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INFLUENCE OF TILLAGE, CROPPING SYSTEMS AND CROP RESIDUES ON SOME PHYSICAL PROPERTIES, ORGANIC FRACTIONS AND THE GROWTH AND YIELD OF NAVY BEANS (PHASEOLUS VULGARIS L.) ON A CHARITY CLAY SOIL

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INFLUENCE OF TILLAGE, CROPPING SYSTEMS AND CROP RESIDUES ON SOME PHYSICAL PROPERTIES, ORGANIC FRACTIONS AND THE GROWTH AND YIELD OF NAVY BEANS (*PHASEOLUS VULGARIS* L.) ON A CHARITY CLAY SOIL

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ABSTRACT

INFLUENCE OF TILLAGE, CROPPING SYSTEMS AND CROP RESIDUES ON SOME PHYSICAL PROPERTIES, ORGANIC FRACTIONS AND THE GROWTH AND YIELD OF NAVY BEANS (*PHASEOLUS VULGARIS* L.) ON A CHARITY CLAY SOIL

By

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Two field experiments were conducted on a Charity clay soil to study the influences of organic residues, cropping sequences, primary and secondary tillage practices on several soil physical parameters and the growth and yield of navy beans. An oats cover crop and spring secondary tillage treatments were studied in one experiment. The second experiment included two amendments of ground corn cobs, four types of primary tillage and three cropping sequences.

Aggregate stability measurements demonstrated that, generally, the stability of soil aggregates decreased during the growing season. The severity of this problem varied with the type and frequency of tillage operations. Eliminating secondary tillage reduced the breakdown of soil aggregates. Application of an organic amendment, either as cover crop or as plant residues, improved the formation and stabilization of aggregates > 0.5 mm in diameter. The organic amend-

ment also overcompensated for adverse effects of tillage practices on soil structure. Mean weight diameter, bulk density and total porosity increased 3-4% in treatments with an organic amendment and zero secondary tillage. A 3-7% increase in saturated hydraulic conductivity was also obtained by these treatments.

Plant growth and yield were the greatest on treatments with organic amendments and high residue cropping sequences. This increase appeared to be due to the improved soil structure and related soil physical properties of the amended treatments. In experiment one, largest yields were obtained with no secondary tillage in the spring. In experiment two, maximum yields were attributed to zero primary tillage when beans followed one year of alfalfa.

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INTRODUCTION

The formation of a stable soil structure under natural conditions is a gradual process. A stable structure enhances soil water conductivity, aeration capacity, bulk density and porosity. Good soil structure also facilitates nutrient mobility and absorption, water utilization and microbial activity. Aggregated soils promote plant productivity by maintaining an ideal air and water porosity, optimum temperature regime, and minimum mechanical impedance to root growth and development. Hence, a well aggregated soil with optimum tilth provides a suitable physical condition for seed germination, seedling emergence, root growth and plant development.

Crusting and compaction of fine textured soils are two major consequences of an unstable structure. These are major problems in many parts of the world, especially on irrigated lands of arid and semi-arid regions in the Middle-East. On fine textured soils, crusting and hard clods may be a problem after plowing. Secondary tillage has been used to break or cut the crust and/or bury the clods so that they do not affect planting. Compact layers, may be natural but are most likely the product of poor management or unfavorable circumstances such as having to harvest a crop on wet soil or working the soil at high moisture levels.

Stability of aggregates is based on a series of physicochemical and biochemical reactions. These forces are dynamic and may be modified by: 1) freezing and thawing; 2) wetting and drying; 3) production of active organic compounds through decomposition of plant residues by soil microorganisms; and, 4) crop management and mechanical manipulation of the soil.

The primary objective of tillage is to mechanically manipulate the soil structure and achieve an optimum soil physical condition which promotes maximum yield. Recent changes in tillage have been oriented toward decreasing the number of trips of machinery across the soil. Although modern reduced tillage systems have many desirable characteristics, the extent to which soil physical conditions can be technically and economically improved has not been determined.

Synthetic soil conditioners have been used with marginal success. However, the use of soil conditioners on a global scale is economically impractical, especially in underdeveloped and developing countries. Plant residues and cover crops along with reduced tillage could improve soil aggregation without major investments.

Wind and water erosion results in the loss of soil, the breakdown of surface aggregates, pollution of the environment, soil crusting and physical damage to young plants. Reduced tillage and cover crop systems conserve both soil and environment by adding active organic matter to the soil, and by reducing the mechanical destruction of soil aggregates.

The primary objective of this research was to study the turn-over rate and influence of organic matter constituents involved in the formation and stabilization of soil aggregates under different tillage practices and cropping sequences. Other objectives were: 1) to correlate the quantities of fats, waxes and lipids, polysaccharides and polyuronides with the stability of aggregates, 2) to determine the turnover of specific organic components during a single growing season of several crop and soil management systems, 3) to determine the influence of plant and soil management systems upon aggregate stability of Charity clay soil, 4) to correlate plant growth and productivity with soil aggregation in these management systems.

This field and laboratory study, initiated in 1974, was conducted on a Charity clay soil in 1976 at the Saginaw Valley Bean and Beet Research Farm. The Farm is located in Saginaw County, at the intersection of Swan Creek and Thomas Roads southwest of Saginaw, Michigan. The two field experiements were a no-secondary tillage management system (on range 5, tiers 3 and 4) and a primary tillage organic residue study (on range 9, tiers 3, 8 and 9). The first experiemnt was established to evaluate the influence of an oats cover crop and secondary tillage upon several soil physical and plant parameters. The second experiment was designed to evaluate the interactions of an organic amendment and three cropping sequences with four primary tillage systems upon soil physical and plant parameters. Navy beans (Phaseolus vulgaris L.) were the indicator crops for both experiments. This crop is planted on nearly 700,000 acres of fine and medium textured soils in Michigan and is very susceptible to soil physical stresses.

LITERATURE REVIEW

General

It is generally accepted that organic matter plays a key role in soil aggregation and it is believed that the main effect is through cementation (1, 27, 29, 37, 38, 52). Organic matter appears to promote aggregate stability by: 1) increasing the inherent strength of aggregates which is controlled by the configuration of the functional group and its degree of substitution as well as any soil condition which influences the effectiveness of polymers, 2) increasing the hydrophobic properties of aggregates, 3) reducing the swelling of aggregates, and 4) reducing the destructive forces of entrapped air (17, 18, 60, 73, 76). It is also known that COOH, NH_2 and OH groups of colloidal organic substances are responsible for this cementation action through hydrolysis, deamination, esterification and acetylation (3, 35, 91, 92).

A stable soil structure refers to the ability of soil granules or aggregates to withstand the impact of farm implements and rain drops, changes in temperature and the movement of water and wind. A soil with stable aggregates provides a medium for good water penetration, aeration and minimum mechanical impedence to root growth and development (9, 79). Soil structure refers to the arrangement of primary particles into compound particles that are separated from adjoining clusters and have properties different from unaggregated primary particles (94). Well aggregated and stable soils are more resistant to deteriorating

factors, such as wind and water or farm machinery, than primary particles of sand, silt, clay and organic matter (41, 96). Excellent work has been done with respect to the processes which aggregate soil particles together. However, the forces which maintain stable aggregates are limited and often contradictory in the literature. One of the most commonly accepted mechanisms will be discussed in the discussion of theories.

The decomposition rate of plant residues by microorganisms and the formation of organic substances is directly related to the dominant species and the amount of soil biomass (2, 8, 9, 25, 59). Simultaneous loss and gain of organic compounds may be measured over a certain period of time and could be described as a turn-over rate. The "turn-over rate" depends upon plant residue maturation, amount and species in the soil biomass and climatic conditions which affect decomposition for a given period of time (46).

Polysaccharides appear to be the most active organic polymers in the formation and stabilization of soil aggregates (1, 44, 63). These compounds are derived from plant residues through the activity of soil organisms upon plant debris (23, 42, 45, 90). H-bonding is suggested as the mechanism through which polysaccharides bind soil particles together (34, 103). The strength of H-bonding depends upon the length of the polymer chain, spacing of the active sites and pK of acidic groups (28, 68). The lower the pK the less is its tendency to coordinate with hydrogen ions. The exact mechanism is unknown and remains to be determined. Generally, the turn-over of sugars in soil carbohydrates appears to be higher than other organic compounds. However, there are polysaccharides which appear to break down more

slowly by microorganisms, especially in the absence of oxygen or when they are adsorbed on the surface of clay particles (35, 95). Different polysaccharide fractions in soils apparently give a similar spectrum of saccharide units upon hydrolysis. The most abundant hexoses and pentoses are galactose, glucose, mannose, xylose, arabinose. Uronic acid content varies, and glucuronic acid is characteristically present.

The term "polyuronide" applies to polysaccharides that are relatively high in uronic acid content. The term includes plant hemicelluloses, which are principally composed of glucuronoxyloglycans and galacturonoarabinoglycans. Plant hemicelluloses decompose rapidly in soil, but their apparent rate of decomposition decreases with time. The apparent decline in rate is likely due to resynthesis by soil microorganisms of polysaccharides containing mainly similar sugars and uronic acids. The resynthesized polymers appear to be linear (35). Hydrolysis yields glucuronic and galacturonic acids, xylose, arabinose and most of the other sugars found in plant hemicelluloses. Increasing uronic acid content in soil polysaccharides leads to increased difficulty in extraction and an inferred greater effectiveness in stabilizing aggregated structures in soils (3, 43, 60). Polyuronides may link clay particles together by the formation of divalent cationic bridges between carbonyl groups on the polymers and the negatively charged clay surface (42). The difficulties involved in isolating individual polysaccharides have restricted systematic study of their relative rates of decomposition.

Fats, waxes and oils are another group of organic compounds which can provide a continuous matrix and physically bind the soil particles into secondary aggregates (52, 74, 85). These compounds result from

incomplete decomposition of plant and animal residues. Their rapid decomposition in well aerated soils results in little accumulation (35). Structurally, these compounds are very diverse ranging from relatively simple materials such as fatty acids and glycerol to complex compounds such as chlorophyll and polynuclear hydrocarbons. These "bitumenous" compounds are hydrophobic. Consequently, aggregate stability is influenced by the rate and degree of wetting which is modified by these compounds (38,43).

Plants generally influence soil structure by the addition of residues which decompose at the surface and in the subsoil. The influence of cropping systems on soil aggregation is a summation of the quantity and quality of organic compounds as well as the biological and physicochemical activity of the soil. Soil aggregation may be improved by the addition of plant residues (74). The effect of residues was greater when it was retained on the surface than when it was plowed under (82). Formation of aggregates under legumes was higher than with non-legumes (72). The content of aggregates (> 0.5 mm), soil organic matter, and plant yield were more than doubled under rotations when compared with continuous cropping systems (100). The relative contribution of these factors to the formation and degradation of aggregates varies with different cropping systems (3, 15, 19, 45, 58). Most crop rotations have been developed to add organic residues to the soil, improve the fertility and reduce diseases.

There is a direct relation between the level and type of organic content of the soil and the cropping system (70, 89, 98). The quality and quantity of organic compounds vary with the kind and characteristics of previous and present crops. Generally, the higher the percent of readily decomposable plant constituents, whether used as cover crop or organic amendments, the greater is their effect on aggregate formation and stabilization (22).

Mechanical impedence of bean roots in compacted soils predisposes the plant to damage by Fusarium solani, f. sp. phaseoli and Rhizoctonia solani, Kuhn, which cause cortical rot of roots and hypocotyles, reducing the absorption of water and nutrients and consequently plant yield. Compacted soils also intensify the incidence of Fusarium root rot on beans (64). Short periods of soil oxygen stress markedly influenced bean growth in Fusarium-infested soils and aggravated the injury caused by Fusarium root rot (65). Addition of plant residues (e.g., barley and others with high C:N) and subsoiling have been recommended as alternatives to control root rot disease (56). All subsoiling treatments applied after seedbed preparation increased both rooting depth and plant vigor. Roots extending into subsoil appear to encounter fewer Fusarium propagules thereby reducing the inoculum potential (20). Residues having a high C:N reduced the disease below non-amended soils (56). The high C:N plant residues control pathogens either by promoting the growth and competition between species or by the formation of toxic substances and their inhibitory effects on the formation of pathogen spores (93).

Intensity of tillage operation and the condition of soil at the time of manipulation are two other factors which affect aggregate size and stability. However, the relation between tillage and cultural practices to soil agregation are not completely understood. In the past, it was believed that applied pressure and moisture would increase the level of soil aggregate by bringing the primary particles together

(77, 105). More recently it was demonstrated that the pressure of farm machinery does not induce water stable aggregates to the same extent as do forces of chemical, biological and other natural factors and may adversely affect aggregate stability (78). The intensity of this diverse effect of tillage practices on soil structure varies with moisture content of soil. The more intense tillage the lower should be the moisture content of the soil to reduce the breakdown of aggregates. Reduced tillage appears to promote soil aggregation of the surface soil when decomposing plant materials are present (54). Other desirable features of reduced tillage are: 1) improved soil moisture and temperature control, 2) reduction of wind and water erosion and crusting of topsoil, 3) lower power and labor costs (86). Several factors should be considered when employing reduced tillage management: 1) control the depth of tillage, 2) maintain a maximum amount of mulch on the soil surface and 3) use implements that have minimal effects on the destruction of aggregates (98).

Relationships among organic components, cropping systems and tillage practices upon soil physical properties and plant yield have been studied extensively during the past two decades. Higher yields on organic amended soils were attributed to the greater stability of aggregates (32, 51, 53, 100). Plant growth appears to be greater in soils with larger aggregates (40). Highest yields, however, were obtained on soils having an intermediate level of aggregates. The decrease in yield under very large aggregates caused by overconsumption and utilization of substrates due to high oxygen content of the soil. Mechanical impedence and/or oxygen deficiency in poorly aggregated soils are the main cause of reduced yield (6, 24, 102).

Soil physical properties such as structural stability, bulk density, porosity and air and water permeabilities are parameters most frequently affected by cropping systems and tillage practices (14). These characteristics were used as indices of oxygen availability, compaction and mechanical impedence (39).

Minimum tillage and increased amount of incorporated plant residues decreased bulk density. Spring plowing combined with minimum tillage resulted in greater porosity (95). Hydraulic conductivity is also a function of aggregate size, (if) size affects the moisture-suction relationship (5). Other factors influencing moisture retention such as compaction, organic matter, aggregate stability and size distribution of aggregates may influence capillary conductivity accordingly. Saturated conductivity increases with the stability of aggregates (30). Air permeability is also directly related to aggregate size and stability (24). Arca (7) reported that a better correlation could be obtained between organic matter and bulk density, if permeability and porosity of the soil were considered.

Energy requirement for seedling emergence is directly related to seedling diameter, degree of compaction, initial soil moisture content and depth of planting (9, 21, 75). Packing of the soil to some extent, improved the seedling emergence of sugar beets (88). The combined effect of compaction and soil moisture has also a significant influence upon seedling emergence (87, 101).

Influence of seasonal variations and environmental factors such as soil moisture and temperature, freezing and thawing, and wetting and drying on soil aggregation and other physical properties have also been studied extensively (11, 12, 13, 33, 66, 84, 90, 104).

Knowledge concerning the possible effect of each factor or parameter on the formation of a stable aggregate is often limited to a few components or is contradictory. In order to understand the effect of one factor, other related parameters should also be considered. Sideri (83) believed that the effect of external conditions on the formation and stabilization of soil structure is a simultaneous phenomena and follows the "Swarm Theory". Since most of the internal and external factors somehow are related and act simultaneously during the course of study in this area it is advisable not to ignore or put stress on one factor in favor of the other(s).

Theory

Two processes of aggregate formation and stabilization are necessary to have a desirable soil structure. The basic structural units of aggregates in most soils consist of clay micells, hydrated polyvalent ions and organic polymers (27, 69, 80, 81). The general combination of these fractions may be represented by:

$$[(C — P — OM)\ x\ ]_y \qquad (1)$$

where, C = clay

P = polyvalent ions

OM = organic matter

x and y = coefficients

The dominant factors which determine the nature of clay-organic interactions are the unique properties of clay mineral, the nature of polyvalent ion and the properties of organic molecules. Charge density of a clay mineral may orient adsorbed organic cations through steric effects. This is especially the case where neutral but polarizable organic molecules are bound to the clay surface. Charge density would

also be expected to affect their orientation within the interlameller layers of swelling clay minerals. Polyvalent ions determine surface activity and therefore the possibilities of protonation of organic compounds. This property of cations varies with the degree of hydration, which in turn depends on solvation energy of the cation. Water is not likely to be acidic enough to protonate many organic molecules. However, when water is associated with metal cations, hydrolysis of this complex produces more or less H+, depending on the properties of the metal ion involved. So, these hydrated ions impart differential proton-donating power to the mineral surface. Where protonation of organic molecules is not involved, the exchangeable ions act as electron acceptors by which they interact with electron-donating functional groups of organic compounds. Such an ion-dipole or coordination type of bonding varies greatly in energy, depending upon the nature of the polyvalent ion (68). This ion-dipole force is a function of the distance between charged particles and is expressed in equation 2.

$$F = f\left(\frac{1}{d^3}\right) \qquad (2)$$

where, F = ion-dipole force

d = distance between charged surfaces

The influence of water upon aggregates is related to their mechanical stability, where all external conditions are similar. The criterion for stability may be expressed as:

$$C > F' \qquad (3)$$

where, C is cohesion force and F' is the pressure resulting from the penetration of water into soil capillaries. The pressure term in

equation 3 changes according to the equation for predicting capillary flow and is expressed as:

$$F' = 2\pi r\delta\cos\theta \qquad (4)$$

where, r = radius of pores

δ = surface tension of entering water

θ = wetting angle at the soil water interface

π = constant coefficient, 3.14

When r and δ are constant, then F' is a function of θ. So as contact angle between soil and water decreases, $\cos\theta$ increases and F approaches its maximum value or:

$$\theta = 0$$

$$\cos\theta = 1$$

$$F' = 2\pi r\delta \qquad (5)$$

As the contact angle decreases the affinity of aggregate pores for water increases. Aggregates rupture when the disruption or slaking forces (F') overcome cohesion (C). Both synthetic and natural organic polymers appear to reduce the forces of entrapped air by increasing the forces which bind the aggregates together and also by increasing the hydrophobic properties of aggregates (4, 48, 75, 96). During the course of this study the forces of entrapped air were reduced during analysis by de-aerating the soil samples before wet-sieving.

In fine textured soils which contain expanding minerals the pattern of orientation of clay coating plays an important role in the stability of aggregates. The degree of hydration and orientation may act together and break the larger aggregates into small sized water stable aggregates by expansion and swelling (18, 50). This may cause a misleading result on water-stability of aggregates by the wet

sieving method. Under this situation the effect of entrapped air is negligible compared to the orientation of clay particles.

MATERIALS AND METHODS

Soil Type and Classification

The soil type for this study was a Charity clay (Aeric, Haplea-quept, fine, illitic (calcareous, mesic). The Charity series consists of poorly drained soils which developed from highly calcareous stratified lacustrine clay and silty clay materials (management group 1c-c). These soils are generally located in nearly level till and lake plain areas. They have an angular structure, friable consistence when moist and plastic consistence when wet. The precent saturation is 51.2%. These features make it very difficult to manipulate the soil during wet periods (57). Several physical and chemical properties of the Ap horizon were analyzed by the commonly accepted methods of the Soil Science Society of America (16). The physical and chemical properties are summarized in Tables 1 and 2, respectively.

The study was conducted on the Saginaw Valley Bean-Beet Research Farm, located in the center of Saginaw County near Swan Creek. Saginaw County is in the east central part of the Lower Peninsula of Michigan, a few miles south of Saginaw Bay. The County is part of the level low lying Saginaw lake plain area which represents old beds of glacial lakes preceeding the present Lake Huron. Surface geolocial formations were laid down by ice and water during the Wisconsin stage of the glacial period and subsequently were smoothed over by waves of glacial lakes and contain some shallow lacustrine deposits.

Table 1. Textural properties of Charity clay soil, Ap horizon (0 - 7.5 cm).

Particle size distribution-%								
sand-size (mm)						silt-sand (mm)		clay-size (mm)
2.00	1.00	0.50	0.25	0.105	0.050	0.005	0.002	< 0.002
0.00	0.55	1.42	2.90	1.09	0.47	7.45	32.33	53.79

Table 2. Some chemical properties of Charity clay soil, Ap horizon (0 - 7.5 cm).

pH		CEC	O.M.	Kg/ha			
1:2	saturated paste	(meg/100g)		P	K	Ca	Mg
7.40	7.20	13.20	4.30	38.11[a]	506.6[a]	11276.0[a]	1853.9[a]

[a]Obtained from Saginaw Valley Bean-Beet Research Report

Field Experiments

Experiment I - Zero Secondary Tillage Management System:

This experiment was conducted on range 5 tiers 3 and 4 of the farm[a]. Crop history of these sites from 1971-1974 was: soybeans, clover, soybeans and navy beans, respectively. A one year crop of alfalfa was fall plowed to a depth of 8-10" (20-25cm), in 1975. Tillage practices in the fall included one pass with a spring tooth drag to a depth of 3-4" (7.5-10 cm) plus a spike tooth drag for leveling. In the spring, two passes of spring tooth plus two passes of spike tooth were applied end to end to the respective treatments (Treatments 1 and 2). An oats cover crop was drilled at the rate of 40 lbs/a (44.84 Kg/ha) into the respective treatments on April 7, 1976. Traffic included one additional pass with sprayer to apply Eptam and Treflan which were incorporated. Navy beans (Phaseolous vulgaris L., variety of 'Sanilac') were planted on June 4, 1976. A fertilizer (18-46-0) with 5% Mn and 2% Zn and 7.5 pounds (3.38 Kg) Thymet was banded at planting time at the rate of 230 lbs/a (258.8 Kg/ha) to a depth of 2" (5 cm) and 1.5" (3.8 cm) to the side. Seedlings emerged on June 18, achieved 50% blossom on July 23, began senescing on August 14, and were harvested on September 30, 1976. A summary of the treatments of this experiment is listed in Table 3.

Experiment II - Primary Tillage and Organic Residue Experiment:

This experiment was conducted on range 9, tiers 4, 8 and 9 of the farm[a]. The cropping sequence for these sites from 1971-1974 was: soybeans, sugarbeets, fallow and navy beans, respectively. Ground

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[a]See MSU, Department of Crop and Soil Sciences mimeo of Saginaw Valley Bean-Beet Research Farm - Research Plot Location, July 1977.

Table 3. Treatments for zero secondary tillage management system.

Treatment	Secondary Tillage	Cover Crop	Herbicide	Row Spacing
			liter/Ha	Cm
1	4 passes	No	Eptam 3.41 Treflan 1.36 Amiben 7.02	71.12
2	4 passes	Oats	Eptam 3.41 Treflan 1.36 Amiben 7.02	71.12
3	Zero	No	Paraquat 1.36 Amiben 11.69	71.12
4	Zero	Oats	Paraquat 1.36 Amiben 11.69	71.12
5	Zero	No	Roundup 4.67 Dinitro 9.37 Amiben 9.37	48.26
6	Zero	Oats	Roundup 4.67 Dinitro 9.37 Amiben 9.37	48.26

corn cobs (2 mesh) were applied at the rate of zero and 18 tons per acre (7.5 M.T./ha) in split plot design and incorporated to a depth of 6" (15 cm) by three passes of vibra shank in May 1974. Primary tillage practices were: 1) fall plow to a depth of 8-10" (20-25 cm), 2) fall Graham Hoeme to a depth of 8-10" (20-25 cm) on October 3, 1975 and 3) spring Graham Hoeme on May 27, 1976. The fourth treatment involved no primary tillage, and the seedbed was prepared by two passes with a vibra shank tiller to a depth of 4-6" (10-15 cm). Secondary tillage in this experiment consisted of 2 passes with the spring tooth set at a depth of 3-4" (7.5-10 cm) and was uniform for all treatments. Navy beans, variety 'Seafarer', were planted on July 7, 1976. The beans emerged on July 10, achieved 50% blossom on August 19, began senescing on September 7, and were harvested on October 4, 1976. Fertilizer was banded at planting at the rate of 200 lbs/a (223.80 Kg/ha) of a (18-46-0) with 5% Mn and 2% Zn and 7.5 pounds (3.38 Kg) Thymet to a depth of 2" (5 cm) and 1.5" (3.8 cm) to the side.

Experimental Design:

The experimental design on range 5 (Experiment I) was a competely randomized block. The design on range 9 (Experiment II) was a split plot with organic amendment as the main factor; cropping sequences and tillage practices were arranged factorially. Rectangular plots of 60 x 7' (18 x 2 m) and three or four rows of 60' x 19" (18 x 0.5 m) or 60' x 28" (18 x 0.71 m) were used in range 5. Plots on range 9 were 60 x 18.6' (18 x 5.6 m) with eight 60' x 28" (18 x 0.71 m) rows.

Soil Measurements

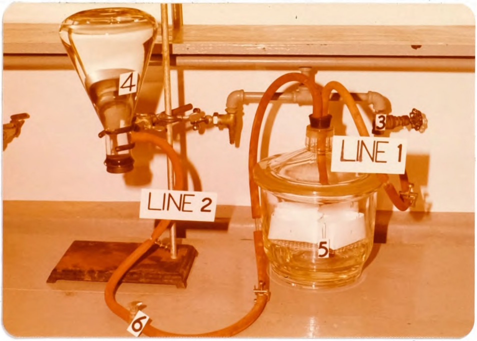
Soil measurements for both experiments were: aggregate stability, bulk density, total porosity and saturated hydraulic conductivity. Crust strength, soil moisture and temperature were measured in the first experiment only.

Two soil samples, disturbed and undisturbed were taken three times during the growing season in range 5 (Experiment I). Sampling dates for this experiment were July 7, July 18, and August 26. The same type of samples were taken twice on range 9 (Experiment II). Sampling dates for this experiment were August 3, and September 7, 1976. Disturbed samples were taken with a shovel to a depth of 3" (7.5 cm). Samples were gently crushed, air dried and passed through a 2mm sieve and stored for future analyses (71). Undisturbed samples were taken at 0-3" (0-7.5 cm) with a double-cylinder hammer-driven core sampler (16). These samples were prepared for saturated hydraulic conductivity, bulk density and total porosity by the conventional methods described by Black, *et al*. (16). Pretreatments of these samples included equilibrating with tap-water to the saturated point at room temperature for 24 hours. Samples were replicated 12 and 8 times for experiments I on range 5, and II on range 9, respectively.

Duplicate disturbed samples from all replicates of each treatment were used for aggregate stability analyses by a modified wet sieving method (47). Aggregates were pre-wetted under vacuum at 60 cm Hg (0.80 bar). The purpose of this procedure was to eliminate the disruptive forces of entrapped gases (61). The system was modified from the recommended form in the literature and developed

for the larger size of samples. Characteristics of the system are described in Figure 2. Paper-boats constructed from Whatman No. 4 filter paper were used for pre-wetting the samples. An air-dried soil, 40 g/sample was wetted under vacuum with degassed distilled water. The processes of removing air from water and the pre-wetting of soils were achieved by an exposure to vacuum for a period of 2 hours. Pre-wetted samples were carefully transferred to the top sieve of the set of sieving machine which contained a nest of 5 standard sieves, 25 cm in diameter and 4.5 cm in depth. Sieves were stacked in the following sequence: 2.00, 1,00, 0.50, 0.25 and 0.106 mm opening, with the largest at the top. The number of strokes per minute was corrected to 60, so that the total period of each analysis was 7 minutes and 43 seconds (106). The soil on each sieve was washed into a 500 ml beaker and dried for 24 hrs at 105°C. Fraction weights were corrected for moisture content and used for mean weight diameter calculations (99, 107). The difference between the sum of retained fractions and the initial dry weight of each sample was expressed as loss or an index to stability of aggregates against wetting. Since mean weight diameter does not show the distribution changes among fractions from one treatment to another, these differences were summarized in distribution histograms.

Cores of undisturbed samples were prepared, weighed and used for saturated hydraulic conductivity measurements (16). The same samples were used to measure and calculate bulk density and total porosity. Crust strength was measured in the field by a Chatillon spring gauge penetrometer (88). Soil pH was measured by the water dilution 1:2 and saturated paste methods (10). Cation exchange capacity was measured by Na-saturation at pH 8.2.



1. Vacuum line.
2. Draining water to and from the desicator.
3. Vacuum source.
4. Water reservoir, containing degased water.
5. Desicator and paper-boats containing soil sample.
6. Two-way stop-cock, for controlling the water to and from the desicator.

Figure 1. System developed to prepare soil aggregates under vacuum for wet sieving analyses.

Soil organic components of this study were extracted by a three step procedure. Soil samples during the entire procedure were equilibriated over $MgCl_2$ crystals at 20% relative humidity for 24 hours. Major moisture adjustments occurred during the first 24 hours of equilibration, Figure 3.

Bitumen (fats, oils and waxes) were extracted by refluxing 100 grams of soil in 250 ml of a 1:1 mixture of absolute ethanol and certified thiophene-free benzene for 24 hours (51). The flasks were cooled and the mixture separated by centrifugation at 7500 rpm with a Sorval superspeed RC - 2 automatic refrigerated centrifuge, equipped with a 1890 ml, 28 degree angle rotor containing 6-250 ml compartments. Samples were run for 20 minutes at 10°C. Low temperatures were required to reduce the reaction between polypropylene centrifuge bottles and benzene. Samples were resuspended in boiling ethanol-benzene mixture and recentrifuged twice. Both supernatant and soil residues were dried at 80°C in a water bath. Upon dessication, bitumenous substances adhered to the taned glass drying beakers as a brown-yellowish residue. Beakers were equilibrated over $CaCl_2$ at 21°C and weighed to the nearest 5th decimal place.

Water soluble polysaccharides were extracted by refluxing the approximately 100g of bitumen-free soil (after re-equilibrating at 20% relative humidity for exact weight) in 250 ml distilled water for 2 hours. The mixture was cooled, centrifuged as above except that boiling distilled water was the solvent used to resuspend the samples. The supernatant was cooled, diluted to 1000 ml with distilled water and divided into two equl aliquots. The first portion was dried on a steam bath, cooled and weighed. The weighed residue was ignited in a

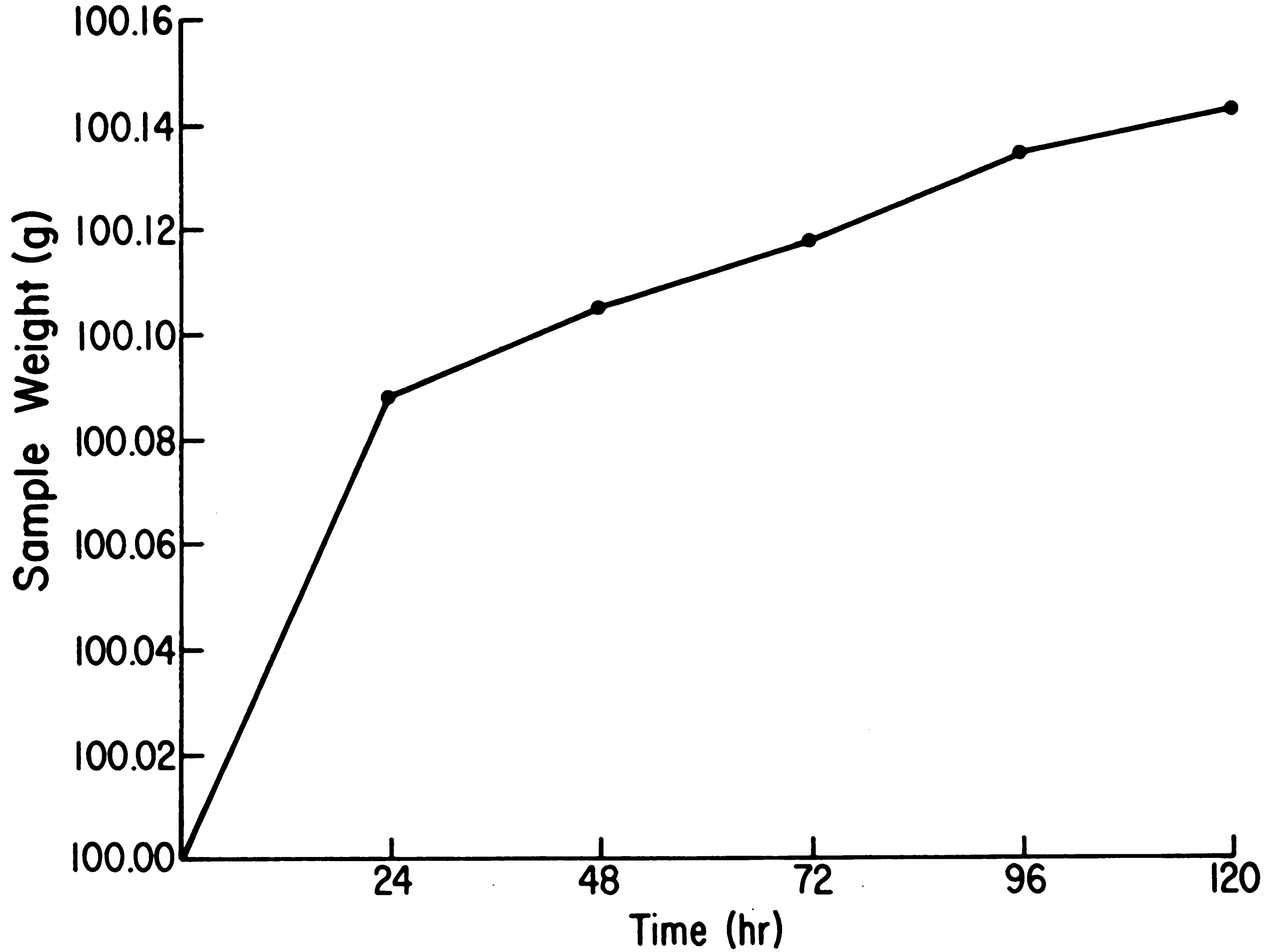


Figure 2. Increase in weight of initially air-dry aggregates (<2 mm) during equilibriation over $MgCl_2$ at 20% relative humidity.

muffle furnace at 550°C for 5 hours, cooled and reweighed. The weight loss was considered as soluble polysaccharides and remaining debris was considered to be ash. The second 500 ml aliquot of supernatant was evaporated to 100 ml on steam bath and frozen for later determination of C:N.

Soil residues from the above extractions were re-equilibrated over saturated $MgCl_2$ and used to determine the content of polyuronides. Accurately weighed samples of approximately 45g, were refluxed with 250 ml of 2% HCl for 5 hours. Samples were cooled, centrifuged and rewashed with 25 ml increments of HCl three additional times. The volume of supernatant was brought to 500 ml by 2% hydrochloric acid. Four 10 ml subsamples were used to measure polyuronide content of the soil by titrating with Fehling's solution according to Stevenson (16).

Round bottom digestion flasks, 500 ml, equipped with Soxhlet condensors were used for refluxing soil samples during the above extraction procedures.

Undecomposed plant residues were separated from aliquots of the same disturbed samples which were used for organic fractionation anaylses. Surface trash was not included in these samples. Satisfactory physical separation was obtained by winnowing. Approximately 10% of the air flow from a 110-120 volts, 60 cycles, 45 cm diameter fan was directed in the sample in a reciprocating shaker set at 160 cycles per minute. Soil particles were separated from plant residues based on density differences. The controlled air stream helped to achieve a complete separation zone. Separation was completed by washing fine soil particles through a nest of 8, 30, 50 and 80 mesh stainless steel sieves and floating off plant residues. The separated plant residues were air-dried and weighed to obtain evidence regarding the rate of disappearance of primary substrates to support an active population of soil organisms.

A Leco carbon analyzer, model 750-100, was used to measure the total carbon content of disturbed soil samples from the primary tillage-organic amendment experiment. It was assumed that negligible carbonate was present at pH 7.2 in soil paste. Equation 6 was used to calculate the organic matter content of the samples:

$$\text{O M \%} = 1.724 \times \text{T.C. \%} \qquad (6)$$

Plant Growth and Production Measurements

Parameters for measuring plant responses to the applied treatments were leaf area, plant dry weights and yield. On range 5, leaf area and plant dry weights were measured on July 7, July 14, and August 26. On range 9, leaf area and plant dry weights were measured on September 7, 1976. Leaf areas were directly measured on a portable Lambda leaf area meter, model LI-3050A. Leaf area index was calculated based on measured leaf area and the area of the rows (55). Dry weight of leaf, stems and total dry weight of the plant were also obtained after drying materials at 70°C for at least 48 hours. Total crop yield, number of pods per plant and number of beans per pod were also determined based on harvesting 25' (7.62 m) of the center of the two rows of each 4 or 8 row plots and one 25' (7.62 m) row of three row plots. A root rot index was also determined by Dr. A.W. Saettler, USDA/ARS, Botany and Plant Pathology on September 17, for experiment on range 9.

Climatic Conditions

The climate of Saginaw County varies from continental to semi-marine. Salient features of the climate are long cold winters with

mild pleasant summers. Maximum and minimum temperatures for April-September are summarized in Table 4. The difference between the winter and summer is 8-10°C. Since local variations in elevation are negligible and the area is buffered by Saginaw Bay, Lake Huron, climatic conditions are about the same for all parts of the county. The average frost free season is approximately 157 days from May-September and is ample for the growth and maturation of many crop species. Rainfall, evenly distributed throughout the growing season, is ordinarily sufficient for excellent crop production, Table 5. Ample amounts of rain during the spring and poor drainage of the soil delay tillage and seeding of the crops. Yields may be reduced by short periods of drought during the growing season (67).

Table 4. Maximum-minimum air temperature from April through September 1976 (C).

Day	April		May		June		July		August		September	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	8	-2	18	8	17	11	21	13	25	10	20	15
2	14	1	13	2	22	3	24	11	22	7	21	4
3	15	-3	6	1	25	5	25	12	28	8	27	10
4	8	1	16	-2	27	7	26	11	25	8	27	15
5	14	-6	26	9	27	9	30	11	25	16	21	10
6	16	1	6	3	28	21	30	12	21	12	25	3
7	11	-2	11	-1	31	11	29	15	22	8	31	10
8	6	-4	16	-2	32	13	22	14	26	9	33	17
9	12	-8	23	-1	33	17	27	10	30	8	22	13
10	16	-3	23	6	31	15	32	20	29	10	19	10
11	5	-4	13	7	32	19	32	12	31	17	27	8
12	11	-8	16	-1	32	13	25	12	29	21	27	7
13	19	-4	22	1	32	12	26	8	27	20	28	10
14	25	1	23	13	32	15	34	14	18	15	29	12
15	27	16	21	10	32	18	32	17	23	9	17	13
16	28	13	20	12	20	16	25	17	24	6	17	15
17	28	15	13	11	24	13	25	10	27	7	23	13
18	28	12	16	4	30	13	30	8	29	7	27	7
19	22	13	20	1	22	13	30	12	30	12	27	7
20	17	8	27	10	27	8	27	20	31	15	17	14
21	21	6	21	8	24	12	27	15	30	13	15	3
22	16	8	19	3	27	16	29	12	32	12	15	1
23	15	1	16	3	28	14	31	20	25	12	15	5
24	15	5	17	1	22	15	27	16	27	11	18	-3
25	2	1	17	6	27	17	27	13	30	13	17	-1
26	2	-1	20	5	30	13	31	15	30	17	13	10
27	9	-1	25	4	31	16	32	19	32	16	16	10
28	16	-1	25	10	27	17	25	15	28	20	16	0
29	17	-1	18	15	22	13	23	17	20	7	21	5
30	18	2	22	11	20	14	28	13	23	2	23	2
31	--	--	21	11	--	--	23	18	28	9	--	--
Average	15	2	18	5	27	13	28	14	27	12	22	8

Table 5. Rainfall distribution from April through September 1976 (cm).

Day	Month					
	April	May	June	July	August	September
1	0.20	----	----	0.66	0.13	0.56
2	----	1.60	----	----	----	----
3	0.05	----	----	----	----	----
4	----	----	----	----	----	----
5	----	3.71	----	----	0.38	----
6	0.03	0.94	----	----	----	----
7	----	----	----	----	----	----
8	----	----	----	----	----	----
9	----	----	----	----	----	----
10	----	0.71	----	----	----	1.24
11	0.15	----	----	0.61	----	----
12	----	----	----	----	0.03	----
13	----	0.03	----	----	0.36	----
14	----	----	----	0.25	1.70	----
15	1.12	----	2.03	----	0.03	0.08
16	----	1.30	----	----	----	0.36
17	----	0.15	----	----	----	----
18	0.18	----	0.61	----	----	----
19	----	----	0.48	----	----	0.03
20	----	----	----	0.69	----	0.53
21	3.71	----	----	----	----	----
22	----	----	----	----	----	----
23	----	----	----	----	----	0.43
24	0.51	----	0.76	----	----	----
25	5.33	0.08	----	----	----	----
26	----	----	----	----	0.23	0.56
27	----	----	----	----	----	0.18
28	----	----	1.32	2.44	----	----
29	----	0.81	0.15	----	----	----
30	----	1.07	8.31	----	----	----
31	----	0.18	----	----	0.25	----
Average	11.53	10.57	13.67	4.65	3.10	3.96

RESULTS AND DISCUSSION

Experiment I. Zero Secondary Tillage Management System

This field experiment was conducted on range 5, tiers 3 and 4 of the Saginaw Valley Bean-Beet Farm. Treatments are listed in Table 3. Soil parameters were: crust strength, mean weight diameter (MWD), bulk density, total porosity and saturated hydraulic conductivity. Plant parameters included: leaf area, dry weight of stems and leaf, total dry weight of plant, number of pods per plant, number of beans per pod and yield.

Physical Soil Parameters

Surface crust strength was measured 17 and 33 days after planting. Differences among treatments were highly significant for both dates, Table 6. Generally, higher crust strengths were measured on treatments with no-cover crop and secondary tillage systems. At 17 days there was a 50% reduction by cover crop and 19% reduction by secondary tillage. This may either be due to pulverizing effect of tillage upon soil which promote the degree of closeness and compaction of aggregates or due to lack of organic matter. These affects are general and appear to be more severe on fine textured soils (4, 75).

Soil aggregate stability, as determined by the wet sieving method, appeared to be influenced both by treatment and time after planting. Table 7 shows significant differences in mean weight diameter and quantity of aggregates less than 0.106 mm in diameter under different treatments for all dates of sampling during the first 84 days of the

Table 6. Crust strengths in relations to secondary tillage and an oats cover crop on Charity clay planted to navy beans. Each value is the mean of 60 replications.

Treatment	Crust strength-Bar	
	Time after planting	
	17 days	33 days
T_1 (4 passes, Eptam, no-cover crop)	143.38	287.55
T_2 (4 passes, Eptam, oats cover crop)	136.18	294.11
T_3 (zero, Paraquat, no-cover crop)	118.71	------
T_4 (zero, Paraquat, oats cover crop)	56.26	124.57
T_5 (zero, Roundup, no-cover crop)	115.68	270.22
T_6 (zero, Roundup, oats cover crop)	79.39	218.29
LSD 0.05	13.730	25.793
LSD 0.01	20.799	39.074

Table 7. Mean weight diameter (MWD) and loss of particles (< .106 mm) in relation to secondary tillage, oats, cover crop and time.

Treatment	Time after planting					
	33 days		42 days		84 days	
	MWD	Particle Loss %	MWD	Particle Loss %	MWD	Particle Loss %
T_1 (4 passes, Eptam. no-cover crop)	0.623	8.750	0.617	14.150	0.499	17.475
T_2 (4 passes, Eptam, oats cover crop)	0.658	13.225	0.619	9.975	0.530	10.275
T_3 (zero, Paraquat, no-cover crop)	-----	-----	0.674	9.300	0.529	18.150
T_4 (zero, Paraquat, oats cover crop)	-----	-----	0.690	11.775	0.522	11.000
T_5 (zero, Roundup, no-cover crop)	0.657	7.850	0.624	9.375	0.562	12.525
T_6 (zero, Roundup, oats cover crop)	0.670	9.985	0.617	14.175	0.558	10.475
LSD 0.05	0.035	2.104	0.025	1.772	0.032	1.548
LSD 0.01	0.053	3.187	0.037	2.685	0.048	2.345

growing season. Higher mean weight diameters and more durable aggregates were formed under treatments with no-spring tillage and oats cover crop. More stable aggregates in treatments with cover crop were formed with time. Table 7 indicates that, although mean weight diameter in treatments with cover crop and no-spring tillage was greater, the amount of loss or aggregates less than 0.106 mm in diameter was also higher under these treatments during the first 33 days of the growing season. Later in the season the quantity of loss decreased considerably under these treatments. This is probably due to the formation of pseudo-aggregates caused by organic matter from the cover crop which stabilized with time (36, 37).

Size distribution diagrams were prepared to show the effect of time and treatments upon each fraction size of aggregates, Figures 4, 5, and 6. There was a general decrease in the quantity of larger aggregates and an increase in smaller fractions during the entire growing season. This is apparently due to deterioration of organic fractions responsible for soil aggregation. The increase in statisitcal difference among the treatments with time was probably due to break-down rather than the formation of larger aggregates. In all cases, the deterioration of aggregates was higher under the treatment with secondary tillage than the ones with zero secondary tillage.

Bulk density and total porosity were significantly different for treatments 33 days after planting. These differences were not detectable at the second and third dates of measurement, Table 8. Generally, there was a small increase in bulk density and a decrease in total porosity with time. This phenomena may have resulted from aggregate decomposition and the filling of pores by fine soil materials from deteriorating larger aggregates, resulting in a more compacted soil (49, 62).

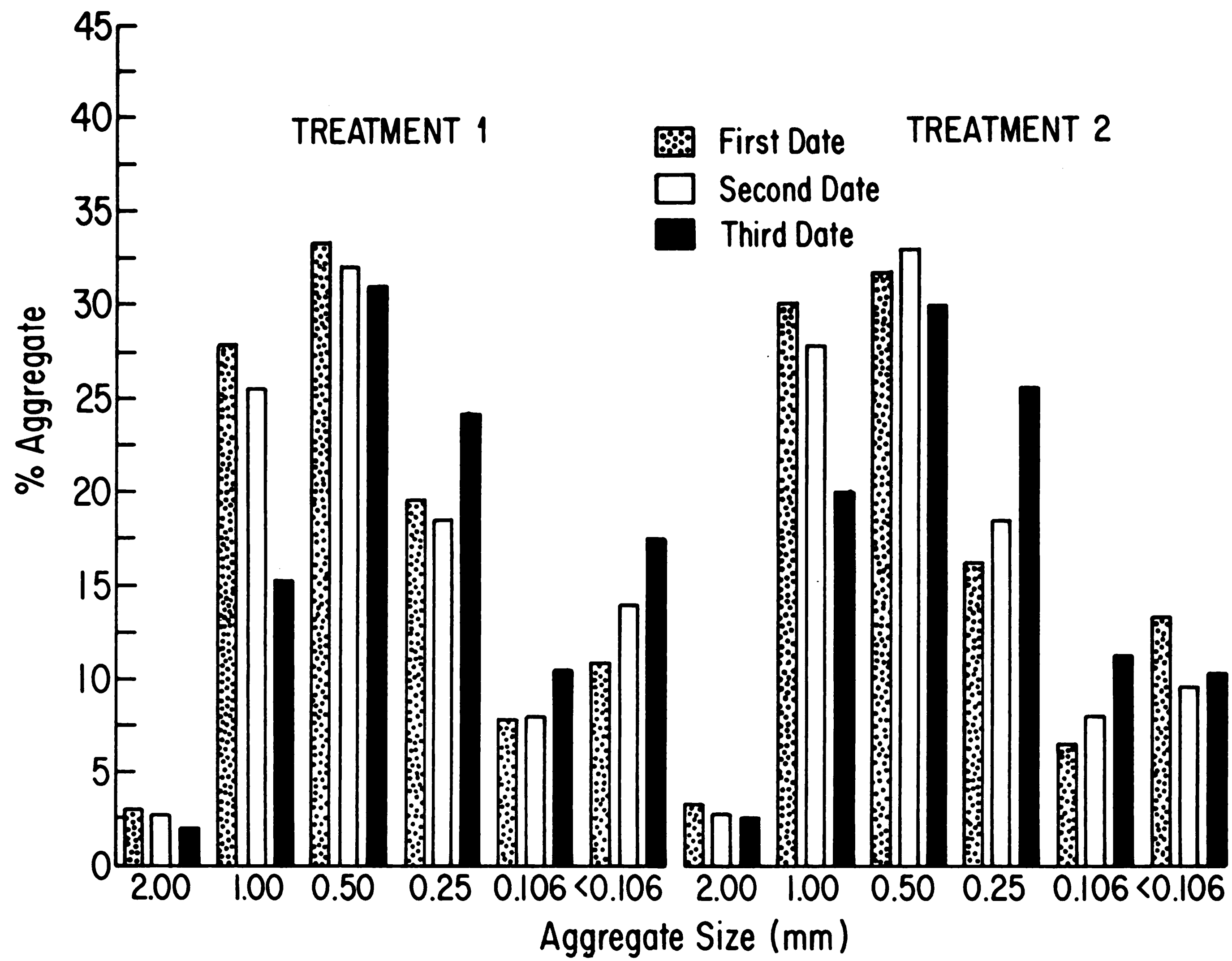


Figure 3. Size distribution of aggregates, 4, 6 and 12 weeks after planting beans, in plots which had received secondary spring tillage (4 passes) without a cover crop (Treatment 1) or with spring planted oats for green manure (Treatment 2).

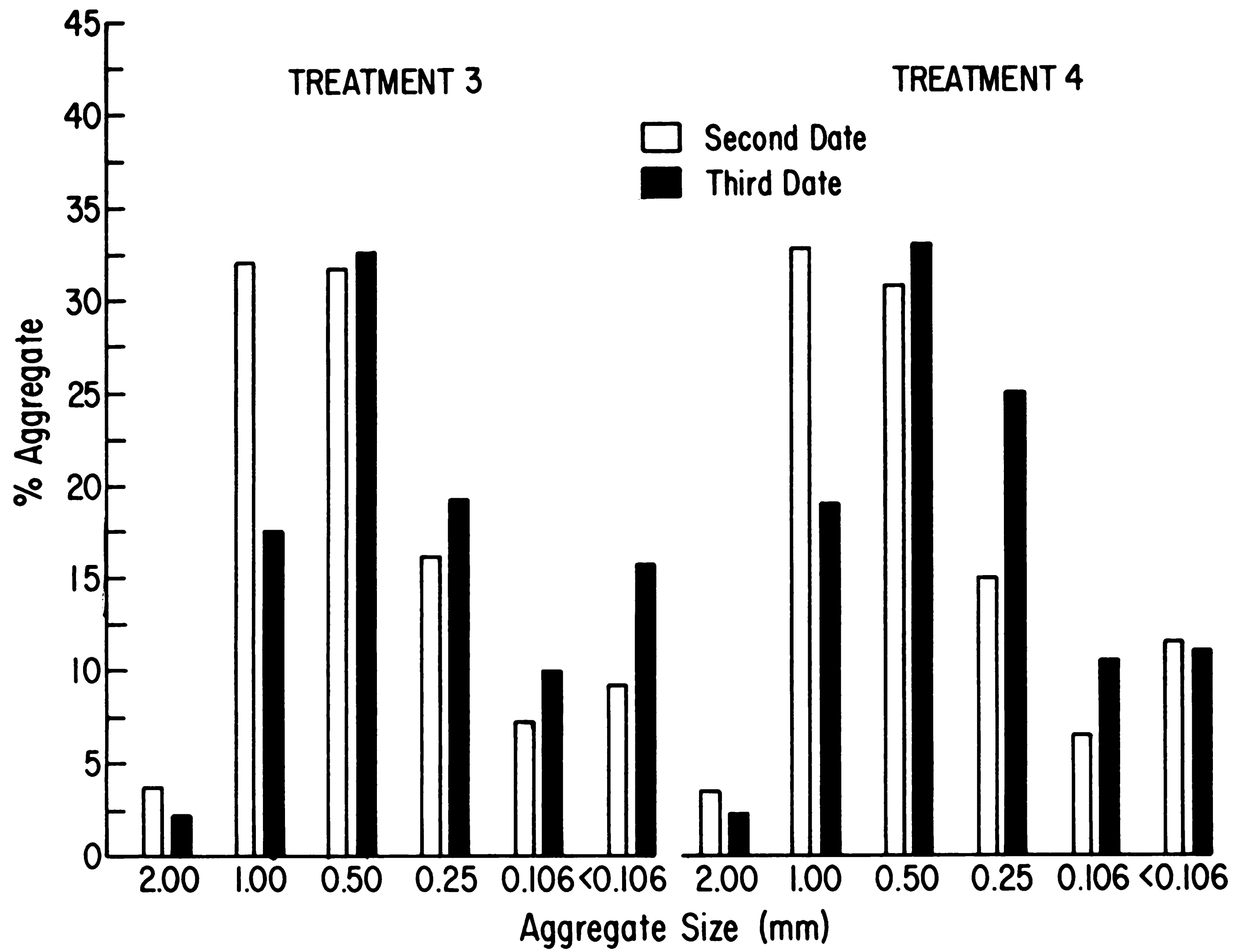


Figure 4. Size distribution of aggregates, 6 and 12 weeks after planting beans, without secondary spring tillage following no-cover crop (Treatment 3) or spring planted oats for green manure (Treatment 4). Paraquat and Amiben were used as herbicides.

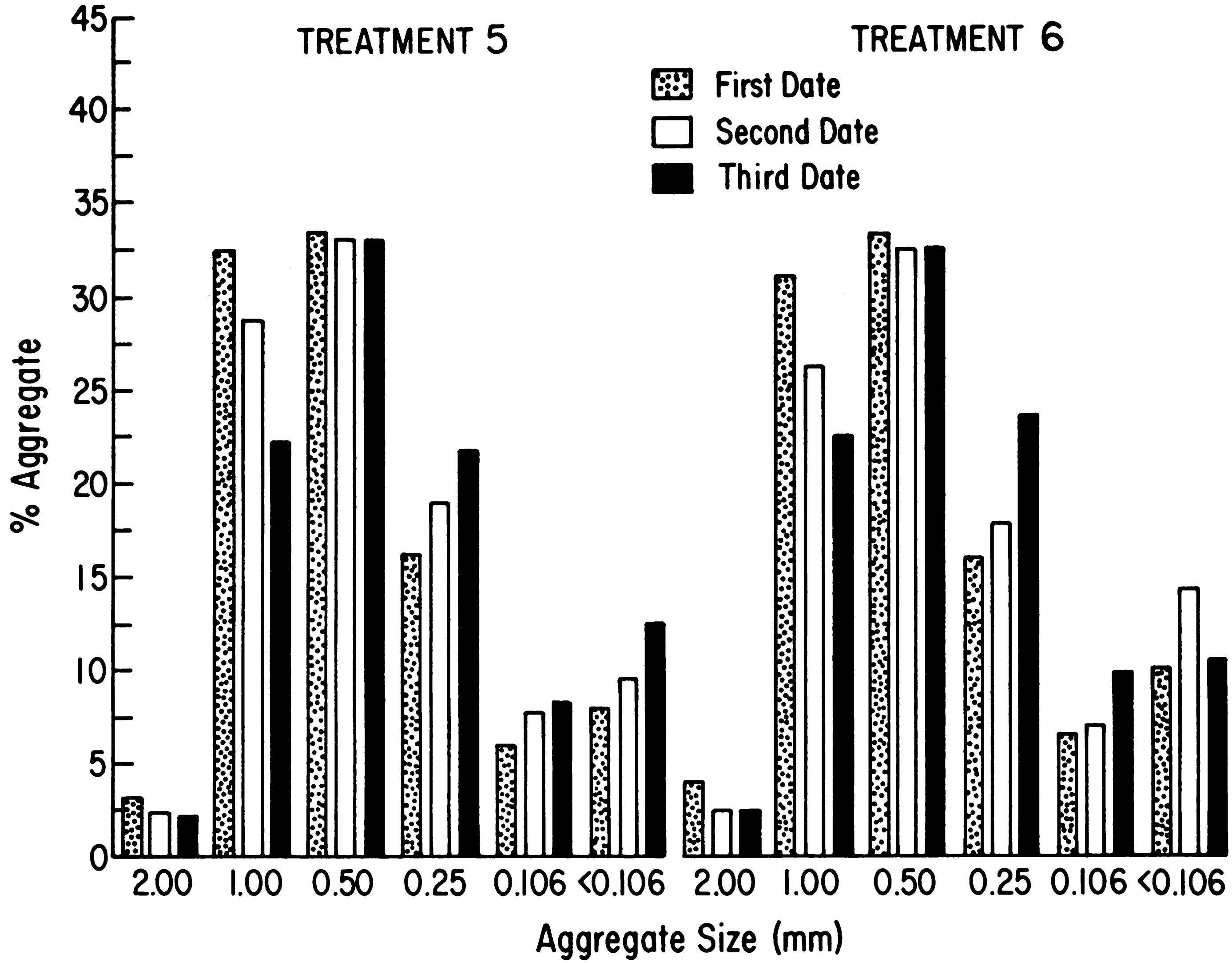


Figure 5. Size distribution of aggregates, 4, 6 and 12 weeks after planting beans, without secondary spring tillage following no cover crop (Treatment 5) or spring planted oats for green manure (Treatment 6). Roundup, Dinitro and Amiben were used as herbicides.

Table 8. Influence of secondary tillage and cover crop upon the bulk density and total porosity of a Charity clay soil, 0-7.5 cm. Each value is the mean of 12 replications.

Treatment	Time after planting					
	33-days		42-days		84-days	
	Bulk density g/cc	Total porosity %	Bulk density g/cc	Total porosity %	Bulk density g/cc	Total porosity %
T_1 (4-passes, Eptam, no-cover crop)	1.185	55.28	1.178	55.55	1.180	55.48
T_2 (4-passes, Eptam, oats cover crop)	1.168	56.08	1.182	55.40	1.222	55.13
T_3 (zero, Paraquat, no-cover crop)	-----	-----	1.189	55.13	1.175	55.69
T_4 (zero, Paraquat, oats cover crop)	-----	-----	1.180	55.48	1.169	56.32
T_5 (zero, Roundup, no-cover crop)	1.173	55.74	1.213	54.25	1.217	54.09
T_6 (zero, Roundup, oats cover crop)	1.140	56.98	1.183	55.38	1.196	54.88
LSD 0.05	0.028	1.355	0.082	3.41	0.316	2.58
LSD 0.01	0.043	2.050	0.125	5.21	0.423	3.91

Table 9 shows that the saturated hydraulic conductivity of non-disturbed soil cores declined during the growing season. Higher saturated conductivities were observed on treatments with cover crops and no-secondary tillage systems. The decline in saturated conductivity was less under treatments with a cover crop and zero-secondary tillage than those with no-cover and secondary tillage, Figure 6. This is probably due to greater aggregate stability of soils with a cover crop, as the cover crop both protects the soil surface as well as provides a source of active organic matter (45, 86).

Table 10 shows the simple correlation coefficients for physical soil factors. There was a positive correlation between mean weight diameter and total porosity but a negative correlation between mean weight diameter and bulk density. Although these coefficients were not statistically significant, their relation agrees with previous studies (39, 101, 102). Saturated hydraulic conductivity was positively correlated with mean weight diameter and total porosity but inversely related to bulk density. Since a greater conductivity generally occurs on less compacted and more porous soils it may be concluded that an increase in the size and stability of soil aggregates result in an increase in the hydraulic conductivity (32, 44, 46, 66).

Biochemical Soil Parameters

Data in Table 11 suggests that the quantity of undecomposed plant debris in the surface 7.5 cm of soil was influenced by both secondary tillage and cover crop. Shallow tillage would have mixed surface debris into the surface soil, as is indicated for treatment T_1 compred with T_5. A similar result was not evident where a succulent young oats cover crop was workedin (T_2 vs. T_6). The incorporated green manure may have accelerated decomposition of older residues. It is frequently observed

Table 9. Effect of secondary tillage and cover crop on the saturated hydraulic conductivity of a Charity clay soil, 0-7.5 cm, during the growing season. Each value is a mean of 12 replications.

Treatment	Saturated hydraulic conductivity-$^{cm}/hr$		
	Time after planting		
	33-days	42-days	84-days
T_1 (4 passes, Eptam, no-cover crop)	30.96	25.17	17.65
T_2 (4 passes, Eptam, oats cover crop)	32.94	23.48	17.01
T_3 (zero, Paraquat, no-cover crop)	-----	23.40	22.76
T_4 (zero, Paraquat, oats cover crop)	-----	29.99	20.33
T_5 (zero, Roundup, no-cover crop)	27.06	23.10	19.51
T_6 (zero, Roundup oats cover crop)	39.72	26.70	20.59
LSD 0.05	1.36	5.27	4.37
LSD 0.01	2.05	7.98	6.27

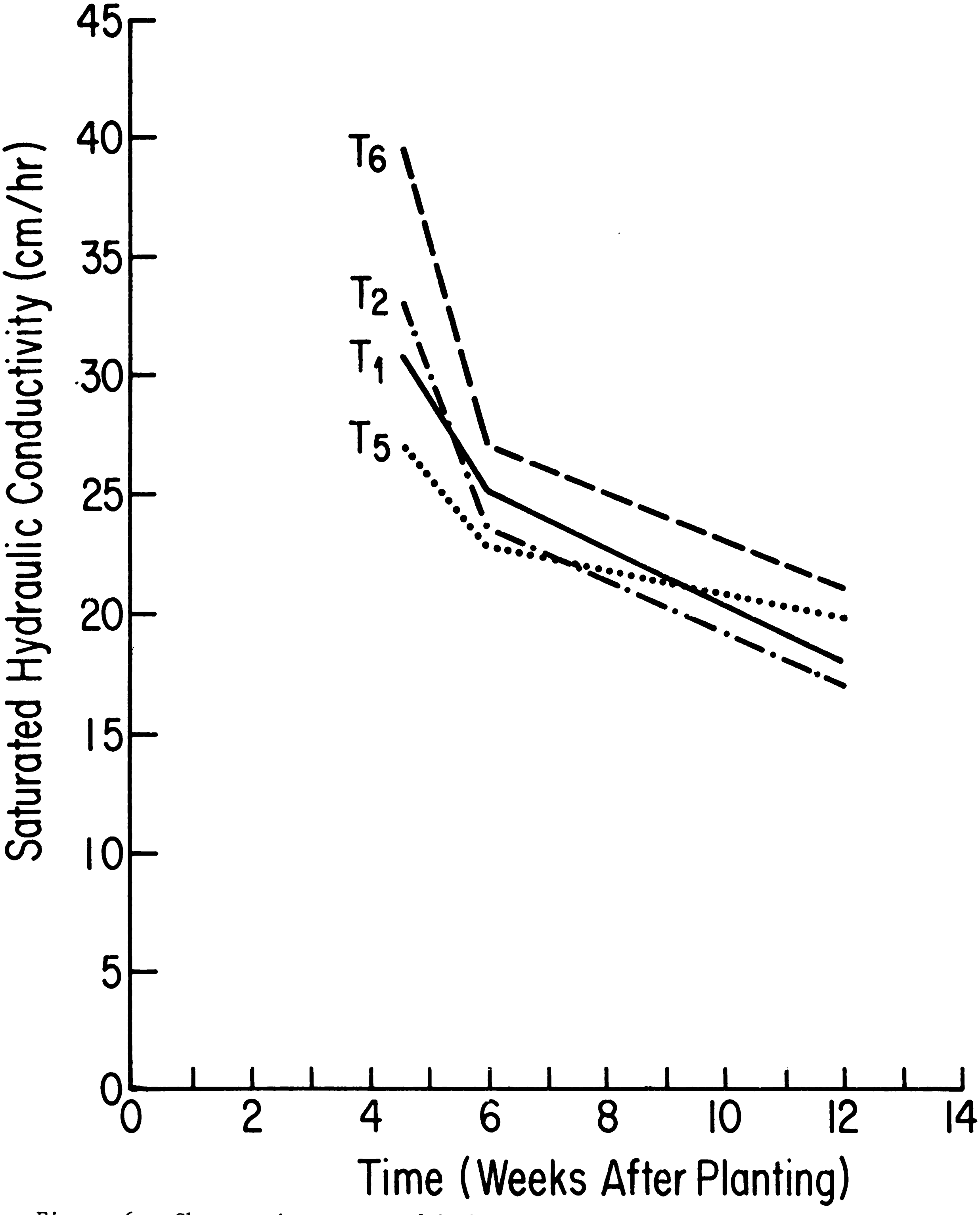


Figure 6. Changes in saturated hydraulic conductivity in the plow layer of Charity clay without spring tillage (Treatments 5 and 6) or with four secondary passes before planting beans (Treatments 1 and 5) or spring planted oats for green manure (Treatments 2 and 6).

Table 10. Simple correlation coefficients among the physical parameters of a Charity clay soil.

Parameter	MWD	Bulk density	Total porosity
Bulk density	r^2=-0.3812		
Total porosity	r^2=0.2803	r^2=-0.9333**	
Saturated hydraulic conductivity	r^2=0.2863	r^2=-0.1470	r^2=0.2461

**Correlation is significant at 0.01 level of probability.

Table 11. Loss of plant residues from a Charity clay soil during the growing season. Each value is the mean of two soils sampled to a depth of 7.5 cm.

Treatment	Plant residues			
	Time after planting			
	33-days		84-days	
	g/205g soil	M.T./ha	g/205g soil	M.T./ha
T_1 (4-passes, Eptam, no-cover crop)	0.073	0.757	0.041	0.428
T_2 (4-passes, Eptam, oats cover crop)	0.039	0.408	0.037	0.385
T_3 (zero, Roundup, no-cover crop)	0.027	0.279	0.012	0.122
T_4 (zero, Roundup oats cover crop)	0.103	1.066	0.077	0.851
LSD 0.05	0.068	0.679	0.039	0.371
LSD 0.01	0.19	1.127	0.065	0.616

that green manures stimulate microbial populations and lead to accelerated depletion of soil organic matter, an affect that has been referred to as a "priming action" (3). The highest recoveries of plant debris were with T_6, where the undisturbed roots of the oats cover crop were undoubtedly an important part of the recovered plant residues.

Bitumen and polysaccharide fractions extracted from soil samples taken 84 days after planting (Table 12) were related directly to the quantities of plant residues recovered after 84 days (Table 11). The simple correlation between plant residues and the polysaccharide fraction was significant at the 5% level of probability (Table 12).

By contrast, the polyuronide fraction tended to be negatively correlated with the level of undecomposed residues. It may be significant that this fraction tended to be correlated negatively with mean weight diameter (Table 13).

The limited evidence from these few samples suggests that the time course of accumulation and depletion of polyuronides is different than for the other two fractions, and that their spatial distribution in relation to aggregated structures in the soil matrix may be different.

Plant Parameters

Leaf area and leaf area index showed significant differences among the treatments in all dates of sampling 84 days after planting, Table 14. Cover crop reduced plant growth on both secondary tillage treatments during the first 84 days of the growing season. Leaf areas were greater on treatments with a cover crop 84 days after planting. But, under no case did the maximum leaf area under these treatments exceed the value with no cover crop and secondary tillage. This phenomena probably was due to the delay in plant growth and development

Table 12. Organic fractions extracted from 0-7.5 cm of Charity clay 84 days after planting navy beans.

Treatment	Organic fraction - g/100g soil		
	Bitumen	Polysaccharides	Polyuronides
T_1 (4-passes, Eptam)	0.0470	0.0588	0.9200
T_2 (4-passes, Eptam)	0.0382	0.0578	0.5470
T_5 (zero, Roundup)	0.0380	0.0534	0.4080
T_6 (zero, Roundup)	0.0436	0.0642	0.3580
LSD 0.05	0.027	0.018	0.537
LSD 0.01	0.046	0.030	0.889

Table 13. Simple correlation coefficients among biochemical component, plant residue and MWD of a Charity clay 84 days after planting with navy beans.

Biochemical Component	Plant residue	MWD
Bitumen	r^2=+0.4347	r^2=+0.0841
Polysaccharides	r^2=+0.8322*	r^2=+0.1939
Polyuronides	r^2=-0.4172	r^2=-0.6043

*Values are significant at 0.05 level of probability.

Table 14. Effect of secondary tillage, cover crop, herbicides and time upon leaf growth of navy beans (var. Sanilac). Each value represents the mean of 10 plants.

Treatment	Time after planting					
	33-days		42-days		84-days	
	LA(cm^2/plant)	LAI	LA(cm^2/plant)	LAI	LA(cm^2/plant)	LAI
T_1 (4 passes, Eptam no cover crop)	689.72	0.98	2432.50	3.42	2008.90	2.83
T_2 (4 passes, Eptam oats cover crop)	516.87	0.73	1720.30	2.42	2391.20	3.36
T_3 (zero, Paraquat, no cover crop)	--	--	509.16	0.72	518.62	0.73
T_4 (zero, Paraquat, oats cover crop)	--	--	166.20	0.24	195.30	0.23
T_5 (zero, Roundup, no cover crop)	997.06	2.07	2473.00	5.13	1200.50	2.49
T_6 (zero, Roundup oats cover crop)	319.24	0.66	1507.70	3.12	1491.10	3.09
LSD 0.05	273.23	0.44	275.83	0.46	947.46	1.36
LSD 0.01	453.15	0.73	457.46	0.76	1571.36	2.26

by competition between main and cover crops for moisture and nutrients early in the season. The size of plants later in the season were equal under all treatments except secondary tillage which had the largest plant size. Reduced growth under treatments three and four was due to incomplete weed control.

Table 15 shows the influence of tillage, cover crop and time upon dry weights of leaf, stem and total shoots of navy beans. All parameters were greater in treatments having secondary tillage. This was probably due to the delayed growth under treatments with a cover crop. This reduction was visible early in the season, when there was competition for moisture between the cover and the main crop. Reduced quantity of dry weights under treatments three and four was due to reduced growth.

Temperature and moisture were significantly modified by secondary tillage and cover crop treatments, Table 16. Treatments with cover crop had less temperature variation during a 24 hour period. The canopy retained heat at night, resulting in higher (1.5-2.5C) soil temperatures during the day. Moisture content of the soil was 1-3% lower under the treatments with a cover crop.

Number of pods per plant and plant yield were significantly affected by treatments of this experiment, Table 17. The only significant difference in the number of beans per pod occurred in treatment four. The results of harvest parameters in this treatment and treatment five were initially low due to the reduced growth under this treatment. This was due partially to ineffectiveness of Paraquat in controlling weeds. Generally, yields were higher in treatments with no cover crop. However, yields were higher in treatments with no secondary

Table 15. Influence of tillage, cover crop, herbicides and time on shoot dry weights of navy beans (var. Sanilac). Each value represents the mean of 10 plants.

Treatment	Time after planting								
	33 days			42 days			84 days		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
	g/plant								
T_1 (4 passes, Eptam, no cover crop)	1.99	1.71	3.70	7.05	8.52	15.57	6.19	17.19	23.39
T_2 (4 passes, Eptam, oats over crop)	0.98	1.99	2.96	5.54	4.43	9.97	6.25	15.43	21.68
T_3 (zero, Paraquat, no cover crop)	--	--	--	2.21	1.55	7.50	1.95	2.36	4.30
T_4 (zero, Paraquat, oats cover crop)	--	--		2.16	2.13	4.28	1.34	1.08	2.41
T_5 (zero, Roundup, no cover crop)	3.46	2.24	5.54	7.53	12.74	20.27	4.05	13.13	17.17
T_6 (zero, Roundup, oats cover crop)	1.37	0.58	1.95	3.34	3.76	7.10	4.80	13.35	18.15
LSD 0.05	0.90	0.99	1.54	1.66	5.70	7.15	3.00	4.89	7.79
LSD 0.01	1.50	1.64	2.56	2.76	9.46	11.85	4.98	8.11	12.91

Table 16. Effect of cover crop on moisture and temperature of a Charity clay soil (0-10 cm). Each value is the average of at least 5 replications.

Date		No cover crop		Oats cover crop	
		Moisture (%)	Temperature (C)	Moisture (%)	Temperature (C)
	Min.	--	--	--	--
May	Max.	--	--	--	--
	Avg.	29.6	19.3	22.2	20.6
	Min.	10.2	18.9	9.9	18.9
June	Max.	26.8	22.2	25.6	23.1
	Avg.	20.1	20.5	20.4	20.6
	Min.	14.0	15.9	12.7	15.4
July	Max.	27.8	22.3	27.9	22.8
	Avg.	20.4	19.4	19.4	19.7

tillage practices. Lower yields under the secondary tillage system may be due to its adverse effects upon soil structure and related physical parameters (72, 82, 95, 105). This situation was intensified by lack of cover crop as a source of organic matter, Table 17. The reduced yield under treatments with secondary tillage conforms with the unfavorable changes which were detected in soil physical parameters of these treatments. Reduced yields on treatments with cover crop was probably due to the competition for soil moisture and nutrients early in the season. Highest yields of this experiment were obtained with 19-inch row spacing.

Simple correlation between leaf area index and total dry weight of plant showed a highly significant correlation in all dates of measurements, Table 18. The same results were obtained between dry weights of leaf, stem and total dry weight. Table 19 shows the significant correlation between number of pods per plant, number of beans per pod and plant yield.

Summary

Aggregate stability as measured by mean weight diameter, demonstrated that aggregates become less stable during the growing season of navy beans, regardless of secondary tillage or cover crop treatments. The rate of change, however, was reduced by eliminating secondary tillage. Cover crop treatments had very little affect upon soil structure until late in the season. This shows the importance of time in the formation process of a stable structure.

Polyuronide content of the soil correlated better with the index of aggregate stability than polysaccharides and bitumens. The quantity of polysaccharides was correlated better with levels of undecomposed

Table 17. Influence of tillage, cover crop and herbicides upon harvest parameters of Sanilac navy beans. Each mean is the average of 6 replications.

Treatment	Pods/plant	Beans/pod	Kg/ha	Lbs/a
T_1 (4 passes, Eptam, no-cover crop)	28.97	3.80	2515.15	2243.93
T_2 (4 passes, Eptam, oats cover crop)	23.63	3.79	1519.19	1356.03
T_3 (zero, Paraquat, no-cover crop)	13.77	3.01	797.07	713.07
T_4 (zero, Paraquat, oats cover crop)	3.72	1.37	164.23	146.92
T_5 (zero, Roundup, no cover crop)	17.63	3.12	2567.07	2296.53
T_6 (zero, Roundup, oats cover crop)	18.83	3.32	2202.05	1969.98
LSD 0.05	7.88	0.96	573.15	512.20
LSD 0.01	11.93	1.45	868.29	775.95

Table 18. Simple correlation coefficients between leaf area index, dry weight of leaf, dry weight of stem and total dry weight of navy beans with time (var. Sanilac).

Parameters	Total dry weight 33-days	42-days	84-days
Leaf area index	r^2=0.9522**	r^2=0.8882**	r^2=0.8671**
Dry weight of leaf	r^2=0.8833**	r^2=0.9706**	r^2=0.9657**
Dry weight of stem	r^2=0.8034**	r^2=0.9903**	r^2=0.9907**

**Values are significant at 0.01 level of probability.

Table 19. Simple correlation coefficients among the harvest parameters of navy beans (var. Sanilac).

Parameters	Plant yield	Number of beans per pod
Number of pods per plant	r^2=0.7365**	r^2=0.7794**
Number of beans per pod	r^2=0.6649**	-----

**Values are significant at 0.01 level of probability.

plant residues in the soil. Changes in plant residues were not great enough nor the period of time long enough for a detailed study of the proposed concept of "turn-over rate". However, changes in levels of these components were detected in this study. To study the interrelationships between plant residues and active organic components of the soil, longer periods of time are necessary. Detailed investigations of these reactions could give a better understanding of the mechanisms of soil aggregation.

Additional soil physical parameters which confirmed the dynamics of soil aggregation during one growing season of navy beans included an increase in bulk density and a decrease in total porosity during the first 84 days after planting. The rate of change of these two parameters was reduced by a cover crop and the absence of secondary tillage. Increased hydraulic conductivity of treatments with cover crop and no secondary tillage confirms their positive influence upon reducing soil compaction. Combinations of a cover crop and no secondary tillage practices also reduced the crust strength of the dense Charity clay soil.

Competition between the cover crop and the main crop early in the season could be controlled by spraying the cover crop at the optimum moisture content. Decompositon rate of plant residues was slower under the cover crop treatments due to lack of moisture and lower temperature. This disadvantage, compared to other beneficial effects of cover crops is negligible and may be resolved with improved management.

Leaf area and leaf area index, dry weight of leaf, dry weight of stem and total dry weight of plant were less under all treatments with cover crop and no-secondary tillage. Competition between the cover and main crops for soil moisture was proposed as the main reason for this decrease.

Harvest parameters appeared to be higher for treatments without a cover crop. No secondary tillage improved the harvest parameters. The adverse affect of secondary tillage on soil structure could be the main reason for the decrease in harvest parameters of these treatments.

Experiment II. Primary Tillage and Organic Residue

This field experiment was conducted on range 9, tiers 4, 8 and 9 of the Saginaw Valley Bean-Beet Research Farm. Its purpose was to study the interaction of applied plant residues, cropping sequences and primary tillage practices and their effects upon soil physical conditions and the production potential of navy beans. A digital computer enhanced the detailed study of all possible interactions between selected parameters and their sources of variation. The results and conclusions in this experiment are based on two dates of sampling and measurements of several soil and plant parameters.

Soil Parameters

Four soil parameters, aggregate stability, bulk density, total porosity and saturated hydraulic conductivity, were selected and measured on August 3, and September 7, 1976. Mean weight diameter was significantly improved early in the season by the organic amendment ($P = 0.012$). This effect was decreased with time, so that no significant differences were detected in mean weight diameter of the treatment of this study late in the season. This decrease was not in fact due to decrease in effectiveness of organic matter, but, it was actually due to breakdown of larger aggregates to smaller ones during the season which eliminates the favorable influences of organic matter. This evidence is quite obvious by comparing the mean weight diameter, Table 20, with the loss of primary and secondary soil particles with

Table 20. Influence of organic amendment, cropping sequence and primary tillage upon the mean weight diameter of aggregate < 2 mm in size. Each value is the average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Time after planting - days					
	26	55	26	55	26	55
Non-amended						
Fall plow	0.564	0.453	0.605	0.506	0.648	0.528
Fall G.H.	0.486	0.462	0.490	0.523	0.525	0.509
Spring G.H.	0.497	0.496	0.576	0.494	0.597	0.502
No tillage	0.355	0.430	0.495	0.531	0.529	0.572
LSD 0.05	0.050	0.043	0.039	0.021	0.048	0.028
LSD 0.01	0.082	0.071	0.065	0.034	0.080	0.046
Amended						
Fall plow	0.622	0.445	0.611	0.576	0.682	0.557
Fall G.H.	0.473	0.457	0.535	0.497	0.528	0.608
Spring G.H.	0.528	0.450	0.606	0.566	0.647	0.521
No tillage	0.428	0.508	0.519	0.458	0.554	0.481
LSD 0.05	0.049	0.048	0.055	0.025	0.027	0.031
LSD 0.01	0.081	0.080	0.092	0.041	0.046	0.051

G.H. = Graham Hoeme

size of less than 0.106 mm in diameter, Table 21. Greater mean weight diameters and more stable aggregates were formed in amended soils 26 days after planting.

Application of organic residues caused a significant difference in bulk density and total porosity, 55 days after planting. The level of significance were $P = 0.029$ and $P = 0.024$ for bulk density and porosity, respectively. Bulk density decreased with application of organic amendment and time of measurement, Table 22. Total porosity was generally increased by the application of amendment, Table 23. This increase in total porosity and decrease in bulk density is probably due to improved soil structure under amended treatments (30). Since mean weight diameter was higher and the quantity of loss of primary and secondary aggregates were lower under these treatments, there was an improvement in formation and stabilization of soil aggregates by application of organic residues to the soil.

Saturated hydraulic conductivities were lower in amended treatments, Table 24. The significance of amendment upon saturated conductivity was statistically higher in the first date of measurement ($P < 0.0005$), than the second date ($P = 0.047$). Generally, there was an increase in hydraulic conductivity of amended treatments and a decrease in conductivities of non-amended treatments during the growing season. This suggests a more stable and uniform structure development with time in the presence of organic matter (19).

Cropping sequences had a significant influence upon mean weight diameter. Largest mean weight diameters were formed under alfalfa and smallest under bean sequences, Table 20. Mean weight diameters from the corn sequence were between the bean and alfalfa sequences.

Table 21. Influence of organic amendment, cropping sequence and primary tillage upon the stability of aggregates. The amount of primary and secondary particles < 0.106 mm in size. Each value is average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Time after planting - days					
	26	55	26	55	26	55
	%					
Non-amended						
Fall plow	13.12	13.05	12.44	13.75	9.31	12.25
Fall G.H.	12.88	12.65	18.19	10.88	13.94	12.38
Spring G.H.	15.79	13.05	12.25	12.44	10.12	12.86
No tillage	14.75	12.45	12.13	12.19	12.19	10.81
LSD 0.05	2.89	1.45	2.49	1.99	0.67	2.01
LSD 0.01	4.80	2.40	4.12	3.29	1.12	3.45
Amended						
Fall plow	9.13	12.96	10.63	11.13	8.90	12.06
Fall G.H.	13.14	13.15	12.50	12.06	14.50	12.31
Spring G.H.	11.88	12.94	11.38	13.44	12.19	14.44
No tillage	12.63	8.04	14.58	11.90	11.56	13.31
LSD 0.05	1.35	1.71	0.95	0.84	1.43	0.75
LSD 0.01	2.23	2.83	1.58	1.39	2.38	1.24

G.H. = Graham Hoeme

Table 22. Influence of organic amendment, cropping sequence and primary tillage upon bulk density of a Charity clay soil. Each mean is the average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Time after planting - days					
	26	55	26	55	26	55
	g/cc					
Non-amended						
Fall plow	1.19	1.12	1.15	1.18	1.21	1.24
Fall G.H.	1.17	1.26	1.10	1.16	1.24	1.14
Spring G.H.	1.16	1.23	1.25	1.21	1.25	1.16
No tillage	1.25	1.17	1.24	1.19	1.24	1.20
LSD 0.05	0.15	0.16	0.14	0.12	0.20	0.11
LSD 0.01	0.25	0.26	0.24	0.21	0.33	0.19
Amended						
Fall plow	1.21	1.15	1.10	1.15	1.19	1.22
Fall G.H.	1.28	1.08	1.17	1.15	1.16	1.07
Spring G.H.	1.26	1.22	1.06	1.20	1.20	1.15
No tillage	1.16	1.19	1.27	1.21	1.22	1.18
LSD 0.05	0.13	0.13	0.12	0.12	0.16	0.07
LSD 0.01	0.22	0.22	0.20	0.21	0.27	0.11

G.H. = Graham Hoeme

Table 23. Effect of organic amendment, cropping sequence and primary tillage upon total porosity of a Charity clay soil. Each value is the average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Time after planting - days					
	26	55	26	55	26	55
	%					
Non-amended						
Fall plow	55.07	55.73	56.78	55.28	54.34	53.80
Fall G.H.	55.79	55.13	58.52	56.11	53.35	57.07
Spring G.H.	56.41	53.39	53.33	54.25	52.74	56.38
No tillage	52.84	55.78	55.55	55.19	53.24	54.93
LSD 0.05	5.67	6.01	5.78	4.76	7.14	4.36
LSD 0.01	9.41	9.97	9.58	7.89	12.29	9.24
Amended						
Fall plow	54.26	56.73	58.63	56.49	54.83	53.98
Fall G.H.	52.05	59.26	55.88	56.92	56.24	59.56
Spring G.H.	52.50	52.95	60.08	55.41	54.93	57.02
No tillage	56.12	55.10	54.23	54.31	53.95	55.47
LSD 0.05	5.45	5.04	4.12	6.07	6.08	2.57
LSD 0.01	9.04	8.37	6.83	10.08	10.09	4.72

G.H. = Graham Hoeme

Statistical levels of significance of these differences increased from $P = 0.011$ to $P < 0.0005$ during the 29 day period between samples. This increase appears to result from formation of larger and more stable aggregates under alfalfa and corn sequences, Table 21. Since the quantity of plant residues under these sequences is higher, it contributes to the formation of more active organic components and stable structures (70, 105). The effect of cropping sequences on total porosity and bulk density was highly significant early in the season when the significant levels for bulk density and total porosity were $P = 0.003$ and $P = 0.004$, respectively. Lowest densities and highest porosities were found under corn-bean and alfalfa-bean sequences, Table 22 and 23. This is probably due to higher content of larger and more stable aggregates under these two cropping sequences. Saturated hydraulic conductivity was not significantly affected by any of the sequences during the entire growing season.

Different tillage practices influenced the mean weight diameters under different cropping sequences and levels of organic amendment, Table 20. Soils on the beans-beans sequence had the greatest mean weight diameters when fall plowed and lowest with no tillage, regardless of organic amendment, Figures 8 and 9. However, mean weight diameters of amended treatments were higher than non-amended treatments. There were no significant differences between fall Graham Hoeme and spring Graham Hoeme treatments for either date of sampling. Four different tillage practices essentially had the same influence upon mean weight diameter under beans-beans sequence 55 days after planting. Decreased mean weight diameter with no tillage treatment was apparently due to the adverse effect of the previous crop. It

Table 24. Influence of organic amendment, cropping sequence and primary tillage upon saturated hydraulic conductivity of a Charity clay soil. Each value is the mean of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Time after planting - days					
	26	55	26	55	26	55
	cm/hr					
Non-amended						
Fall plow	17.10	14.94	16.02	17.00	17.95	18.25
Fall G.H.	21.64	16.86	17.59	16.96	15.64	18.26
Spring G.H.	18.85	13.49	15.56	15.43	14.25	13.41
No tillage	14.20	15.07	15.64	14.95	16.91	14.40
LSD 0.05	10.41	4.61	13.01	8.10	7.96	8.27
LSD 0.01	17.26	7.64	21.58	13.43	13.21	13.72
Amended						
Fall plow	12.06	11.33	15.09	12.78	12.49	15.83
Fall G.H.	15.05	15.88	16.15	14.84	16.03	16.44
Spring G.H.	11.97	14.61	11.95	14.11	10.88	13.50
No tillage	15.00	18.69	15.92	13.46	13.73	14.92
LSD 0.05	11.03	8.54	4.22	6.87	8.51	8.71
LSD 0.01	18.29	14.16	7.00	11.40	14.12	14.45

G.H. = Graham Hoeme

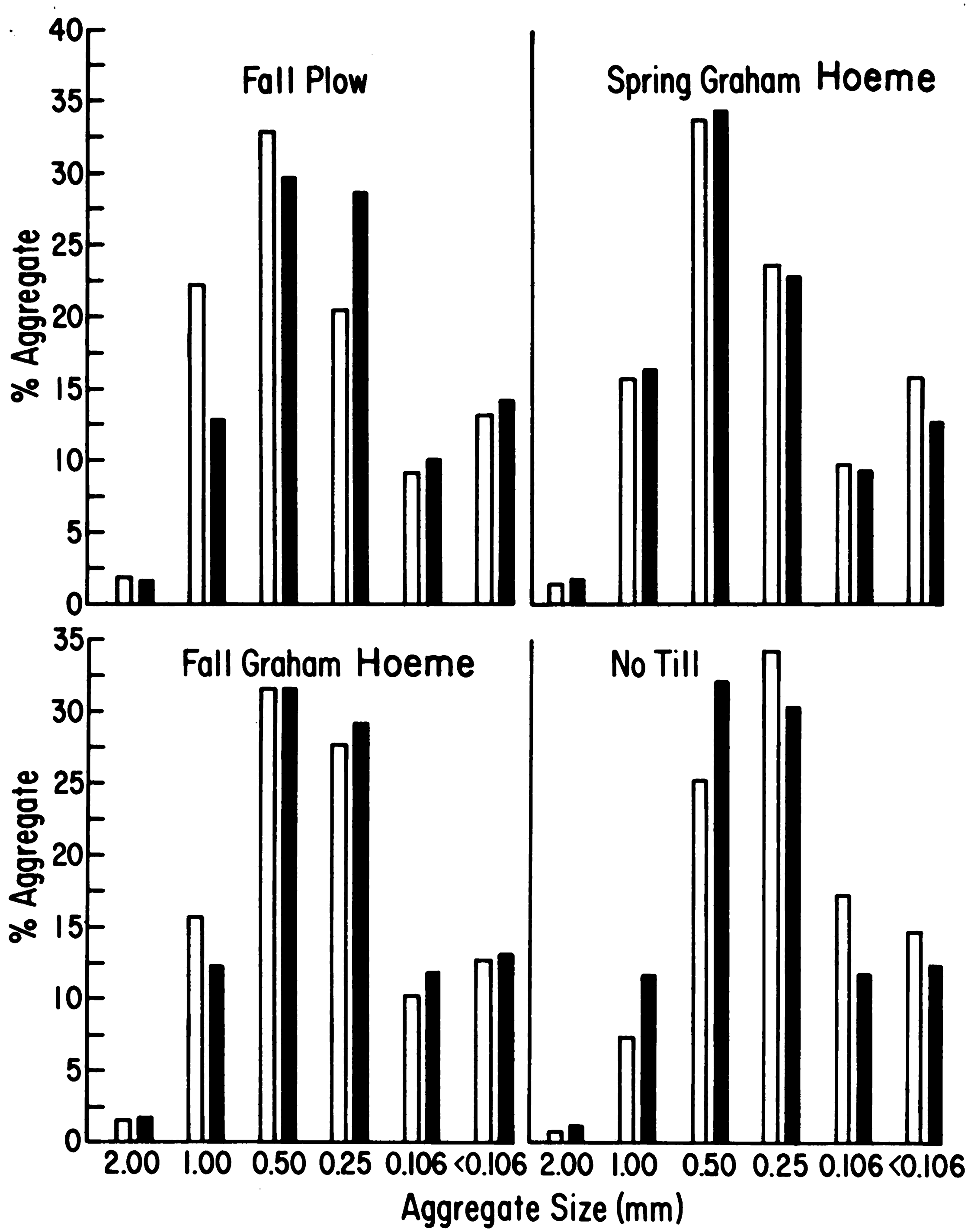


Figure 7. Comparison of primary tillage practices: rye distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting the second crop of beans in a <u>bean-bean</u> sequence without organic amendment.

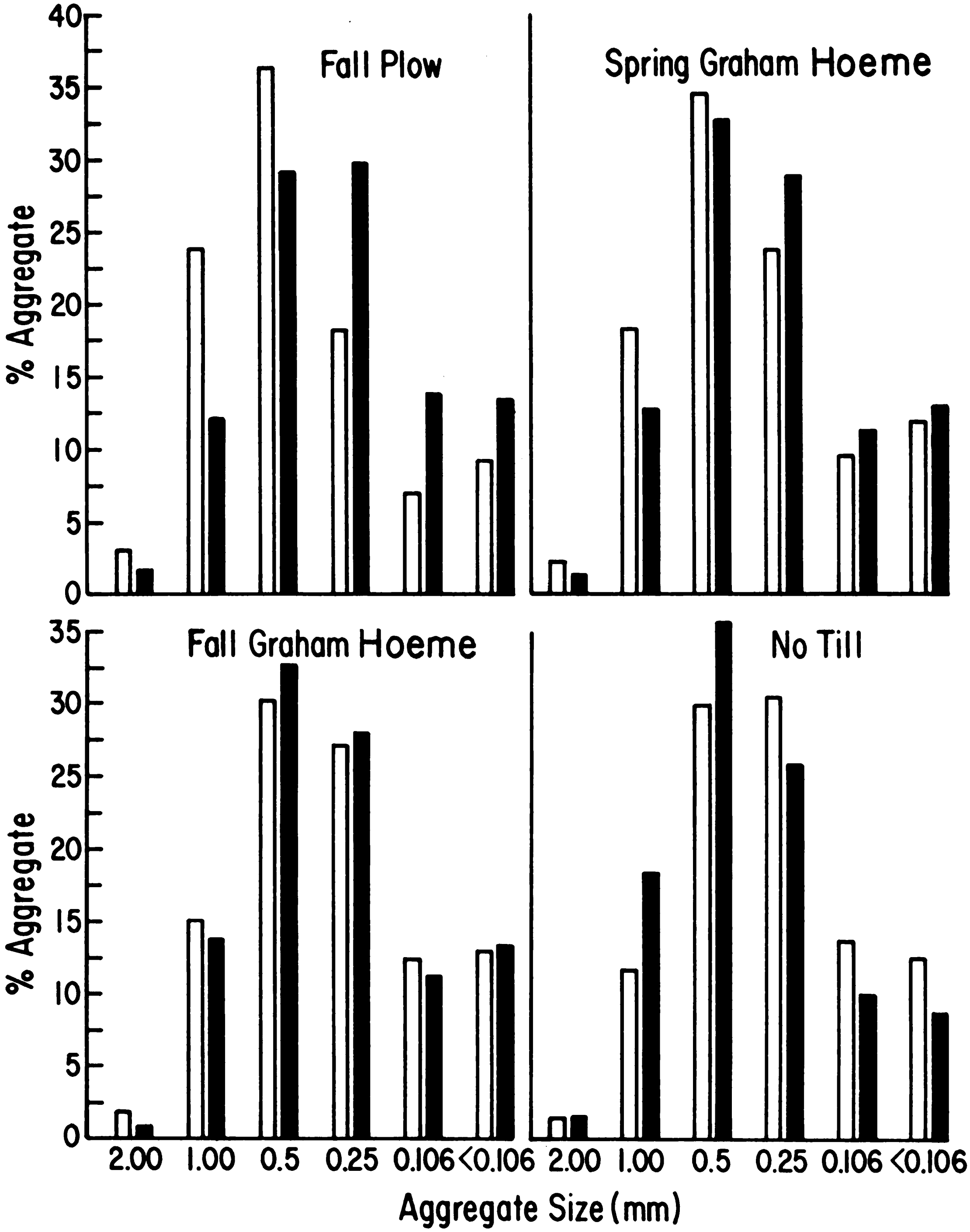


Figure 8. Comparison of primary tillage practices: size distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting the second crop of beans in a bean-bean sequence with 7.5 M.T./ha corn cobs incorporated before the second bean crop.

is suggested that the previous crop may have destroyed the soil structure as determined in Table 21 of this study, and may have reduced the influence of environmental factors due to less mechanical manipulation of the soil under no tillage. This reduction in influence of environmental factors will intensify the unfavorable condition for the decomposition of organic residues and formation of larger and more stable aggregates. Fall plowing, however, exposes the soil to freezing and thawing conditions which enhance the formation of more stable structures both directly and/or through the formation of active organic components by promoting the decomposition of plant residues (11, 13, 85).

Fall plowing and spring Graham Hoeme caused the best distribution of stable aggregates in the corn-beans sequence Graham Hoeme and no primary tillage had the same influence on the aggregate stability under both amended and non-amended corn-beans sequence 26 days after planting, Figures 9 and 10. No statistically differences were detected between four tillage systems under corn-beans sequence 55 days after planting. The same results were obtained for the alfalfa-beans sequence, except that in this sequence the mean weight diameter increased under amended case with fall Graham Hoeme late in the season, Figures 11 and 12. Higher mean weight diameters under deep chiseling (Graham Hoeme) may be due to undercutting of the soil and less disturbance of the surface soil (82).

The statistical significance of the influences of interaction of organic amendment, cropping sequences and tillage practices upon mean weight diameters were $P = 0.09$ and $P = 0.005$ for first and second dates of measurements, respectively. During the first 26 days of the

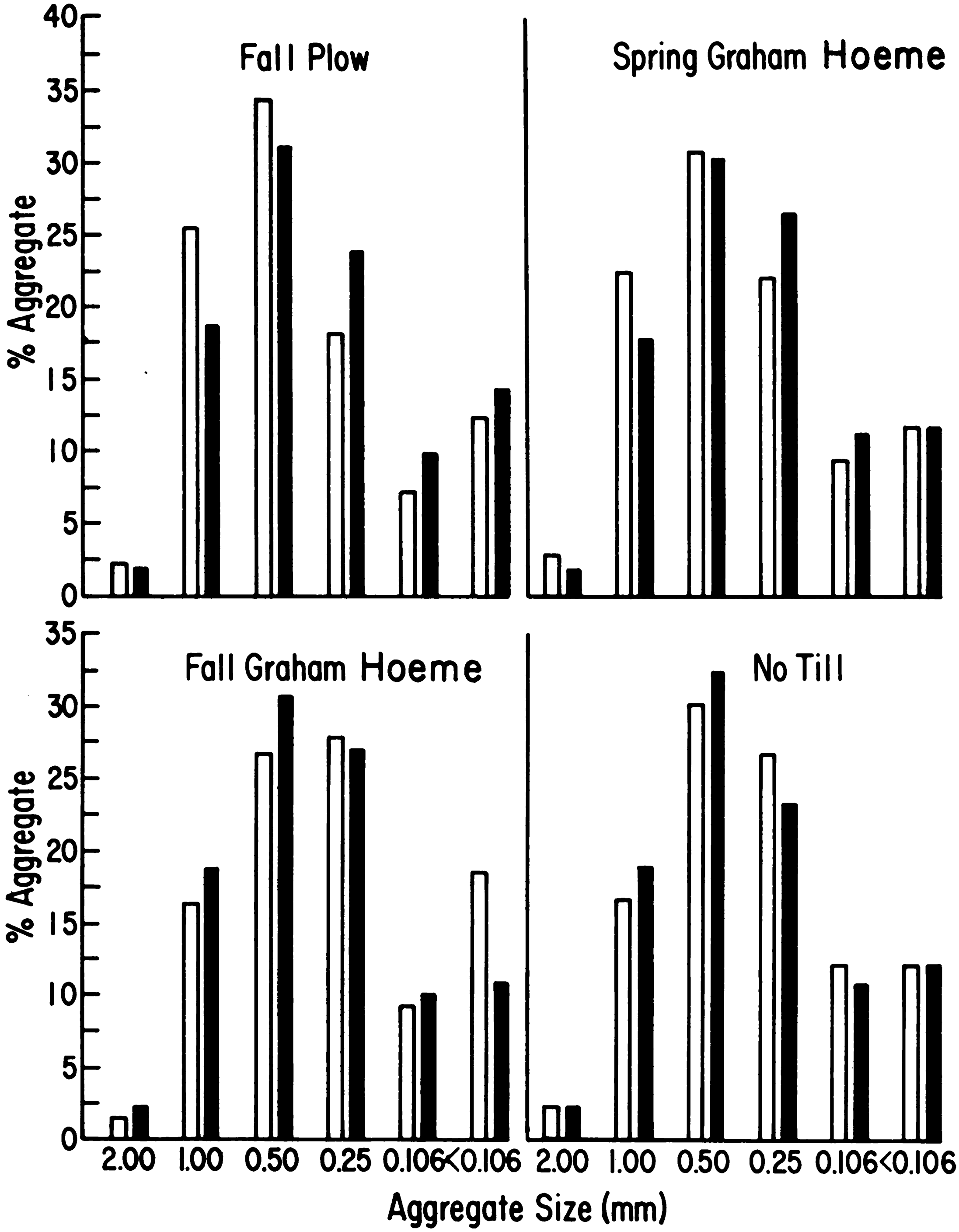


Figure 9. Comparison of primary tillage practices: size distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting the second crop of beans in a corn-bean sequence without organic amendment.

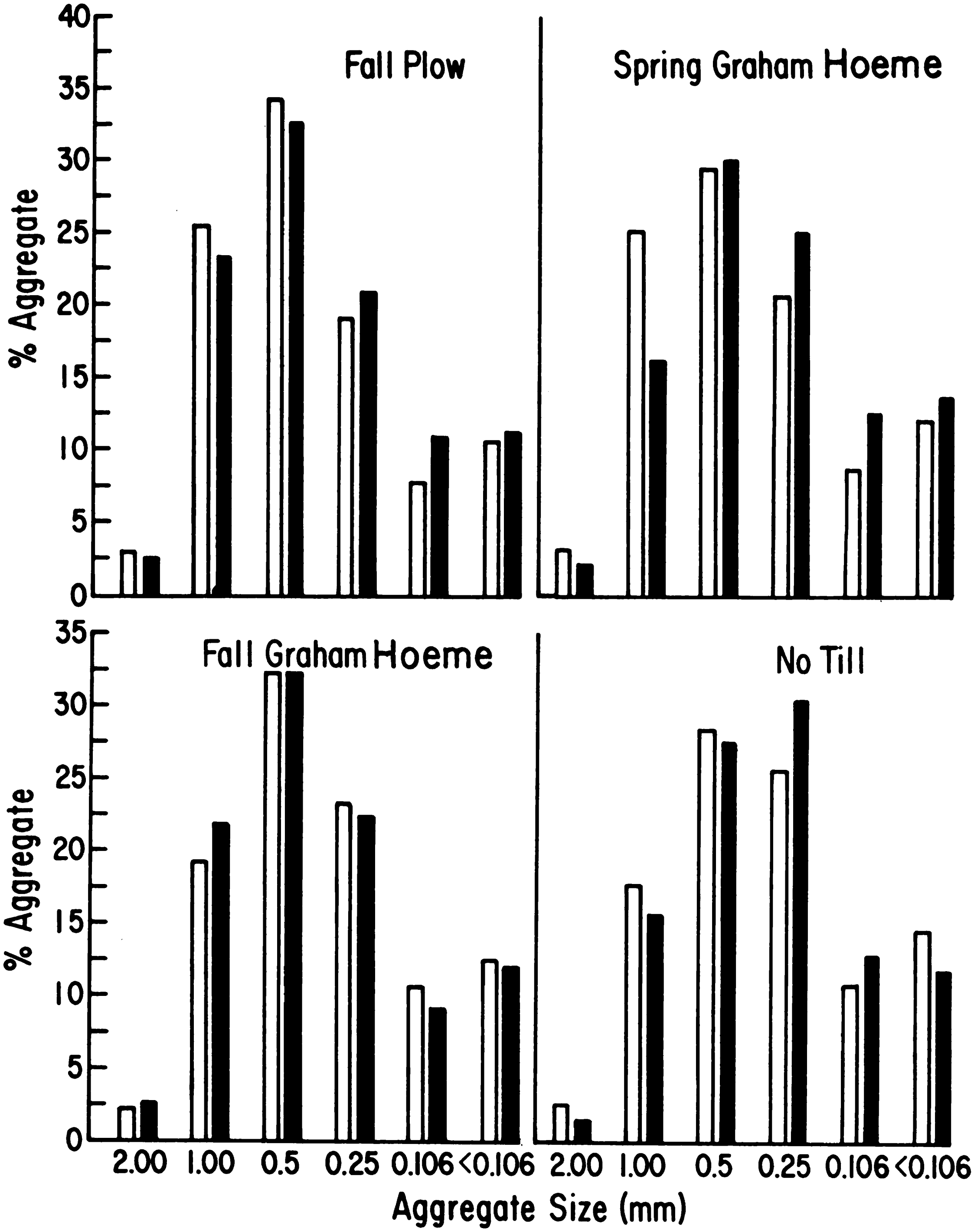


Figure 10. Comparison of primary tillage practices: size distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting of the second crop of beans in a corn-bean sequence with 7.5 M.T./ha corn cobs incorporated before the second bean crop.

growing season highest mean weight diameters were obtained under the alfalfa-beans sequence with organic amendment and lowest in beans-beans with no amendment. The influence of tillage practices on mean weight diameter was different under different cropping sequences regardless of organic amendment. Fall plowing was the best primary tillage practice for the beans-beans sequence. The fall plowed and spring Graham Hoeme chiseled sequences had essentially the same statistical significance for mean weight diameter under both corn-beans and alfalfa-beans sequences. However, there were no statistical differences in the influence of the four tillage practices on mean weight diameters under any of the cropping sequences and amendment levels 55 days after planting, Table 20.

The combined effects of organic amendment, cropping sequences and tillage practices upon bulk density were statistically significant $P = 0.005$ and $P = .040$ for the first and second date of measurement, respectively. Generally, bulk density increased for all cropping sequences and tillage practices regardless of amendment, except for amended treatments of the alfalfa-beans sequence. Lowest bulk densities were obtained on the alfalfa-beans sequence with amendment and the highest under beans-beans with organic amendment. The influence of tillage practices on bulk density was more detectable late in the season, Table 23. The same results were obtained with total porosity.

Saturated hydraulic conductivity was not affected by the combination of organic amendment, cropping sequence and tillage practices during the first 55 days of growing season. However, water movement was the slowest in the zero and spring tillage and non-amended treatments regardless of cropping sequence. Conductivity was the slowest on spring tilled treatments of all cropping sequences of the amended treatments.

Table 25 shows the simple correlation coefficients between organic amendment, cropping sequence, tillage practices and soil physical para-

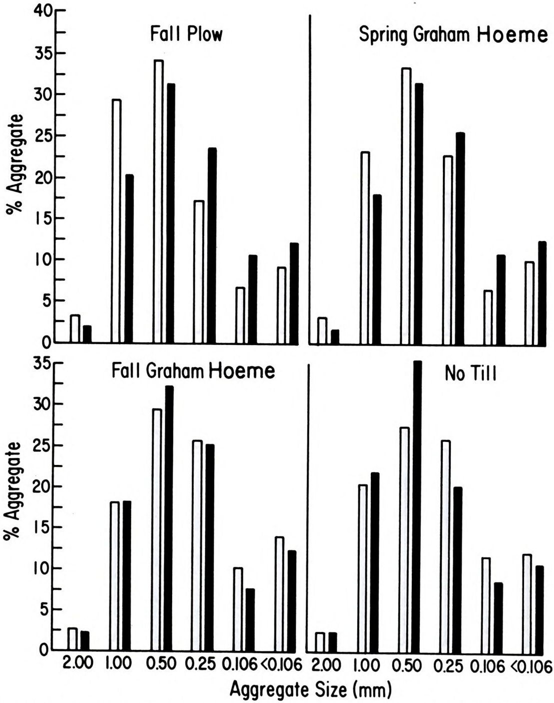


Figure 11. Comparison of primary tillage practices: size distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting the second crop of beans is an alfalfa-bean sequence without organic amendment.

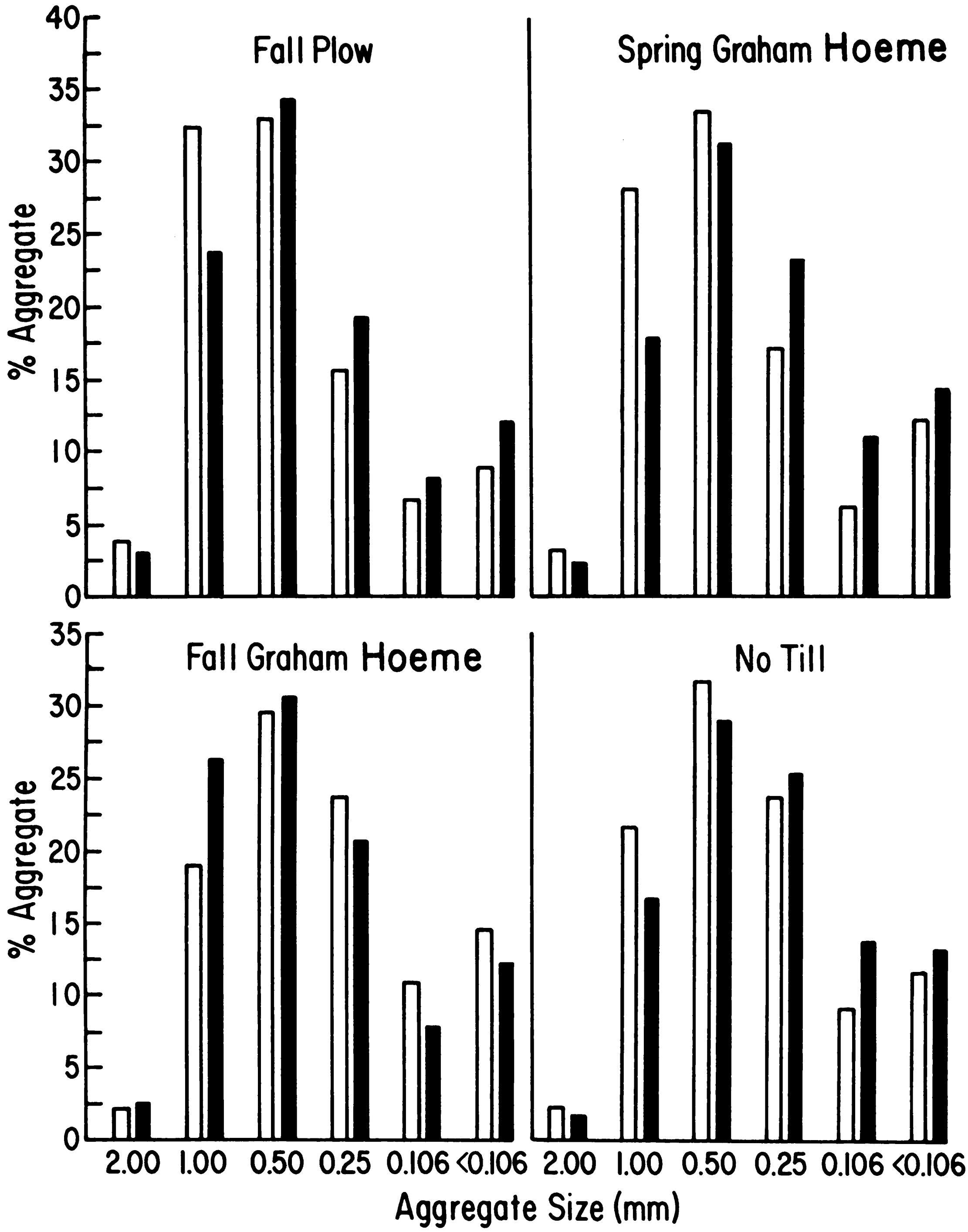


Figure 12. Comparison of primary tillage practices: size distribution of aggregates 26 days (open bars) and 55 days (solid bars) after planting the second crop of beans in an alfalfa-bean sequence with 7.5 M.T./ha corn cobs incorporated before the second bean crop.

Table 25. Simple correlation coefficients between organic amendment levels, cropping sequence, primary tillage and soil physical parameters, 55 days after planting.

Source of variance	Organic amendment	Cropping sequence	Tillage practices
MWD	$r^2-0.064$	$r^2=0.580$*	$r^2=0.012$
Loss	$r^2=0.028$	$r^2=0.002$	$r^2=0.368$
Bulk density	$r^2=0.196$	$r^2=0.076$	$r^2=0.025$
Total porosity	$r^2=0.208$	$r^2=0.077$	$r^2=0.014$
Saturated hydraulic conductivity	$r^2=0.176$	$r^2=0.071$	$r^2=0.117$

*Values are significant at 0.05 level of probability.

meters 55 days after planting. Earlier in the season, these coefficients were much smaller. The only significant correlation detected was between mean weight diameter and cropping sequence. This shows the influence of previous crop upon organic contents of the soil and formation of more stable aggregates.

The organic content of the soil showed a significant difference under different cropping sequences, Table 26. Higher organic contents occurred in alfalfa-beans and beans-beans sequences for both levels of amendment. Organic components were lower under corn-beans than the other two sequences. Reduced oxidation under beans-beans sequence may be due to less variation in soil atmospheric conditions. This confirms the result of aggregate stability measurements. According to aggregate stability analysis this sequence had the fewest large aggregates which were generally the least stable. Higher soil organic matter content of alfalfa-beans sequence is probably due to larger amounts of plant residues returned from alfalfa or to production of larger amounts of difficulty oxidizable, high molecular weight end product of decomposition (45, 70).

Plant Parameters

Leaf area, leaf area index and plant dry weights were measured as an index of plant growth during the season. Levels of organic amendment did not statistically influence any of these parameters. Cropping sequences had a significant affect on leaf area and leaf area index ($P = 0.0006$). Generally, the largest bean plants followed alfalfa, the smallest followed beans, with corn having a moderate effect upon plant growth, Table 27. Cropping sequences also changed the dry weight of leaf, stem and as a result total dry weight of navy beans. The effect of sequences were statistically significant upon dry weight of stem

Table 26. Effect of organic amendment and cropping sequence on the organic matter content of a Charity clay soil expressed as %. Each value is the average of 6 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Organic carbon	Organic matter[a]	Organic carbon	Organic matter[a]	Organic carbon	Organic matter[a]
Non-amended°						
No tillage	2.62	4.52	2.01	3.46	2.47	4.25
Amended						
No tillage	2.78	4.80	2.14	3.7O	2.65	4.65
LSD 0.05	0.202	0.348	0.202	0.348	0.202	0.348
LSD 0.01	0.305	0.526	0.305	0.526	0.305	0.526

[a]Calculated according to the equation: 0 M = 0.724 x O.C.

Table 27. Influence of organic amendment, cropping sequences and primary tillage upon leaf growth and root rot of navy beans.

Treatment	Previous crop								
	Beans			Corn			Alfalfa		
	LA (cm^2/plant)[a]	LAI	RRI[b]	LA (cm^2/plant)[a]	LAI	RRI[b]	LA (cm^2/plant)[a]	LAI	RRI[b]
Non-amended									
Fall plow	1477	2.08	1.28	1432	2.44	1.32	1337	1.88	1.30
Fall G.H.	918	1.29	1.16	1172	1.68	1.31	1093	1.54	1.22
Spring G.H.	1221	1.72	1.30	1194	2.01	1.30	1434	2.02	1.29
No tillage	1104	1.55	1.37	1213	1.65	1.35	1451	2.04	1.33
LSD 0.05	--	--	0.40	--	--	0.47	--	--	0.37
LSD 0.01	--	--	0.67	--	--	0.77	--	--	0.61
Amended									
Fall plow	1026	1.44	1.20	1189	1.62	1.25	1516	2.13	1.27
Fall G.H.	1276	1.79	1.36	1121	1.58	1.31	1497	2.11	1.39
Spring G.H.	1225	1.72	1.32	1279	1.80	1.27	2075	2.92	1.26
No tillage	929	1.31	1.44	1452	2.04	1.30	1726	2.43	1.35
LSD 0.05	--	--	0.33	--	--	0.82	--	--	0.44
LSD 0.01	--	---	0.55	--	--	1.36	--	--	0.73

[a] Each value is the average of 5 plants.
[b] Each mean is the average of 4 replications. Index was from 0 (white roots) to 5 (dead roots).

G.H. = Graham Hoeme

(P = 0.001), dry weight of leaf (P = 0.012) and total dry weight (P = 0.001). Plant dry weights were greatest on the alfalfa-beans and lowest on the corn-beans sequences, Table 28. Primary tillage practices did not affect the leaf area, but significantly influenced plant dry weight. The greatest influence of primary tillage systems was upon the dry weight of leaf and total dry weight of plant (P = 0.021) and the lowest influence on dry weight of stems (P = 0.036). Additional statistical comparisons were not determined due to limited numer of replications.

Root rot evaluations, based on an index of 0 (healthy) to 5 (dead) plants, were made on September 17, when the plants were 64 days old. Table 27 indicates that root rot disease was signficant on the beans-beans sequence. No-tillage treatment had the highest number of infected roots for both amended and non-amended treatments. Reduced root growth and more compacted soil, based on field observation, may be the principal detrimental factors of the no primary tillage system which influences the root rot (64, 65). Fall applied Graham Hoeme tillage had the lowest number of infected roots for non-amended and the fall plowed in the lowest amended treatments. Subsoiling or any type of mechanical manipulation appears to decrease the disease through increased rooting depth and its regeneration (20).

Bean yield, number of pods per plant and number of beans per pod were the final set of plant parameters measured in this experiment. An organic amendment of 7.5 metric tons per hectare of <2 mesh corn cobs applied in 1974, influenced the number of pods per plant (P = 0.084). Cropping sequences significantly influenced the yield and number of pods per plant but not the number of beans per pod (P = 0.005). Higher

Table 28. Influence of organic amendment, cropping sequence and primary tillage upon dry weight components of many beans (var. Seafarer). Each value is the average of 5 plants.

Treatment	Previous crop								
	Beans			Corn			Alfalfa		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
	g/plant								
Non-amended									
Fall plow	4.58	13.80	18.38	4.46	14.77	19.23	4.05	13.69	17.73
Fall G.H.	2.96	8.78	11.74	4.02	12.31	16.33	3.52	11.81	15.33
Spring G.H.	4.04	12.13	16.17	4.01	13.05	17.06	4.60	15.32	19.92
No tillage	3.94	7.79	11.73	4.04	12.65	16.69	4.86	17.61	22.47
Mean	3.88	10.63	14.51	4.13	13.20	17.33	4.26	14.61	18.87
Amended									
Fall plow	4.60	9.76	14.36	3.53	9.69	13.22	4.27	16.78	21.05
Fall G.H.	2.21	3.65	5.86	4.01	11.26	15.27	4.80	15.09	19.89
Spring G.H.	4.41	11.60	16.01	4.51	15.11	19.62	6.41	21.53	27.94
No tillage	3.33	6.83	10.16	3.97	14.50	18.47	4.47	21.74	26.21
Mean	3.64	7.96	11.60	4.01	12.64	16.65	4.99	18.79	23.78

G.H. = Graham Hoeme

numbers of pods per plant were achieved on beans after alfalfa and corn sequences, Table 29.

Number of pods per plant were not significantly influenced by tillage treatments. But, primary tillage systems significantly influenced the number of beans per pod (P = 0.031). Beans after beans without amendment produced the highest number of beans per plant with zero primary tillage and the lowest with spring Graham Hoeme. Fall plowing and fall Graham Hoeme chiseling had the same influence upon the number of beans per plant in non-amended treatments of beans-beans sequence. No significant differences were detected among tillage treatments of corn-beans sequence regardless of amendment. This was also true for the amended beans-beans sequence. In the alfalfa-beans sequence the highest number of beans per plant (pods/plant x beans/pod) produced on the no-tillage treatments and lowest on the spring Graham Hoeme with amendment. Greater harvest parameters under the alfalfa-beans and corn-beans sequences were probably due to improved and more stable soil structure, Table 29, and agrees with the literature (26, 70, 95).

The influence of primary tillage systems on yield was statistically significant (P = 0.023). In the continuous bean sequence, maximum yield was obtained by fall plowing and minimum with spring Graham Hoeme chiseling on both amended and non-amended treatments, Table 30. However, yield of amended treatments was 10-15% higher than non-amended ones. Fall Graham Hoeme and no tillage systems had similar influences upon yields. If amended, fall plowed treatments of the beans-beans sequence had 8% higher yields than spring Graham Hoeme chiseled treatments. Yields of fall Graham Hoeme chiseled and no-tilled treatments were lower than fall plowing and greater than spring Graham Hoeme

Table 29. Influence of organic amendment, cropping sequence and primary tillage upon harvest parameters of navy beans (var. Seafarer). Each mean is the average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	Pods per plant	Beans per plant	Pods per plant	Beans per plant	Pods per plant	Beans per plant
Non-amended						
Fall plow	14.35	3.34	20.00	3.36	19.60	3.30
Fall G.H.	18.70	3.34	17.40	3.36	16.00	3.40
Spring G.H.	12.85	2.86	17.50	2.93	16.95	2.94
No tillage	17.95	3.50	18.70	3.31	15.75	3.33
LSD 0.05	7.53	1.11	10.64	1.28	8.74	8.99
LSD 0.01	12.49	1.84	17.64	2.12	14.50	1.64
Amended						
Fall plowed	14.60	3.18	16.15	3.52	16.00	3.39
Fall G.H.	15.45	3.49	15.50	3.50	16.85	3.14
Spring G.H.	12.95	3.15	19.30	3.11	14.05	3.64
No tillage	10.90	3.48	17.70	3.63	17.60	3.44
LSD 0.05	9.49	1.50	10.98	1.07	7.18	1.06
LSD 0.01	15.75	2.49	18.21	1.77	11.91	1.75

G.H. = Graham Hoeme

Table 30. Influence of organic amendment, cropping sequence and primary tillage upon yield of navy beans (var. Seafarer). Each value is the average of 4 replications.

Treatment	Previous crop					
	Beans		Corn		Alfalfa	
	lb/a	kg/ha	lb/a	kg/ha	1lb/a	kg/ha
Non-amended						
Fall plow	905.18	1014.59	1125.50	1261.54	1155.13	1294.75
Fall G.H.	790.13	885.93	1051.30	1178.37	1208.55	1354.62
Spring G.H.	667.40	748.07	970.95	1088.31	1301.93	1459.29
No tillage	806.45	903.92	1239.78	1389.63	1257.80	1409.98
LSD 0.05	352.29	393.50	270.01	301.60	406.65	454.22
LSD 0.01	585.27	652.63	447.82	500.21	674.42	753.33
Amended						
Fall plow	919.60	1030.75	1103.25	1236.60	1271.70	1425.41
Fall G.H.	861.50	965.63	1009.68	1131.72	1221.10	1368.69
Spring G.H.	777.18	871.12	948.20	1062.81	1306.75	1464.69
No tillage	841.43	943.13	1101.65	1243.80	1277.80	1432.24
LSD 0.05	271.59	303.37	356.06	397.72	371.05	414.47
LSD 0.01	450.43	503.13	590.52	659.61	615.39	687.39

G.H. = Graham Hoeme

chiseled ones. In the corn sequence, no primary tillage had the best yield under non-amended treatments. Fall plowing and fall Graham Hoeme chiseling gave the moderate and spring Graham Hoeme chiseling had the lowest yield in corn-beans sequence. No significant differences were obtained in yield response of navy beans to the primary tillage practices of the corn-beans sequence in organic amended treatments. However, spring Graham Hoeme chiseling had the lowest yield even when amended. No significant differences were detected for yields among tillage practices of alfalfa-beans sequence, regardless of organic amendment. Highest yields were obtained with this sequence which were 3-5% greater in amended treatments than non-amended ones.

Table 31 shows the simple correlation coefficients among some of the plant factors and plant parameters with variables of this study. The only statistically significant coefficient showed the effect of cropping sequences on yield. This was expected since the yield in alfalfa-beans sequence was approximately 20% greater than corn-beans and 50% greater than beans-beans sequence regardless of amendment, Table 30. This trend in response of navy beans to cropping sequences agrees well with the soil physical measurements obtained in this experiment. Plant residues from previous crop(s) contributed to the formation and stabilization of soil structure by providing greater quantities of active organic matter. So, actually organic matter decreases the adverse effects of tillage operations on soil structure, by formation of more durable soil aggregates.

Since the correlation of harvest parameters to treatments in this experiment are from one growing season, which was shortened by a killing frost, it is recommended that studies relating primary tillage

Table 31. Simple correlation coefficients among plant parameters and sources of variation for primary tillage and organic residue experiment.

Parameters	Organic amendment	Cropping sequence	Tillage practices	Root rot
Yield	r^2=0.0268	r^2=0.8042**	r^2=0.0281	r^2=0.0339
Number of pods per plant	r^2=-0.1180	r^2=0.3128	r^2=0.0404	r^2=0.0709
Number of beans per plant	r^2=0.1680	r^2=0.0294	r^2=0.1470	r^2=0.0229
Root rot	r^2=0.0948	r^2=0.0165	r^2=0.2932	

** Statistically significant at 0.01 level of probability.

to navy beans growth and yield and the influence of organic matter upon this interaction, should be continued for at least two additional years.

Summary

This experiment demonstrated the influence of organic residues, cropping sequences and primary tillage practices upon a number of soil physical factors, plant growth and yield of navy beans. Decline in the aggregate stability was measured by a reduction in larger aggregates, increased bulk density, decreased total porosity and saturated hydraulic conductivity. Application of plant residues as organic amendment appeared to improve aggregate stability by increasing the quantity of larger aggregates and their mean weight diameter. The loss of primary and secondary soil particles less than 0.106 mm in diameter also was higher under amended treatments. Indicating that the time frame for the microbial transformations of organic residues was not well represented in this study.

Cropping sequences had a very significant affect of the formation and stabilization of aggregates. Larger aggregates were formed under the alfalfa-beans sequence and smaller, less stable ones occurred in the beans-beans sequence. The greatest improvement in soil structure was obtained through the application of organic residues to the beans-beans and corn-beans sequences. This was probably due to lack of active organic matter in these sequences.

Tillage practices had a significant effect on aggregates early in the season. This effect, however, disappeared with time and could be due to the breakdown of larger aggregates and the formation of more uniform smaller ones.

Analysis of the soil samples for organic matter indicated a significant difference in the net retention of carbon and organic matter from residues of crops grown under different cropping sequences. Increases due to corn cobs added as an amendment were small and not statistically significant. Residual organic matter levels were lowest under corn-beans and highest in beans-beans and alfalfa-beans sequences. It was proposed that this may either be due to lesser aeration in poorly aggregated soils under the beans-beans sequence or to production of larger quantities of resistant high molecular weight decomposition production from alfalfa.

Generally, bulk density increased and total porosity decreased under all treatments over the growing season. These changes were probably due to breakdown of larger aggregates and the filling of pores which in turn enhances the compaction of the soil. Amendment of the organic residues had a favorable infuence upon both parameters. Amendment also increased the hydraulic properties of a Charity clay soil. This difference was greater on the corn-beans sequence. Conductivity generally decreased with time for non-amended treatments and increased with amended ones which supports the concept of formation of more stable aggregates with application of organic residues with time.

Leaf area and plant size were affected by levels of organic amendment and previous crop. Plants were larger on crop rotations preceeded by alfalfa and corn and amended with organic residues. The disease of plant roots appeared to be influenced by primary tillage practices when organic resiudes were low. High organic residue treatments appeared to overcompensate for any adverse effect of tillage except in beans-beans sequences.

Navy bean yields and other harvest parameters were also influenced by the treatments of this experiment. Plant yield was mianly a function of cropping sequences and tillage practices. No statistically significant differences were detected in yield with respect to organic amendment application. Highest yield was obtained with alfalfa-beans and lowest under beans-beans sequences. Influence of primary tillage practices on harvest parameters was different with different cropping sequences. The variation in response of harvest parameters to mechanical manipulation of the soil was due to change in stability of aggregates under different sequences. Number of pods per plant was significantly influenced by organic residues and cropping sequences. High values of this paramater were obtained with alfalfa-beans and corn-beans sequences under amended treatments. Apparently tillage practices affected the number of beans per pod under beans-beans sequence with non-amended treatments. Highest quantities of this parameter was obtained with no tillage and lowest with spring Graham Hoeme tillage. Fall plowing and fall Graham Hoeme chiseling had the same influence upon number of beans per pod.

CONCLUSIONS

Both experiments of this study demonstrated that, soil aggregates greater than 0.5 mm in diameter breakdown to smaller sized aggregares continuously during the growing season of navy beans. The deterioration of aggregates resulted in a more compacted surface soil having a higher density, lower porosity and a declining saturated hydraulic conductivity with time. Strength of the surface crust was directly correlated to the destruction of soil aggregates. This study also demonstrated that the type and intensity of tillage operations are important in promoting the deterioration of aggregates and othe physical characteristics of a Charity clay soil. The intensity of breakdown of aggregates was decreased considerably by the application of an organic amendment either as an oats cover crop or as a corn cob residue. This phenomena was probably due to the "priming factor" and the transformation of organic residues to active organic components with time. These active organic compounds contribute to the formation and stabilization of soil structure. Since there was some undecomposed plant residues in the soil at the end of the growing season, it was concluded that the time frame of this study was not long enough for complete transformation of added organic amendments. However, changes in levels of these active components were detected during the period of this study.

Secondary tillage treatment caused an increase in bulk density and surface crust strength of a Charity clay soil. It also resulted in a decrease in total porosity and saturated hydraulic conductivity. The application of an organic amendment as a cover crop reduced the adverse effects of secondary tillage.

Cropping sequence significantly influenced the soil physical properties and navy bean yield. Total porosity and saturated conductivity were greater in alfalfa-beans and corn-beans than the beans-beans sequence. This improvement in the soil physical condition promoted plant growth and resulted in an increase in yield of alfalfa-beans and corn-beans sequences. Cropping sequence also influenced the affect of primary tillage practices upon soil and plant parameters of this study.

In the beans-beans sequence, the best soil physical conditions and plant growth were obtained with fall plowing and the worst with spring Graham Hoeme chiseling. Fall Graham Hoeme and no primary tillage treatments had a moderate influence upon soil and plant parameters.

In the corn-beans sequence, no primary tillage system had the most desirable influence upon soil conditions and plant growth. Fall plowing and fall Graham Hoeme chiseling had a moderate affect and spring Graham Hoeme chiseling had the least desirable influence upon soil and plant parameters.

In the alfalfa-beans sequence, the responses of soil physical parameters and plant yield to all primary tillage treatments were similar. This indicates that the primary tillage operations did not influence the stability of soil structure in alfalfa-beans sequence as much as the other sequences.

In all sequences, the results in soil physical conditions and navy beans growth and production were considerably increased by application of an organic amendment to the soil.

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