EFFECTS OF CROPPING INTENSITY ON SOIL ORGANIC MATTER AND AGGREGATE STABILITY

R. A. Bowman, R. L. Anderson, D. C. Nielsen,
M. F. Vigil, and A. D. Halvorson

ABSTRACT

Long-term conventional-till practices associated with winter wheat-fallow (WF) in the Central Great Plains have resulted in extensive soil erosion, soil organic matter (SOM) loss, and general decline in crop productivity. We can reverse this trend by intensifying the cropping system with three- and four-year rotations under reduced- or no-till practices. With time and proper fertilization, we produce and conserve more residue, increase SOM, build stable aggregates, reduce erosion, and increase our production potential. Studies at the Akron USDA-ARS Research Station have been conducted since 1990 to evaluate various tillage and cropping sequencings for greater productivity, acceptable soil and water quality, and economic viability. While the greatest differences in SOM come from spatial variability, there is a trend at this time for more SOM as cropping intensity increases, and as tillage intensity decreases. Changes from 1990 reflect about a 7% increase in SOM in the tillage depth (0-6 inches). An increase in non-erodible stable aggregates (>0.84 mm) at the 0-1 inch depth was also observed for reduced- and no-till treatments compared to the conventional WF. The challenge, therefore, is to select sequencings that not only produce good SOM and soil tilth, but also good yields, less pest interference, and long-term resource and economic sustainability.

INTRODUCTION

The conversion of Great Plains grasslands to clean-till small grain farmlands since the mid to late 19th century has resulted in significant losses of soil organic matter (Hass al., 1957; Bauer and Black, 1981; Bowman et al., 1990). These losses of SOM occurred primarily because of wind erosion from lack of sufficient surface crop residue, and because of decomposition of existing organic matter through increased aeration and soil contact from tillage. These processes result in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical, and biological properties such as rooting depth, water storage and soil aggregation. On a global basis, with about 40% more organic carbon residing in the SOM than in terrestrial plant biomass (Jenkinson, 1981), the conversion of grassland (high source of fixed organic carbon) to wheat-fallow (low organic carbon input) could create with time a significant increase in global carbon dioxide (CO_2). Conversely, management practices which increase net biomass production could reverse this trend, recapture CO_2 from the atmosphere, and provide additional monetary and soil stability benefits.

In the last few years many studies on cropping systems have been conducted in the Central Great Plains. Wood et al. (1990) reported on the impacts of cropping intensity on carbon and nitrogen changes at three different catenary sequences across a north-south available-water transect in eastern Colorado. Their studies primarily addressed changes in active SOM pools such as mineralizable C and N. These active fractions were directly related to cropping intensity, and to increased surface crop residue. Follett and Schimel (1989) studied microbial biomass changes as tillage intensity increased, and found a direct relationship between microbial biomass content and a decrease in tillage intensity.

Cropping intensity and sequencing have significant effects on soil structure or soil tilth (Elliott, 1986). Angers and Mehuys (1988) found significantly more water-stable aggregates under alfalfa than under corn after just two years. This binding of soil peds by some form of the organic matter or inorganic constituents to form stable aggregates is an important deterrent to soil loss by wind and water erosion, and is an important part of evaluating cropping sequencings.

Our overall objectives, therefore, were to evaluate different cropping and tillage systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, pest pressures and SOM buildup. Our studies include many more crops and combinations of sequencings than have been previously studied in the Great Plains. This paper reports on the changes in SOM from 1990, when plots were established, to 1995. Dry aggregate stability was also assessed on selected plots to determine potential for wind erosion.

MATERIALS AND METHODS

Plot studies were established in 1990 on a previously cropped (WF) Weld silt loam (Fine, montmorillonitic, mesic aridic Paleustolls) to determine, among other factors, the effects of different cropping intensities and tillage systems on SOM and on non-erodible stable aggregates. Twenty different rotation combinations (Table 1) were replicated three times on 30-foot by 100-foot plots. All phases of a rotation was present every year. Thus, 12 years (year 2002) is the earliest all cropping intensities can be compared together. Data before this time will not all be in sink, but can still be meaningful to show trends and significant changes.

Data on soil organic matter and nitrogen were collected (at least 4 cores from each plot) on selected adjacent plots at the 0-2 and 0-6 inch depths. Similarly, data for stable aggregates (>0.84 mm) were determined on the top 1 inch of soil profile. For tillage practices, CT (conventional tillage) generally involved 5 to 7 equipment passes during the fallow period; RT (reduced tillage), a combination of herbicides and 2 to 3 equipment passes; and NT (no tillage), a combination of residual and contact herbicides. Adequate N and P were applied for all crops. Management practices for these plots have been described in more detail by Halvorson et al. (1994). In 1990 soils were sampled in the spring and fall, and in 1995 in the spring for the SOM evaluation. Stable aggregate analyses were conducted on summer 1995 samples.

Soil organic matter (organic carbon and total nitrogen) was determined by C-N Analyzer and by dichromate digestion (Nelson and Sommers, 1982). No attempt was made to separate out small amounts of litter or particulate matter collected in the < 2.0 mm soil samples. Stable aggregates against wind erosion were determined by weight from air-dried field samples (1-inch depth) taken in two different areas of a treatment plot. No crushing or 2-mm prescreening was done to these samples. The two fractions retained on a 2-mm and a 850-micrometer (0.85 mm) screen after 5-minute shake on a mechanical shaker at its lowest power was deemed to represent the non-erodible fraction or stable aggregate. This fraction was used for comparative purposes among tillage treatments since the Chepil rotary sieve is the standard for assessing wind erosion fractions, and our mechanical shaking method still needs to be field calibrated against the rotary sieve (Chepil, 1952).

Comparisons were made by year (1990 versus 1995) for selected matched treatments. No 0-2 inch samples were collected in 1990, and not all treatment sites were sampled. Comparisons were also made by tillage (CT, RT, NT) and by cropping intensity (eg. 0.5 = W-F; 0.67 = W-C-F; 0.75 = W-C-M-F; 1.00 = W-C-M). Because of the large spatial variability, treatment comparisons for cropping intensities were assessed in blocks to obtain adjacent treatments with differing tillage and cropping intensity so spatial differences could be minimized.

Data were analyzed by analysis of variance for mean differences at the 0.05 significance level.

RESULTS AND DISCUSSION

The spatial variability in C and N across the 20-acre field is shown in Figure 1. Note that two adjacent blocks represent one replication of 60 different treatments. In 1993, the average for SOM for the 0-6 inch depth across the 3 replicates from east to west (bottom to top) was 1.42%, 1.16%, and 1.03%, respectively. The lowest value of all 180 treatments was 0.77 and the highest, 1.75%. This difference in SOM was caused primarily by wind erosion over time (even before the establishment of the plots) as evidenced by the shallow depth to lime (8 inches) on the north west corner (plot #180) versus the south east corner (22 inches near plot #1). Total N values reflected essentially the same trend as SOM, with C:N ratios from 8.0 to 11.5 depending upon the amount of inorganic N in the soil sample. Because cropping intensity varied from 0.5 to 1.0, N application varied accordingly. Thus, there were plots in 1993 where fertilizer N was applied only once (FWF), or all three years (WCM). Generally, the organic C to organic N ratio was about 9.5. Over the long term this C:N ratio reflects well the decomposition/residue input status of the soil, where lower values reflect greater tillage and longer fallow periods. Conversely, as cropping intensity increases and more residue is produced, C:N ratio widens. This 1993 data showed a spatial difference of about 35% between block replicates (60 treatments each), and over a 100-fold difference between the smallest and largest sample.

Before an assessment of changes in SOM resulting from tillage and cropping intensities was made, a direct comparison of same plots (treatments) was conducted for SOM content in 1990 and 1995. Since all plots were not sampled in 1990, 23 were selected across the three replications for comparison. The data (Fig. 2) showed an 8% increase in SOM in the top 6 inches over this 5-year period for these 23 sample sites. These samples represented a variety of cropping and tillage systems. Of the 23 sites, 18 showed higher values for 1995 compared to 1990, and 5 showed less. These differences ranged from 9% less to 14 % more SOM in 1995. Using a t-test, we found a significant difference at the 5% level. The total number of plot samples collected in 1990 was 48. The data showed that the starting SOM content for plots across the field was highly variable. For this reason blocking was introduced to obtain more closely the same starting values.

The comparison of tillage systems (Fig. 3) showed significant SOM differences (5% level) only at the 0-2 inch depth. Both the NT and RT treatments showed a 14% increase in SOM over the CT for this depth. However, when the assessment was made at the 0-6 inch depth, there was no significance from tillage. These comparisons were made with the 1995 data for the 0.05 cropping intensity level since higher cropping intensities (>0.5) contained no CT treatments. Even though there were no differences in SOM content at the 0-6 depth, the higher SOM and presumably, higher litter content of the surface 0-2 inches will probably positively influence water intake and erosion (Larsen et al., 1978), and consequently, yield potential with time. While a significant effect probably could have been obtained by comparing all RTs and NTs against the few CTs, this comparison is confounded by cropping intensity, and increases in SOM may be due mostly to more crops per time than to tillage systems.

With respect to cropping intensity, different tillage systems from the same block were assessed together if they contained the same number of crops per unit time (WCF-RT, WCF-NT; WMCF-RT, WMCF-NT). Thus, for the 0.5 cropping intensity, all CT, RT, and NT wheat-fallow treatments were assessed together. Intensities greater than 0.5 contained only RT and NT treatments. The data (Fig. 4) represented 0-2 and 0-6 inch depths aggregated around blocks to minimize non-treatment variability. Thus, while all treatments within the study were employed for tillage comparisons (all 18 of 180), the 0.5 cropping intensity (WF) was comprised of samples within adjacent blocks only. Data for the 0-2 inch varied from 1.72% SOM with 0.5 intensity to > 2.00% for the 0.75 and 1.00 cropping intensities. The WF systems contained significantly less SOM than those with greater cropping intensities. As stated before, this increase at the surface is significant for increase water infiltration and against erosion. At the 0-6 inch depth, SOM content ranged from 1.44% (0.5 cropping intensity) to 1.63% (1.00 cropping intensity), with the greater intensity rotations containing significantly more SOM in the 0-6 inch depth than the WF systems.

Stable aggregates were assessed with selected samples only (Fig. 5). The comparisons were made for tillage treatments only. The procedure is purely experimental at this time, and the data preliminary. . There is a trend for greater percentage of stable aggregates as tillage decreased. One conventional tillage plot sample (data not included in Fig. 5) where erosion was high (north west corner) contained a large percentage of aggregated materials. It is felt that this aggregation was derived primarily from calcium carbonate (mixing with shallow secondary lime), and not from SOM. The effect on wind erosion, regardless of source, would be the same, more stable aggregates and less erosion. Earlier data from western soils show significant correspondence between SOM content and stable aggregates (Kemper, 1966). This data also showed a large increase in percent aggregate stability as SOM increased from 1 to 2%. The stable aggregates are usually responsible for not only reduction in wind erosion, but also increased water infiltration.

Although these rotations are only 5 years old, some significant trends are developing. Decreasing the summer fallow through cropping intensification has resulted in a positive change in SOM. This increase in SOM could be interpreted as a combination of SOM increases from more residue, and decreases in losses from less erosion.

While management decisions for sequencings will never be made purely on the basis of SOM content, we hope to provide sufficient data and information from our research to show the benefits of increased residues, and residue management.

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Table 1. Grain and forage yields for crops grown in various rotations.

ROTATION	94 GRAIN YIELD Bu/A	94 FORAGE YIELD Lb/A	AVERAGE YIELD 92-94
1) Millet (M)-NT	31		32 Bu/A
2) ALFALFA		1019	1560
3) GRASS-NT		1318	1710
4) Silage Corn (SC)-Wheat (W)-NT		1.6Tn/A	2.1Tn/A
*W-SC-NT (OAT)		967	10 Bu/A
5) W-PEA-NT	18		25 Bu/A
**PEA-W-NT		717	39 Bu/A
6) Forage Millet (FM)-C-RT		973	2980 Lb/A
Corn (C)-FM-RT	20		31 Bu/A
7) W-F-CT	25		30 Bu/A
W-F-NT	28		40 Bu/A
W-F-RT	24		42 Bu/A
8) W-M-NT	14		23 Bu/A
M-W-NT	38		43 Bu/A
9) M-SUN-RT	21		33 Bu/A
SUN-M-RT	523Lb/A		850 Lb/A
10) C-SUN-RT	10		21 Bu/A
SUN-C-RT	537Lb/A		1115 Lb/A
11) C-M-NT	22		22 Bu/A
M-C-NT	28		34 Bu/A
12) W-C-F-NT	27		35 Bu/A
C-F-W-NT	30		51 Bu/A
13) W-C-F-RT	39		45 Bu/A
C-F-W-RT	47		51 Bu/A
14) M-W-C-NT	29		36 Bu/A
W-C-M-NT	22		15 Bu/A
C-M-W-NT	42		49 Bu/A
15) M-W-SAF-RT	0		17 Bu/A
W-SAF-M-RT	12		10 Bu/A
SAF-M-W-RT	488Lb/A		15 Bu/A
16) W-M-F-RT	26		38 Bu/A
M-F-W-RT	28		42 Bu/A
17) M-F-W-C-RT	28		35 Bu/A
W-C-M-F-RT	31		43 Bu/A
C-M-F-W-RT	31		42 Bu/A
18) C-F-W-M-NT	9		24 Bu/A
W-M-C-F-NT	31		39 Bu/A
M-C-F-W-NT	36		40 Bu/A
19) C-F-W-M-RT	18		18 Bu/A
W-M-C-F-RT	29		44 Bu/A
M-C-F-W-RT	36		44 Bu/A
20) SAF-F-W-C-RT	116Lb/A		20 Bu/A
W-C-SAF-F-RT	27		32 Bu/A
C-SAF-F-W-RT	31		34 Bu/A

* Wheat yields from 1992 and 1993, oat hay grown instead of wheat in 1994.
** Pea harvested for grain in 1992, 1993, and as hay in 1994.

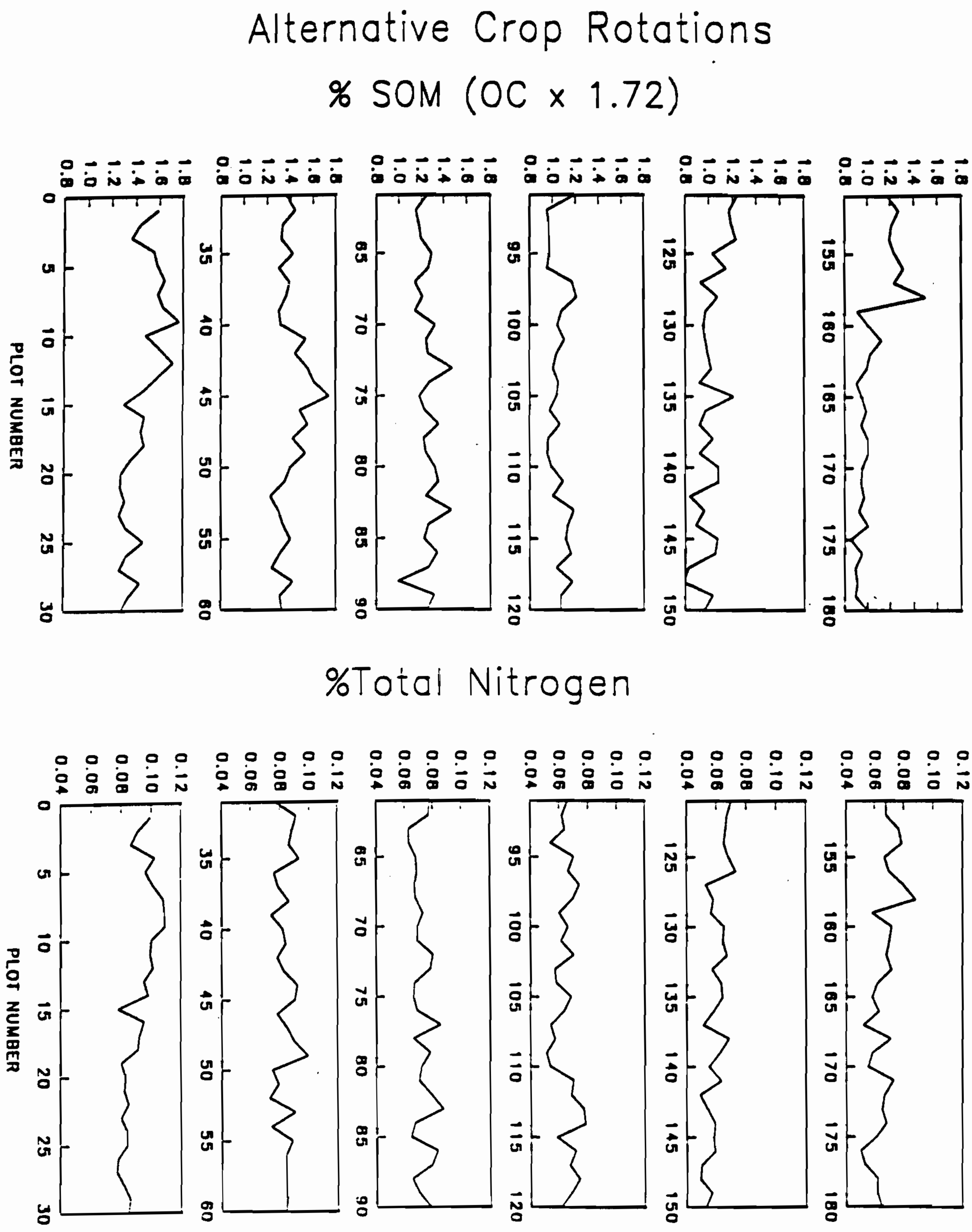

Fig. 1. Soil Organic Matter and Total N content across study site (Data 1993).

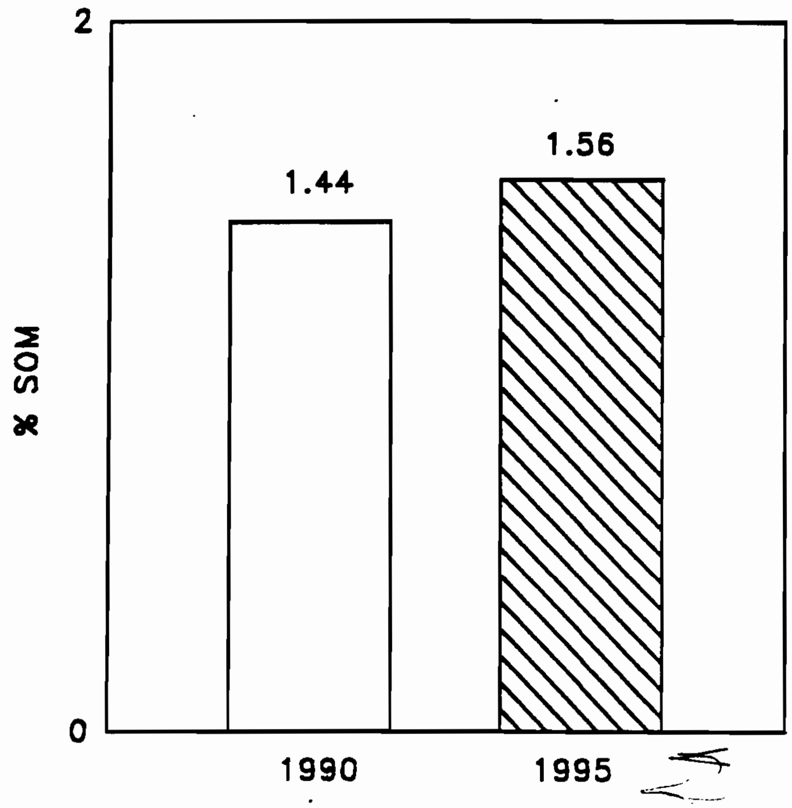

Fig. 2. Comparison of SOM for same plots for 1990 and 1995 (0–6").

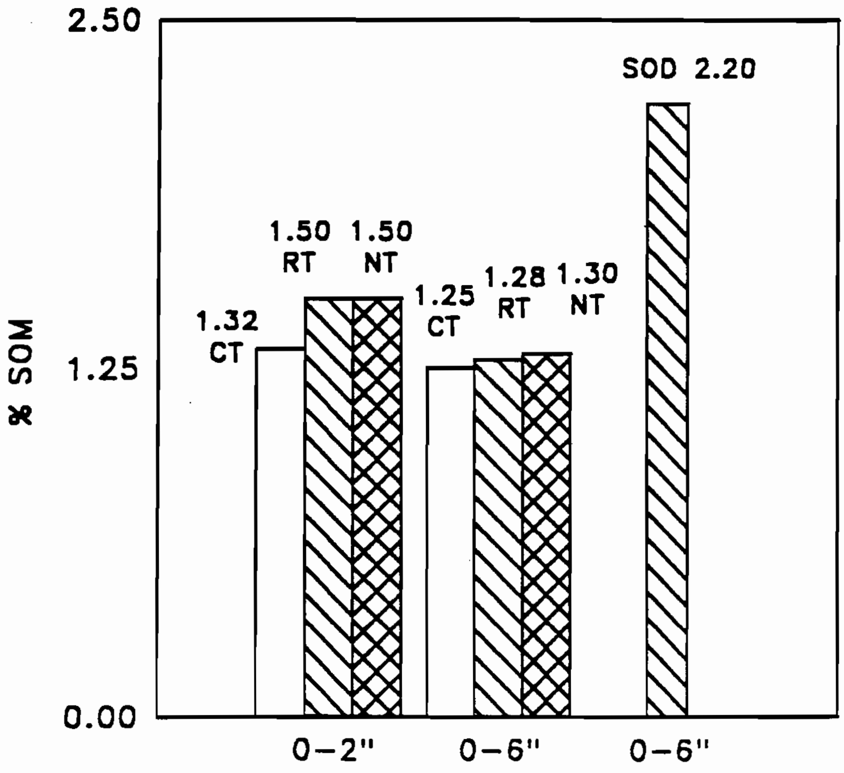

Fig. 3. SOM content among tillage systems.

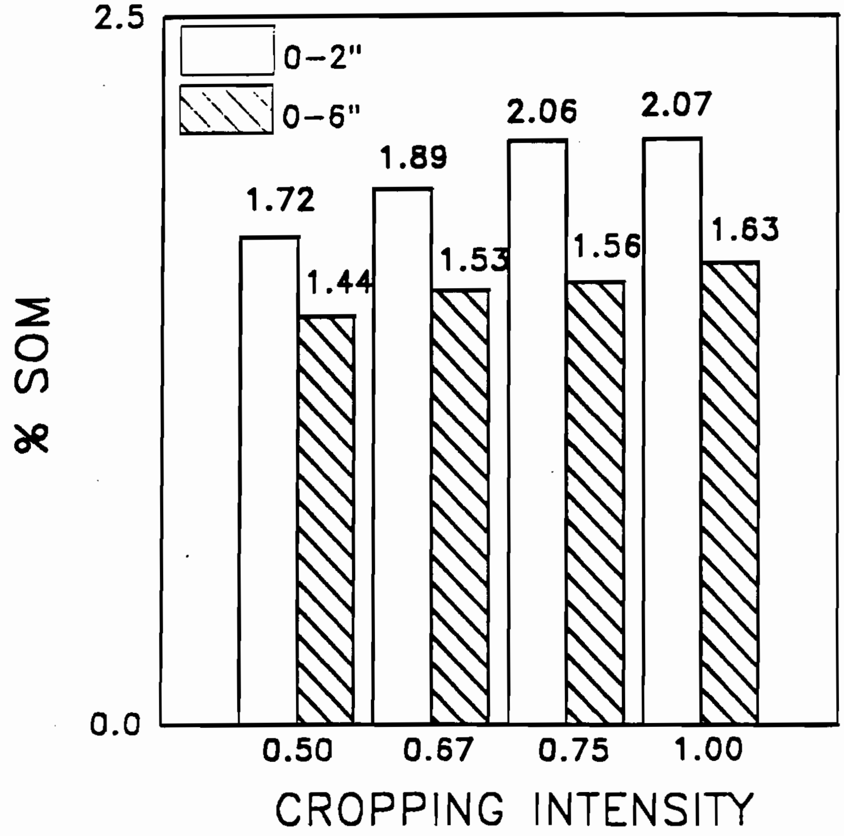

Fig. 4. SOM content as a function of cropping intensity.

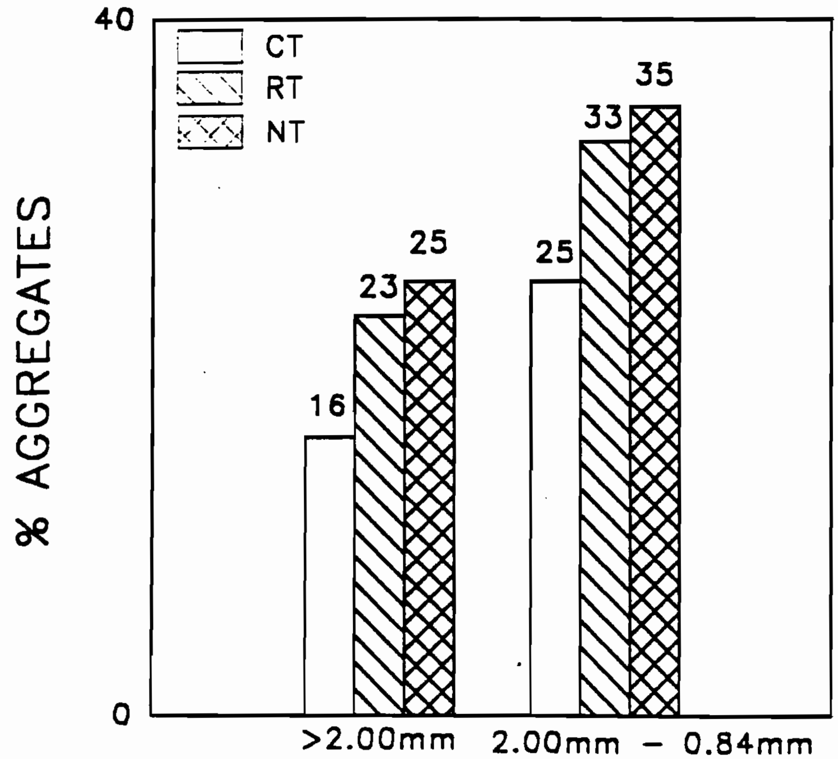

Fig. 5. Percent of total soil (0–1") retained on 2.0mm and 0.84mm screens.