CARBON SEQUESTRATION In Dryland Soils and Plant Residue as Influenced by Tillage and Crop Rotation

U.M. Sainju,* A. Lenssen, T. Caesar, and J. Waddell
USDA-ARS, Sidney, MT

ABSTRACT

The effects of six years of tillage [conventional till (CT) and no-till (NT)], crop rotations [continuous spring wheat (CW), spring wheat-fallow (W-F), spring wheat-lentil (W-L), spring wheat-spring wheat-fallow (W-W-F), and spring wheat-pea-fallow (W-P-F)], and Conservation Reserves Program (CRP) was examined on total plant biomass (stems + leaves) returned to the soil, residue cover, amount, and C content, and soil organic C (SOC) and particulate organic C (POC) contents in Havre, MT. Total plant biomass was greater in CW than in other rotations. Residue cover was greater in NT than in CT and greater in CRP than in crop rotations. Residue amount and C content was greater in NT with CW than in other treatments, except in CT with CRP and W-F and in NT with CRP and W-W-F. The SOC at 0- to 5-cm depth was 23% greater in NT than in CT but POC was not influenced by tillage and crop rotation. From 1998 to 2003, SOC at 0- to 20-cm was decreased by 4% in CT but was increased by 3% in NT. Carbon can be sequestered in dryland soils and crop residue using reduced tillage and increased cropping intensity, such as NT with CW, compared with traditional practice, such as CT with W-F system, thereby helping to improve soil quality and productivity and reduce soil erosion.

INTRODUCTION

Conventional tillage and wheat-fallow system have resulted in 30 to 50% loss of its original soil organic C (SOC) level during the last 50 to 100 yr in drylands of Northern Great Plains (Haas et al., 1957; Peterson et al., 1998). While cultivation is done to prepare seedbeds for planting crops and controlling weeds, fallowing is done to increase water storage and production of succeeding crops (Eck and Jones, 1992; Jones and Popham, 1997). Intensive tillage increases the oxidation of SOC (Follet and Schimel, 1989) and fallowing increases its loss by reducing the amount of plant residue returned to the soil and exposing the soil surface to wind erosion (Halvorson et al., 2002; West and Post, 2002). Sustainable soil and crop management practices that reduce tillage intensity and increase the amount of crop residue returned to the soil are needed to conserve C in plant residue and soil and to sustain crop yields.


Conventional till soil


No-till soil


Residue collection


Landscape of the experimental site

OBJECTIVES

1. Examine the influence of tillage and crop rotation on total amount of plant residue returned to the soil from 1998 to 2003, and plant residue cover, amount, and C content in 2004 in Havre, MT.

2. Determine the effects of six years of tillage and crop rotation on SOC and particulate organic C (POC) at 0- to 5- and 5- to 20-cm depths.

3. Compare plant residue and soil C contents under crops and conservation reserves program (CRP).

MATERIALS and METHODS

Location: Havre, MT.

Tillage: Conventional tillage (CT) and no-till (NT).

Crop rotation: Continuous spring wheat (CW), spring wheat-fallow (W-F), spring wheat-lentil (W-L), spring wheat-pea-fallow (W-P-F), spring wheat-spring wheat-fallow (W-W-F), and conservation reserves program (CRP).

Design: Split-plot treatment with tillage as main factor and crop rotation as split-plot factor with three replications.

Crop planting: April to May. Harvest: July to August.

Plant biomass collection: 1 m^2 area within the plot in July and August 1998 to 2003.

Crop residue cover: USDA-NRCS point method in March 2004.

Crop residue amount: Five 0.09 m^2 areas within the plot.

Soil sample collection: Five 5 cm (i.d.) cores within the plot at 0- to 5- and 5- to 20-cm depths.

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RESULTS and DISCUSSION

Total biomass yield from 1998 to 2003 was greater in CW than in other crop rotations (Table 1). Similarly, residue cover was greater in NT than in CT and in CRP than in crop rotations. Although, biomass yield was not measured in CRP, increased amount of biomass residue returned to the soil increased residue cover.

Residue amount and C content were greater in CRP and W-F than in other rotations in CT but were greater in CRP and CW than in W-L and W-P-F in NT (Table 2). The difference in the rate of decomposition of biomass residue as influenced by tillage probably resulted in the variations in the amount of residue and C content between crop rotations in CT and NT. For example, residue amount and C content were lower in CW than in other rotations in CT but were higher in NT, although total amount of biomass returned to the soil was higher in CW than in other rotations.

The SOC content at 0- to 5-cm depth was 23% greater in NT than in CT (Table 3). The SOC at 5- to 20- and POC at 0- to 5- and 5- to 20-cm were not influenced by tillage and crop rotation. After 6 yr, SOC at 0- to 20-cm was increased by 3% in NT but was reduced by 4% in CT. With adoption of NT, about 100 kg C ha^{-1} yr^{-1} was sequestered in the drylands of Northern Great Plains. Considering that plant biomass residue contained 40% C, about 9% of residue C was sequestered as soil C after 6 yr.

CONCLUSIONS

1. Because of higher biomass production and reduced rate of decomposition, C can be conserved in plant residue and soil using NT with CW in drylands of Northern Great Plains. The conservation of C with these management practices can be similar to that under forages and grasses in CRP.

2. The rate of C sequestration using NT is estimated to be 100 kg ha^{-1} yr^{-1}.

3. Sequestering C will not only reduce soil erosion, but also improve soil quality and crop productivity and help to mitigate some of the deleterious effects of global warming.

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TABLES

Table 1. Total biomass (stems + leaves) yields of crops from 1998 to 2003 and crop residue cover in 2004.

Treatment	Total biomass yield	Residue cover
	Mg ha^{-1}	%
Tillage†		
CT	15.78a	43b
NT	17.04a	57a
Crop rotation‡		
CRP	---------	94a
CW	15.53a	60bc
W-F	10.63c	45cd
W-L	13.14b	69b
W-W-F	11.30c	50cd
W-P-F	11.39c	41d

† Tillage are CT, conventional tillage; and NT, no-till.
‡ Crop rotation are CRP, conservation reserves program; CW, continuous wheat; W-F, spring wheat-fallow; W-L, spring wheat-lentil; W-P-F, spring wheat-pea-fallow; and W-W-F, spring wheat-spring wheat-fallow.

Table 2. Crop residue amount and C content in 2004.

	Residue amount		C content	
Crop rotation†	CT‡	NT‡	CT	NT
	----------Mg ha^{-1}----------		----------kg ha^{-1}----------	
CRP	2.63	2.83	1112	1220
CW	0.44	2.47	149	963
W-F	2.01	1.60	830	647
W-L	0.22	1.43	73	585
W-W-F	1.07	2.32	411	906
W-P-F	0.67	1.39	262	544
LSD (0.10)	0.95		281	

† Crop rotation are CRP, conservation reserves program; CW, continuous wheat; W-F, spring wheat-fallow; W-L, spring wheat-lentil; W-P-F, spring wheat-pea-fallow; and W-W-F, spring wheat-spring wheat-fallow.
‡ Tillage are CT, conventional tillage; and NT, no-till.

Table 3. Soil organic C (SOC) and particulate organic C (POC) in 2004.

	SOC at depth (cm)			POC at depth (cm)		
Treatment	0-5	5-20	0-20	0-5	5-20	0-20
	---------------------Mg ha^{-1}---------------------					
Tillage†						
CT	5.2b	14.5a	19.7a	1.9a	4.7a	6.6a
NT	6.4a	14.7a	21.1a	2.2a	5.1a	7.3a
Crop rotation‡						
CRP	6.2a	14.9a	21.1a	2.1a	5.2a	7.3a
CW	6.0a	14.2a	20.2a	2.0a	4.8a	6.8a
W-F	5.5a	14.2a	19.7a	2.0a	4.7a	6.7a
W-L	6.0a	14.8a	20.8a	2.1a	4.9a	7.0a
W-W-F	6.0a	14.6a	19.6a	2.1a	5.0a	7.1a
W-P-F	5.7a	14.6a	20.4a	2.0a	5.0a	7.0a

† Tillage are CT, conventional tillage; and NT, no-till.
‡ Crop rotation are CRP, conservation reserves program; CW, continuous wheat; W-F, spring wheat-fallow; W-L, spring wheat-lentil; W-P-F, spring wheat-pea-fallow; and W-W-F, spring wheat-spring wheat-fallow.