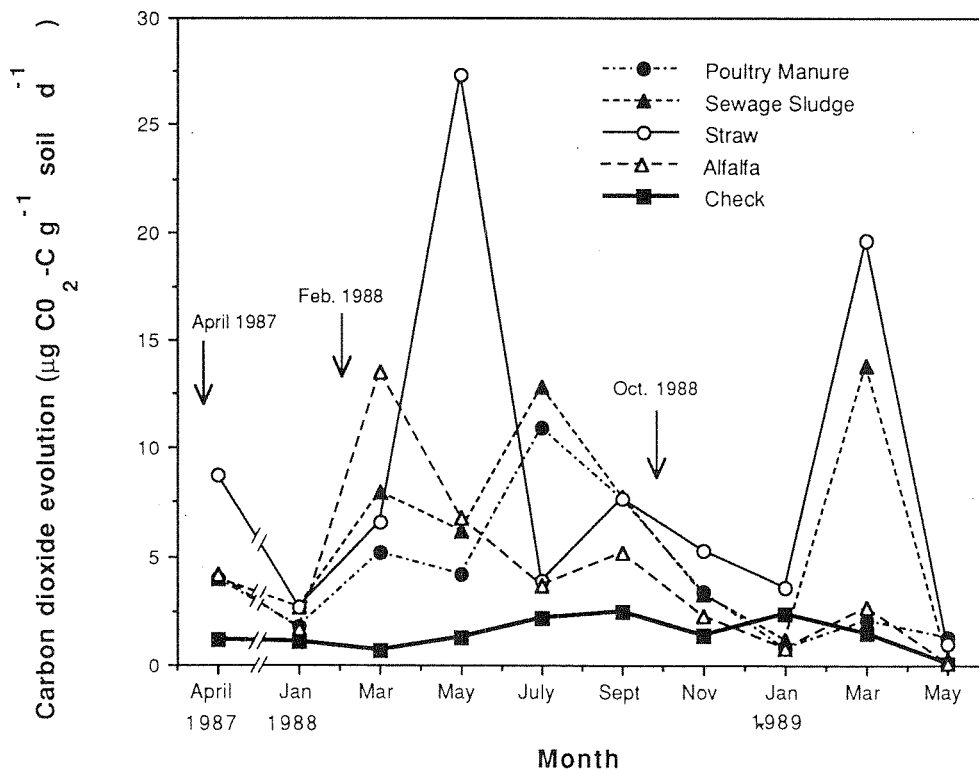


Fig. 3. Influence of organic amendment on soil respiration.  $LSD_{(0.05)} = 1.20$ . Arrows indicate addition of organic amendments.

ration rates by 140, 198, 290 and 180% with the poultry manure, sewage sludge, barley straw, and alfalfa additions, respectively, over the unamended plots (Table 1). The organic amendments also significantly increased the soil organic matter content by 57, 84, 37, and 13% with the poultry manure, sewage sludge, barley straw, and alfalfa additions, respectively, when compared with the unamended plots during the 25-mo study (Table 1; Fig. 4).

### Aggregate Stability

Although aggregate formation and stabilization are often discussed together, the two processes involve different forces, which may or may not be occurring at the same time.

Martin et al. (1955) defined a soil aggregate as a "naturally occurring cluster or group of soil particles in which the forces holding the particles together are stronger than the forces between adjacent aggregates." Aggregate formation involves the orientation of the soil particles so that physical forces between them will hold them firmly when allowed to dry. Aggregate stabilization by clays or organic matter must be occurring along with aggregate formation if a permanent increase in soil aggregation is to take place. Development of soil structure must be promoted and maintained to cause an increase in the rate of water movement into a soil.

A comparison of the effects of the four organic amendments on soil aggregate stability is illustrated in Fig. 5. The treatment means, standard error of the mean, and the LSDs for the four treatments and the unamended check for the 25-mo study are presented in Table 1. This study showed that barley straw was significantly more effective in increasing aggregate stability than were the poultry manure, sewage sludge, and alfalfa treatments. Statistical analyses of the first organic addition (April 1987-January 1988) indicated that soil aggregate stability was significantly correlated with the presence of specific monosaccharides (fucose [ $r = 0.42^{***}$ —significant at  $P = 0.001$ ], glucose [ $r = 0.34^{***}$ —significant at  $P = 0.001$ ], mannose [ $r = 0.34^{***}$ —significant at  $P = 0.001$ ], and the total saccharide content ( $r = 0.37^{***}$ —significant at  $P = 0.001$ ) of the amended soil. Aggregate stability after the second organic addition (February 1988-September 1988) was correlated with the extractable saccharides (ribitol [ $r = 0.25^*$ —significant at  $P = 0.05$ ], arabinose [ $r = 0.27^{**}$ —significant at  $P = 0.01$ ], galactose [ $r = 0.39^{***}$ —significant at  $P = 0.001$ ], glucose [ $r = 0.35^{***}$ —significant at  $P = 0.001$ ], xylose [ $r = 0.27^{**}$ —significant at  $P = 0.01$ ], and total saccharide content ( $r = 0.39^{***}$ —significant at  $P = 0.001$ ). However, there was no significant correlation between extractable saccharides and aggregate stability after the third treatment (October 1988-May 1989).

Microbial polysaccharides are thought to play a significant role in increased soil aggregation (Waksman and Martin, 1939; Peele, 1940; Gilmour et al., 1948). Cheshire et al. (1983, 1984) demonstrated that treatment of a grassland soil with perborate and tetraborate increased the disruption of stable aggregates. Continued oxidation progressively decreased the soil saccharide content and concomitantly decreased soil aggregate

stability. Chaney and Swift (1986) found that bacterial polymers resulted in immediate aggregation (within 1 d) but glucose-mediated aggregation reached a maximum 21 d after incubation. The physical attachment of soils has also been shown to be a result of microbial growth. Tiessen and Stewart (1988) reported that in many cases, attachment of microorganisms may bridge two or more mineral particles and that microbial cementation was still visibly involved in aggregation after the bacterial cells themselves had disappeared. Oades and Ladd (1977) reported that microaggregates are stabilized by binding of humic substances. Humus bridging is more stable than the transient effects of extracellular polysaccharides on aggregation (Chaney and Swift, 1986). The binding effects of polysaccharides on soil aggregation appears to be transient. The significant correlations between aggregate stability and the saccharide content with the first two organic additions indicated that saccharide materials initially contribute to the stabilization of soil aggregates. The lack of significant correlations between saccharides and aggregation with the decomposition of the third organic addition suggests that other soil organic fractions, namely soil humus, may be responsible for long-term aggregate stabilization.

For the 25-mo study, aggregate stability was increased by 22, 24, 59, and 40% with the poultry manure, sewage sludge, barley straw, and alfalfa treatments, respectively, when compared with the unamended plots.

The unamended plots also increased in aggregation throughout this long-term study. The plots were maintained in a fallow state, which removed the effects vegetation may have had on the aggregation process. It is possible that the weekly irrigation schedule employed was responsible for the increase in aggregation. Physical processes such as wetting and drying and freezing and thawing cycles have been reported to increase soil aggregation. Bouyoucos (1924) found that alternating wetting and drying cycles caused soil granulation by swelling of the colloids. The cohesive forces pull the soil particles together as the water is removed in the drying cycle. Telfair et al. (1957) found that during a 2-yr period, wetting and drying cycles caused planes of weakness that provided the initial faces of aggregates forming platy soil structure. In our work, weekly irrigation provided enough water to keep the plots damp in the fall through early spring, but during the warm late spring and summer months, the soil surface became dry to a depth of several centimeters. Generally, the greatest increases in soil aggregation in the unamended and amended soils were observed during the warm summer months. Aggregate stability is a function of the physical forming forces present in both the amended and unamended plots and of the aggregate stabilization forces present in the amended plots due to the release of aggregating agents by soil microorganisms upon decomposition of the applied organic materials.

### Bulk Density

The measured bulk densities initially dropped sharply with the first organic amendment incorporation and beginning of the weekly irrigation schedule (Fig. 6). Powers et al. (1975) suggested that decreased bulk

Table 1. Comparison of effects of organic amendments (means of 25-mo study) on soil parameters and water infiltration parameters.

Parameter	Amendments†					LSD <sub>(0.05)</sub>
	Poultry manure	Sewage sludge	Straw	Alfalfa	Check	
Total extractable saccharides, mg saccharides g <sup>-1</sup> soil	2.18 (0.09)	2.01 (0.09)	2.36 (0.10)	1.80 (0.07)	1.38 (0.04)	0.30
CO <sub>2</sub> evolution, µg CO <sub>2</sub> g <sup>-1</sup> soil day <sup>-1</sup>	3.40 (0.30)	4.20 (0.40)	5.50 (0.60)	3.95 (0.50)	1.40 (0.20)	1.20
Organic matter content, g organic matter kg <sup>-1</sup> soil	15.7 (0.4)	18.5 (0.5)	13.7 (0.3)	11.3 (0.2)	10.0 (0.2)	0.96
Aggregate stability, g stable aggregate kg <sup>-1</sup>	366.1 (25.0)	367.1 (26.0)	478.1 (27.0)	423.4 (28.0)	299.5 (20.0)	69.6
Bulk density, g soil cm <sup>-3</sup>	1.37 (0.02)	1.33 (0.04)	1.32 (0.02)	1.38 (0.02)	1.48 (0.02)	0.05
Cumulative infiltration, mm H <sub>2</sub> O 4 h <sup>-1</sup> event	43.5 (2.9)	51.1 (3.4)	55.8 (4.4)	55.3 (3.9)	36.8 (3.3)	10.39
Sorptivity, cm H <sub>2</sub> O sec <sup>-1/2</sup>	0.12 (0.01)	0.14 (0.01)	0.16 (0.02)	0.15 (0.01)	0.09 (5.5 × 10 <sup>-3</sup> )	0.03
Moisture content, g H <sub>2</sub> O kg <sup>-1</sup> soil	110.7 (4.0)	117.2 (5.0)	135.0 (5.0)	113.0 (4.0)	108.4 (5.0)	12.9

† Values in parentheses indicate standard error of the mean.

density upon organic applications were a result of a dilution effect of the added amendments with the more dense mineral fraction of the soil. This dilution effect most likely played a role in the initial decreased bulk density measurements (April-August, 1987) due to the inclusion of large amounts of the organic amendments in the sampled bulk density cores. The second organic addition (February, 1988) did not induce the large decreases in bulk density that were found with the first addition. This may have been due to a more rapid rate of organic residue decomposition. Incorporation of the

organic amendments (April, 1987) and beginning of weekly irrigation broke a 2-yr fallow period in this Arlington soil. The organic decomposition was noticeably slower with the first organic addition than in the second addition. The fall organic incorporation (October, 1988) resulted in the largest differences measured between the organic treatments. This may have been the result of the cooler weather during the winter months slowing the microbial decomposition of the amendments and allowing them to remain longer in the soil.

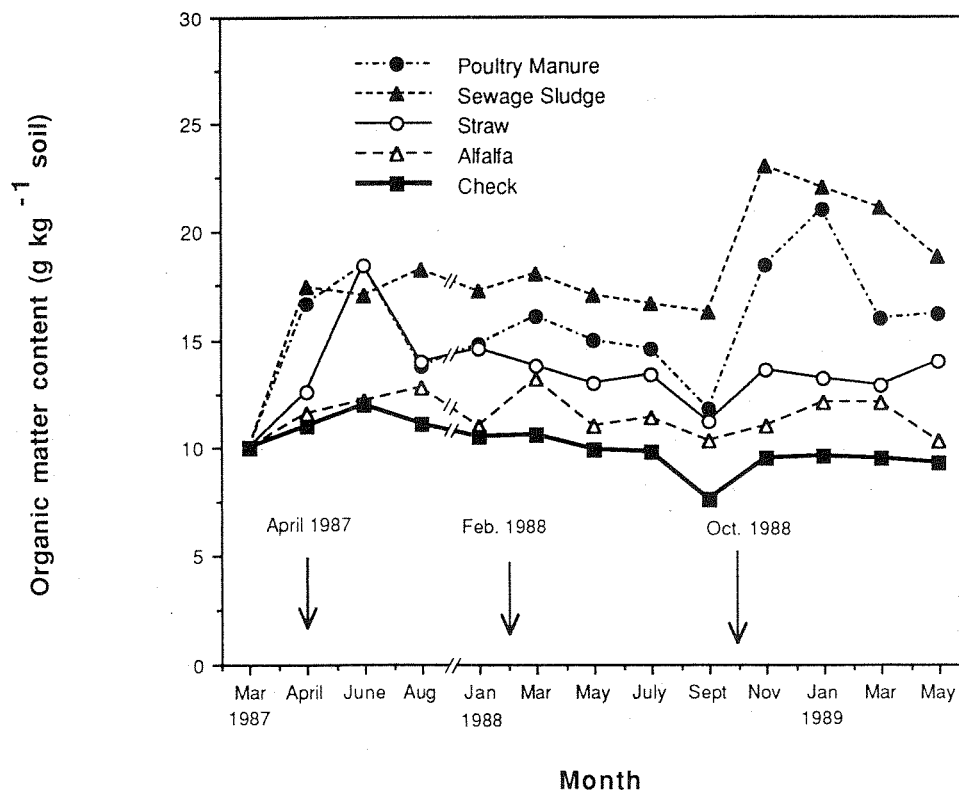


Fig. 4. Influence of organic amendment on soil organic matter content. LSD<sub>(0.05)</sub> = 0.96. Arrows indicate addition of organic amendments.

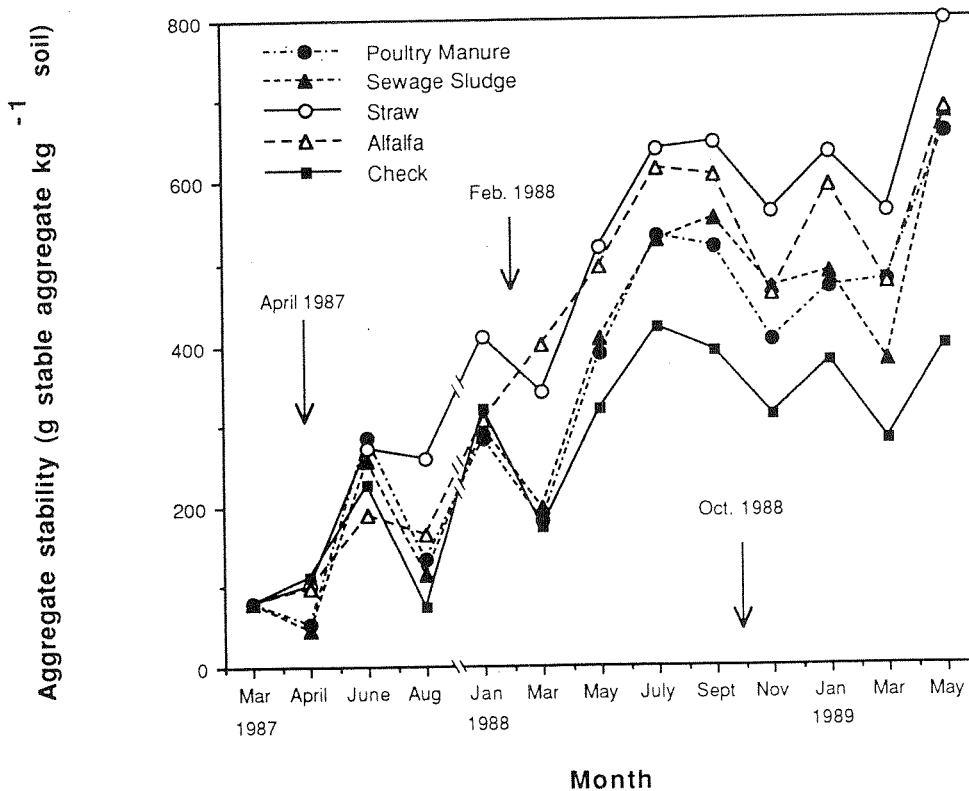


Fig. 5. Influence of organic amendments on soil aggregate stability.  $LSD_{(0.05)} = 69.6$ . Arrows indicate addition of organic amendments.

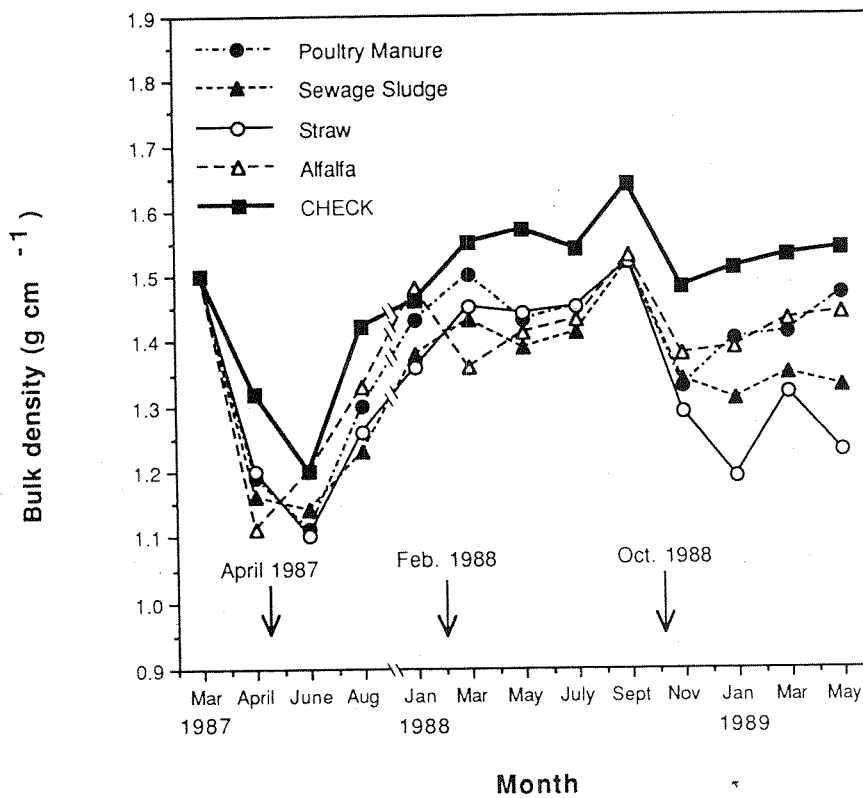


Fig. 6. Influence of organic amendments on soil bulk density.  $LSD_{(0.05)} = 0.05$ . Arrows indicate addition of organic amendments.

The decreased bulk densities measured during the study were found to be inversely related to the increased organic matter content, aggregate stability, and soil respiration in the organic-amended soil. The barley straw and sewage sludge were more effective in decreasing bulk densities than poultry manure or alfalfa, but all treatments were significantly more effective in decreasing bulk density when compared with the unamended plots (Table 1). The treatments decreased the mean bulk density by 7, 10, 11, and 7% with the poultry manure, sewage sludge, barley straw, and alfalfa additions, respectively, when compared with the unamended plots during the 25-mo study.

Although it is important to note the dilution effect of added organic material on bulk density, the greatest measured differences in bulk density between treatments in this study were observed when almost all of the added organic residues were completely decomposed (May, 1989).

### Cumulative Infiltration Rates

The ability of a soil to transmit water depends on the arrangement of the soil particles and stability of the aggregates. In all cases, the organic amendments increased the cumulative infiltration rates when compared with the unamended plots (Table 1; Fig. 7).

Statistical analyses indicated that the increased cumulative infiltration rates measured after the first addition of organic amendments were correlated with increased aggregate stability ( $r = 0.32^{**}$ —significant at  $P = 0.01$ ). The cumulative infiltration rates upon the second ( $r = -0.40^{***}$ —significant at  $P = 0.001$ ) and third ( $r = -0.37^{***}$ —significant at  $P = 0.001$ ) organic treatments were inversely correlated with decreased bulk densities. Overall, this study showed that infiltration rates were increased more by decreased bulk density in the tillage zone and influenced less by increased aggregate stability. Multiple linear regression analyses of the relationships between cumulative infiltration rates and the physiochemical properties (bulk density, aggregate stability, organic matter content, and total saccharide content) indicated that a decrease in bulk density and an increase in aggregate stability were the major factors affecting infiltration during this 2-yr study. Soil organic matter content and the total saccharide content were not significantly related to the cumulative infiltration rates. The additions of barley straw, alfalfa, and sewage sludge were significantly more effective than the treatments of poultry manure or tillage only (unamended plot) for increasing cumulative water infiltration rates (Table 1). The organic amendments increased the mean cumulative infiltration rates (0-240 min) by 18, 39, 52, and 50% with the poultry manure, sewage sludge, barley straw, and alfalfa amendments, respectively, during the 2-yr study. Increased infiltration rates, resulting from applications of organic materials, have been reported by Pillsbury and Huberty (1941a,b), Parker and Jenny (1945) and Johnson (1957). They found that applications of animal manure or other organic amendments to soil greatly increased water infiltration and were directly related to the quantity of organic material applied. Parker and Jenny (1945) reported that the application of animal

manure to the surface 130 mm of soil was as effective in increasing water infiltration as were the rooting systems of cover crops.

### Sorptivity

During the early stages of the infiltration process, water transmittance is nearly uniform in all directions, independent of both the gravity and the geometry of the soil (Philip, 1969). This one-dimensional absorption or sorptivity ( $S$ ) of water into a medium at time  $t$  is described by the equation (Philip, 1969).

$$S = I t^{-1/2}$$

where  $I$  = cumulative infiltration (cm water  $\text{cm}^{-3}$ ) at  $t = 10$  min.

Incorporation of the organic amendments significantly increased the sorptivity of the Arlington soil except for the poultry manure treatment (Table 1). In general the first organic application resulted in the greatest increase in sorptivity in the amended soil (Fig. 8). Over the 25-mo study, the plant residues nearly doubled the sorptivity of the Arlington soil when compared to the tillage only treatment (unamended plot) (Fig. 8). Sorptivity estimates at the 10-min measurement were correlated with decreased bulk density ( $r = 0.54^{**}$ —significant at  $P = 0.01$ ) and increased organic C content ( $r = 0.51^{**}$ —significant at  $P = 0.01$ ) but were not significantly correlated with increased aggregate stability during the 25-mo study. Incorporation of the organic amendments increased the mean sorptivity 25, 56, 78, and 67% for the poultry manure, sewage sludge, barley straw, and alfalfa, respectively, when compared to the tillage only treatment during the study.

### Moisture Content

The soil gravimetric moisture content was increased by additions of organic amendments to soil (Fig. 9). All plots followed a seasonal cycle of increased moisture content during the wet winter months followed by a decrease in the summer months. Gravimetric or volumetric water content (gravimetric moisture by bulk density) were not found to be significantly correlated with sorptivity measured during the 25-mo study. Sorptivity is influenced by both soil structure and the antecedent water content of a soil (Bouwer, 1978). Dry soils have a higher water sorptivity than wet soils. In this study, the soil was maintained in a damp state by irrigating weekly and may not have dried sufficiently to show significant sorptivity effects during infiltration measurements. The barley straw treatment was the only organic amendment that significantly increased the gravimetric moisture content when compared with the other treatments (Table 1). The organic amendments increased the mean gravimetric moisture content by 3, 9, 25, and 4% with the poultry manure, sewage sludge, barley straw, and alfalfa additions, respectively, when compared with the unamended plots during the 25-mo study.

In conclusion, the data presented in this study show that the incorporation of organic residues increased soil aggregation, soil microbial respiration, and water infiltration parameters and decreased soil bulk densi-



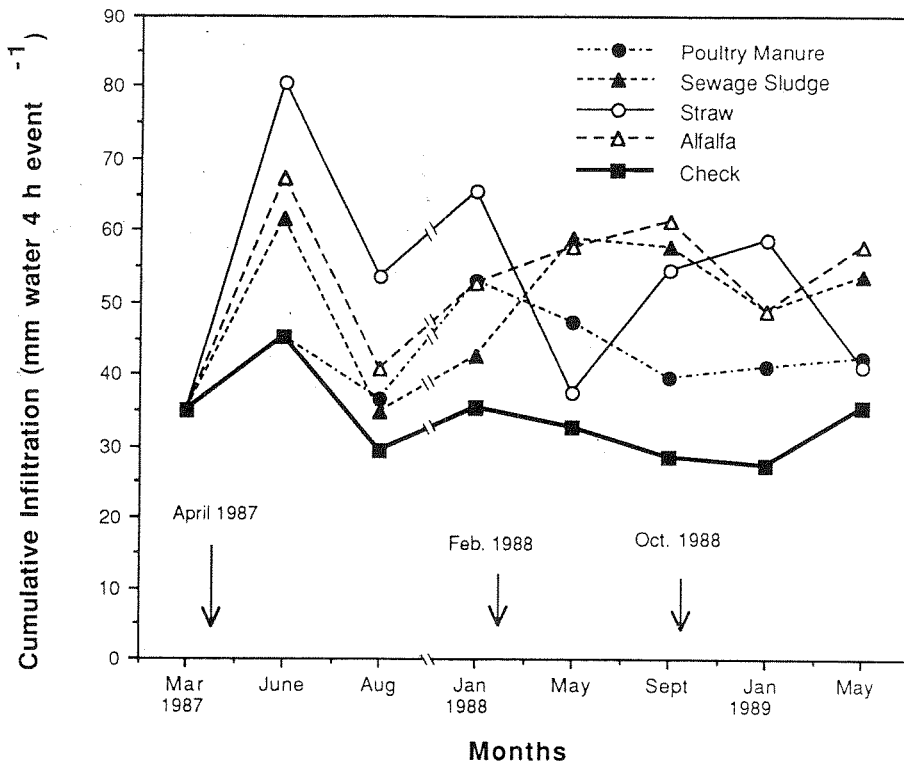


Fig. 7. Influence of organic amendments on soil cumulative water infiltration rates.  $LSD_{(0.05)} = 10.39$ . Arrows indicate addition of organic amendments.

ties. The role of polysaccharides in aggregate stabilization appears to be important in the initial stabilization

of the aggregate formed by physical processes. This stabilization role appears to be a transient one, becom-

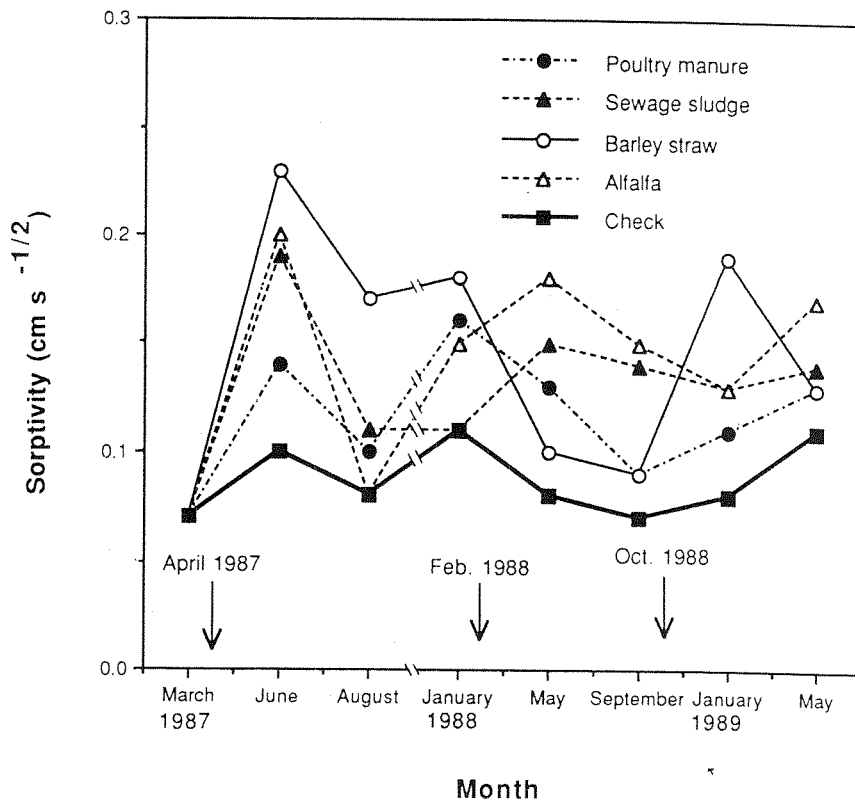


Fig. 8. Influence of organic amendments on soil sorptivity.  $LSD_{(0.05)} = 1.1 \times 10^{-2}$ . Arrows indicate addition of organic amendments.

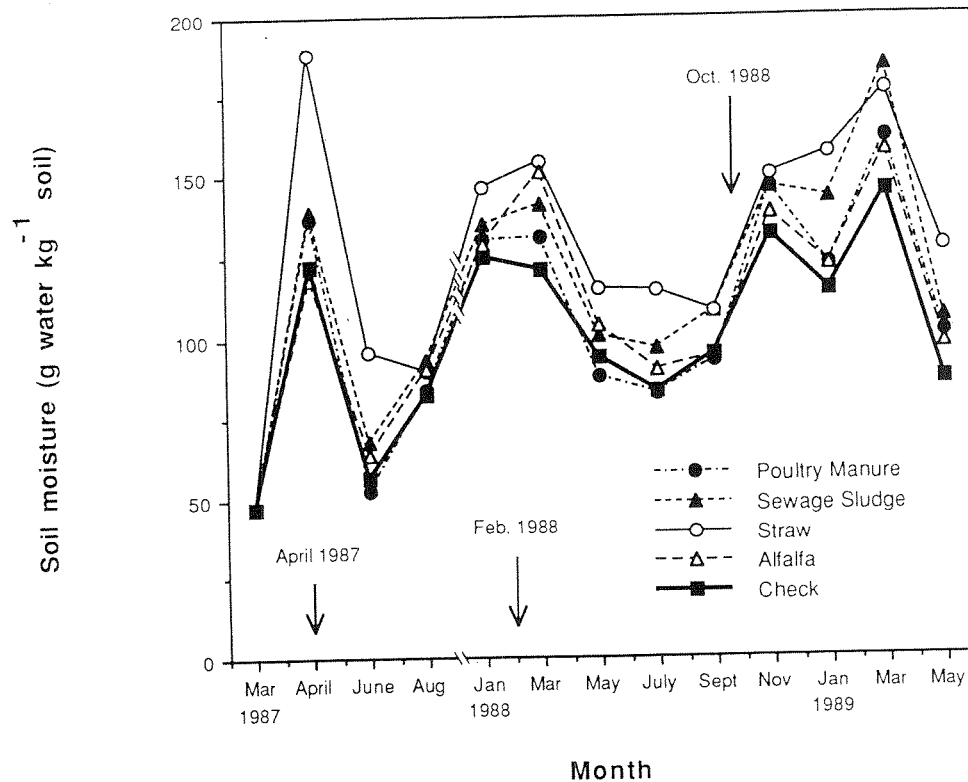


Fig. 9. Influence of organic amendments on soil gravimetric moisture content.  $LSD_{(0.05)} = 12.9$ . Arrows indicate addition of organic amendments.

ing less effective with increased production of other microbial products and the formation of humus bridging. The added organic carbon increases the soil sorptivity in the tillage zone and infiltration rates. Regular organic additions should be an integral part of a successful management plan to enhance infiltration rates in soil.

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