DRYLAND SUNFLOWERS: EFFECTS ON SOIL ORGANIC MATTER AND EROSION

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ABSTRACT

Sunflower production has increased steadily over the last few years in the central Great Plains. This increase can be attributed to the presence of a processing plant in western Kansas, competitive profitability with other crops, and the advantages that a warm-season, broad-leaf crop provide in a winter wheat-summer fallow rotation. While much research has been done on fertility and water use, very little data exist on the role of sunflowers in a rotation relative to changes in soil quality. We conducted research on a Weld loam at the 0-2 and 0-6 inch depths on soil organic matter (SOM) changes (decomposition effects) and textural changes (erosion effects) in physically close plots (30 x 100 feet) of the same rotation length with and without sunflowers. Our data showed significantly lower concentrations of SOM at the 0-2 inch depth ($p = 0.05$) and 0-6 inch depth ($p = 0.10$) for plots with sunflowers versus those without sunflowers. The extra tillage for sunflowers for herbicide incorporation may have contributed to this decomposition of SOM. Data for soluble organic carbon, which is usually associated with stable aggregates, showed similar results. Results for texture at this time show a trend towards enrichment of sand for treatments in sunflowers. Surprisingly, no difference existed for particulate organic matter-carbon. The nature of the small plots and the confounding from snow catchment and flat residue removal by wind make it imperative that this research be extended to farmer-size fields where wheat-sunflower-fallow and wheat-corn-fallow treatments can be compared with the same soil series and climatic conditions.

INTRODUCTION

Sunflower production in the central Great Plains has increased steadily over the last several years (Lyon and Meyer, 1995). Many reasons have contributed to this dramatic increase. Its competitive profitability with other crops, and the installation of the Northern Sun processing plant in Goodland, Kansas, has made it possible for greater profits with easier marketing and transportation. The introduction of a warm-season, broad-leaf crop in a cereal-based cropping system has long been desirable as a hedge against increased weed infestation in a wheat-fallow system. The presence of a tap root may also in some instances alleviate surface compaction generated through long-term clean-tillage wheat-fallow. The need to scavenge "escaped nitrates" and water after harvesting shallow-rooted crops such as proso millet also provides another advantage for the deep-rooted sunflower crop.

Since much of the research and data for this crop was obtained in the Northern Plains where climatic conditions are cooler, frost periods longer, and where residues persist longer, we in the central Great Plains need to develop our own management data base on sunflower production for our soil types and climatic conditions. Investigations in western Kansas and eastern Colorado are beginning to address these questions (Nielsen, 1995; Lyon, 1995; Sunderman, 1995). One of our greatest concerns in the central Great Plains is the residue levels and available water at wheat planting after a sunflower-fallow sequence. Secondarily to this, is the effects of tillage which is invariably used to incorporate herbicides, on crop residue persistence, soil organic matter (SOM) decomposition and soil erosion.

The objective of this paper is to present and discuss preliminary data obtained at the USDA-ARS Akron Research Station on the effects of sunflowers on soil quality as measured by SOM and soil loss (erosion) changes among similar-length rotations in proximity with and without sunflowers.

MATERIALS AND METHODS

The research on appropriate rotations for the central Great Plains was started in 1990, and conducted on a Weld loam (fine, montmorillonitic, mesic, pachic Paleustolls) near Akron, Colorado (Table 1). The area receives an average of about 16.5 inches of precipitation with about 80% occurring from April to September. Site elevation is about 4600 feet. Open pan evaporation is about 53 inches, and frost-free period is about 120 days.

We used a randomized complete block design with three replications. Plot size for each treatment was 100 feet by 30 feet. The experimental design addressed rotation sequencing (cropping intensity) as its principal objective; thus, fertilization, weed control, tillage, etc., were conducted according to accepted practices, and research intent. A standard protocol for reduced-till required one or two mechanical tillages (sweeps only), and residual (extra tillage with sunflowers) and contact herbicides. For a more detailed account of these operations, please refer to Bowman and Halvorson (1997), Anderson et al., (1998), Halvorson et al., (1995). Suffice to say that all rotations with sunflowers used a reduced-tillage system even with the continuous cropping rotations like proso millet-sunflower (M-S) and wheat-sunflower-millet-pea (W-S-M-P) The continuous cropping equivalent without sunflowers (M-W) used no-till, but W-corn (C)-M-P used reduced-till. Invariably though, sunflowers required extra tillage because of herbicide incorporation which was not done in a comparable millet operation. So in two of the 12 comparisons tillage differed slightly.

The comparisons for SOM levels and erosion effects were conducted with selected rotations of the same length and within physical proximity to minimize soil spatial differences (Table 2). It was assumed that with other crops being equal in the rotation, and with changes occurring where sunflower was substituting for corn, millet, or wheat, a direct effect of sunflower on the rotation could be obtained.

Soil samples were taken in the spring of 1997 from the 0-2 and 0-6 inch depths for SOM changes, and for soil textural changes. Soil organic carbon and nitrogen were assessed with a C-N analyzer, and by chromic acid digestion (Heanes, 1984) and Kjeldahl digestion (Nelson and Sommers, 1986). Although an assessment of stable aggregates was not made, soluble organic carbon levels in the sunflower and no-sunflower plots were quantified. The particulate organic matter-carbon (POM-V) was also measured at the 0-2 inch depth in the matched plots (Gregorich and Ellert, 1993). Soil texture was done by the hydrometer method, and percent sand was also evaluated with the POM-C procedure which results in a combination of sand and SOM.

Statistical analyses included t-tests (p =0.10 and 0.05) for the means of the 12 matched pairs. Highest and lowest values, standard deviations, and coefficient of variations were also assessed.

RESULTS AND DISCUSSION

The native sod in comparison to these cultivated sites contained more SOM, clay, and higher CEC (Table 1). The Weld soil series, which is a dominant series in Washington County, is intermediate in fertility between our Rago and Platner series. Like most soil series in semiarid dryland, wheat-fallow systems, cultivation usually reduced the native soil organic matter content by 40 to 50 % (Bowman et al., 1990). In contrast, matched plots because of essentially the same types of management, did not differ in bulk density and pH. There was a tendency for low pH values for both pairs of treatments because of greater nitrogen fertilizer use relative to W-F. Because of soil spatial variability, the pairs were selected within one or two plots of each other. It was assumed that any significant differences from these same length rotations (Table 2) would come from the direct effects of sunflower on the soil properties. The authors recognize still that the relatively short time span and the size of the plots may present some misgivings relative to extrapolated field interpretations.

Twelve matched plots (Table 2) were compared at the 0-2 and 0-6 inch depths for SOM concentration, particulate organic matter-carbon content, soluble organic matter content, and soil particle size distribution. These specific measurements were made because data from preliminary observations have suggested, especially in the central Great Plains, that sunflowers in a rotation may cause loss in soil quality from greater erosion and SOM decline.

Results (Table 3) showed significantly lower concentrations ($p= 0.05$) in SOM at the 0-2 inch depth for the mean of the plots with sunflowers (1.5%) versus those plots without (1.7%). Data for N essentially paralleled that of SOM. Carbon to N rations were generally close to 10 since N values did not include nitrates. An evaluation of all 12 matched plots for SOM concentrations (data not shown) showed that 5 pairs were relatively close to the same values, but 7 from the sunflower plots had lower concentrations than the concentrations in the matched non-sunflower plots. Quite likely the one to two extra tillages in sunflowers to increase the herbicide effectiveness may have contributed to this decline by increasing soil residue/SOM contact and aeration. Minimum and maximum SOM concentrations were more a function of position in the landscape and spatial variability than of treatments. Rotations with greater cropping intensity, however, did show a trend towards greater SOM concentration in the surface 2 inches.

For the 0-6 inch depth this difference was only significant at the 0.1 level (1.42% for sunflower plots versus 1.55% for non-sunflower plots). Maximum and minimum values were much closer together than for the surface depth.

For the soluble organic carbon, results (Table 4) at the 0-2 inch and 0-6 inch depths showed significant differences at the $p = 0.1$ level. Values for both depths seemed to converge more than for the other soil measurements like SOM and N. Both depths showed about an equal increase in soluble carbon for plots without sunflowers. Usually the level of soluble organic carbon is positively correlated with greater soil aggregation (Angers et al., 1992) which can reduce erosion. Stable aggregates analyses have not been determined at this time, but will be conducted in the spring and summer of 1998 since analyses require air-dried soils without mechanical grinding and all 1997 soils have been ground.

The data for texture (Table 5) did show significant increases in the average percentage of sand at the $p = 0.1$ level for plots with sunflowers. This occurred primarily from large decreases in fines for sunflower plots for three of the 12 comparisons. The plots that showed large differences were the M-S versus the M-W, and two of the W-S-M-P vs the W-C-M-P plots. At this time these differences, or some of it, could have been due to initial spatial differences. If real, the data suggest that some erosion could be taking place, and that loss of SOM is from decomposition and some erosion. These results clearly underscore the need for more residue, and an herbicide requiring no tillage.

CONCLUSIONS

Data represent small field plots, and this should be considered in its interpretation. It does appear from these plots, though, that greater organic matter decomposition, and/or some erosion were occurring in plots with sunflowers, compared to similar rotations without sunflowers, especially at the 0-2 inch depth. The lower residue production with sunflowers (versus corn, for instance) may have also contributed to this difference in SOM. We need to increase the residue cover during the sunflower-fallow period, and minimize the tillage with herbicides, or obtain more effective no-till herbicides.

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Table 1. Selected physical and chemical characteristics of Weld loam for the 0-6 inch depth.

Soil	Sod	Cultivated
pH (0.01M CaCl2)	6.3	5.9
Db, g/cc	1.15	1.38
Soil Organic Matter (%)	1.70	1.34
Total N, (%)	0.09	0.07
NaHCO3-P (ug/g)	12	22
Silt (%)	20	16
Clay (%)	21	16
CEC, me/100g	16	13

Table 2. Comparison of equal length rotations in proximity with and without sunflowers.

No-Sunflower	Sunflower	Pairs
W-CORN-F (Reduced-Till)	W-SUNFLOWER-F (Reduced-Till)	1
W-MILLET-F (Reduced-Till)	W-SUNFLOWER-F (Reduced-Till)	1
WHEAT-M (No-Till)	SUNFLOWER-M (Reduced-Till)	2
W-CORN-M-Pea (Reduced-Till)	W-SUNFLOWER-M-Pea (Reduced-Till)	3
W-C-MILLET-F (Reduced-Till)	W-C-SUNFLOWER-F (Reduced-Till)	5

Table 3. Soil organic matter (SOM) and total Kjeldahl N (TKN) comparisons for the 0-2 and 0-6 inch depths for the 12 pairs.

Parameter	No-Sunflower	Sunflower	No-Sunflower	Sunflower
	----------------0 - 2"	----------------	----------------0 - 6"	----------------
SOM				
Mean (%)	1.70* *	1.50	1.55*	1.42
Std. Dev.	0.35	0.29	0.18	0.24
Min. (%)	1.12	0.96	0.97	0.87
Max (%)	2.25	1.87	1.76	1.76
TKN				
Mean (%)	0.11	0.090	0.091	0.084
Std. Dev.	0.03	0.03	0.02	0.02
Min. (%)	0.06	0.06	0.06	0.05
Max. (%)	0.13	0.11	0.10	0.10

* p = 0.10.
** p = 0.05

Table 4. Comparison of soluble organic carbon concentrations for the 0-2 and 0-6 inch depths for the 12 pairs.

	No-Sunflower	Sunflower	No-Sunflower	Sunflower
	----------------0 - 2"	----------------	----------------0 - 6"	----------------
Mean (mg/kg)	590*	547	559*	526
Std. Dev.	128	124	137	116
Coeff. Var. (%)	22	23	24	22
Max. (mg/kg)	751	690	765	659
Min. (mg/kg)	315	314	310	298

. * p = 0.10

Table 5. Textural changes and particulate organic matter-C changes at the 0-2 inch depth for plots with and without sunflowers.

	No-Sunflower	Sunflower
	---------------------------- 0 - 2 inch	------------------------------
Sand (%)	34*	38
Silt (%)	41	38
POM-C (%)	0.37	0.33

* p = 0.10