Published March, 1990

Fallow Management Practices for Wheat Production in the Central Great Plains

D. E. Smika*

ABSTRACT

Information comparing reduced and no-till fallow management practices to conventional stubble mulch fallow for wheat production in a wheat-fallow rotation in the semiarid Central Great Plains is limited. A 12-yr study conducted at the Central Great Plains Research Station near Akron, CO evaluated the following seven soil management practices for their effectiveness for promoting soil water storage, reducing soil erosion potential, maintaining soil nutrient availability, and increasing winter wheat (*Triticum aestivum* L.) production and quality: (i) conventional stubble mulch tillage; three practices where weed control was achieved with herbicides except for (ii) one tillage operation performed as needed for weed control in early spring, (iii) immediately after harvest, and (iv) late fall (October); (v) chemical weed control except for one tillage after harvest and one tillage the following summer; (vi) chemical weed control with three tillage operations just prior to wheat seeding; (vii) and no-till, all weed control achieved with herbicides. Nitrogen fertilizer as urea-ammonium nitrate (UAN) was applied to all practices at the end of each fallow period at 56 kg ha^{-1}. The soil at the research site is a montmorillonitic, mesic Aridic Paleustoll. No-till consistently produced 10% more grain, had 9% higher soil water storage efficiency, and 7% fewer erodible-sized soil particles than conventional tillage. The NO_3–N availability was comparable for all practices. The reduced-tillage practices fell between the no-till and conventional tillage extremes and varied with year-to-year climatic differences.

FALLOWING SOIL for 9 to 14 months before seeding to store adequate soil water is a recognized practice in areas receiving 400 mm or less annual precipitation to ensure emergence and establishment of winter wheat (6,11). To achieve maximum soil water storage, all vegetative growth must be controlled during the fallow period. Tillage has been the standard means for controlling weeds, but unfortunately, promotes soil drying (4,8). The tillage implements commonly used in the Central Great Plains also affect the wind erosion potential of the soil by destroying residue (2) and influencing soil aggregation (9).

The development of herbicides to replace mechanical tillage for fallow weed control has improved water storage (3,5,11,12,14). This improvement is due to several factors, but include the capability to maintain standing residue (10), and minimize residue reduction during fallow (5,11). The adoption of no-tillage fallow has been slow due to several factors, including lack of acceptable labeled herbicides, cost of labeled herbicides, and lack of suitable equipment for seeding winter wheat into nontilled wheat stubble. Various reduced tillage fallow management practices have been adopted throughout the area which minimize the problems confronting no-till adoption. The basis for adoption of a reduced tillage fallow management practice currently being used varies with the operation. Five of the systems used in the area were included in this study to determine the effect of tillage time during fallow on (i) soil water storage, (ii) soil NO_3–N accumulation, (iii) soil aggregation, and (iv) subsequent winter wheat growth, development, and production. Comparison of the reduced tillage practices to conventional mechanical stubble mulch or no-tillage were made to identify a reduced tillage fallow management practice for the area.

MATERIALS AND METHODS

The study was conducted at the Central Great Plains Research Station near Akron, CO from 1975 to 1987. The soil of the study area is a Weld silt loam. The average annual precipitation of the area since 1950 is 393 mm and during the study period averaged 419 mm. Annual precipitation during the study period was considered average if the total amount was ± 50 mm of the long-time average. When precipitation deviated more than 50 mm from the long-term average, the year was considered wet or dry. Using these criteria, there were three dry years, four average years, and five wet years.

Treatments were initiated in 1975 in a winter wheat-fallow rotation and remained on the same plots for the duration of the study. There were offsetting phases of the rotation so that data could be collected on both phases each year. Practices are described in Table 1 and briefly were: (A) conventional stubble mulch, (B) one blade tillage in May or June, (C) one blade tillage after harvest, (D) one blade tillage in late April, (E) blade tillage after harvest and again the following June, (F) one blade tillage in June and rodweed tillages in July and August (this practice is the most widely used), and (G) no-tillage. All other weed control was with combinations of 9 to 10-month-residual plus contact herbicides, 90-d-residual herbicides, plus contact herbicides or contact herbicides alone. Tillage operations and herbicide applications were made only when needed for weed control, therefore, specific date varied from year to year. Also, specific herbicides and rates used varied with species and density of weeds present at the time of application.

Treatments were replicated four times in a randomized complete block design, with 11.0- by 30.5-m plots. Hard red winter wheat was seeded with a hoe drill in mid-September in rows 30 cm apart. All plots received 56 kg ha^{-1} of N as UAN broadcast prior to seeding.

Soil water was determined gravimetrically at the start of fallow (July) in late fall (November), late winter (February or early March), and at the end of fallow (September). Samples were taken from two locations per plot in 30-cm increments to a depth of 1.8 m (except the last 3 yr when the sampling depth was 3.3 m). Soil samples for NO_3–N determination were collected in the same increments at the end of fallow. Soil NO_3–N was determined by a Cd reduction autoanalyzer method (13). Soil aggregate size distribution was determined by the technique described by Chepil (1) on samples collected from the surface 5 cm of soil immediately following seeding of the wheat. Crop water use was defined as the difference in soil water content from seeding to harvest, plus growing-period precipitation.

An initial stand determination was made between emergence and tillering. The number of tillers per plant was determined at heading by counting the stems in 2 m of a row in two locations per plot divided by the initial stand determination for the plot. At maturity, the number of heads per

---

Central Great Plains Res. Stn., P.O. Box 400, Akron, CO 80720. Contribution from Northern Plains Area, USDA-ARS. Received 15 June 1988. *Corresponding author.

Published in Agron. J. 82:319–323 (1990).

Table 1. Time of events for seven fallow practice treatments used in a 12-yr study at the Central Great Plains Research Station, Akron, CO.

Treatment (Harvest) July		Time during fallow						
		September	October	April	May	June	July	August
		Event						
A	Blade tillage	Blade tillage			Blade tillage	Rodweeder		
B	9–10 month residual + contact herbicide			Blade tillage	90-d residual		Contact herbicide	
C	Blade tillage + 9–10 month residual herbicide				90-d residual		Contact herbicide	
D	90-d residual + contact herbicide		Blade tillage	90-day residual contact + herbicide		Contact herbicide		
E	Blade tillage + 9–10 month residual herbicide					Blade or rodweed tillage	60-d residual + contact herbicide	Contact herbicide
F	9–10 month residual + contact herbicide						Blade or rodweed tillage as needed	
G	9–10 month residual + contact herbicide				90-d residual herbicide		Contact herbicide	

plant, the number of kernels per head, weight per kernel, test weight, grain protein and grain and straw production were determined. The number of heads per plant were determined by counting heads in 2 m of row in two locations per plot and dividing by the initial stand determination for the plot. The number of kernels per head were determined by hand threshing each of 100 heads randomly selected within each plot and counting the number of kernels in each head. The weight per kernel was determined by weighing the kernels from each head and dividing by the number of kernels present. Test weight was determined using standard test weight procedures. Grain yield was determined by combine harvesting an area 3.7 by 23.2 m in the middle of each plot. Straw production was determined by removing and weighing all plant material from a 2.2-m^2 area in two locations of each plot and subtracting the weight of grain calculated from the grain yield determination. Grain protein was determined by multiplying total N in grain by 5.7.

Analysis of variance was completed by year and combined over years to determine a year by treatment interaction. Each treatment was compared to the conventional tillage treatment (A) with an LSD at $P < 0.05$.

RESULTS AND DISCUSSION

Soil water storage during fallow and precipitation storage efficiency were higher with no-tillage than with conventional tillage (Table 2). While storage efficiency values are high, they do not reflect the complete picture. As this study progressed, there was increasing evidence that the wheat crop was not using all of the water stored deep in the soil profile. Therefore, soil sampling was extended to 3.3 m in the conventional (A), no-till (G), and one reduced tillage practice (F) during the last 3 yr of the study (Fig. 1). Since part of the difference in soil water content below the 1.8-m depth was created before deep sampling was initiated, conclusions regarding differences between practices are difficult to make.

Table 2. Fallow period soil water storage to 1.8 m depth, precipitation storage efficiency, crop water use, and production efficiency (12-yr average) as influenced by fallow management practice, Akron, CO.

Fallow management practice†						
A	B	C	D	E	F	G
Fallow water storage, mm						
212	240	242	244	248	228	256*
Precipitation storage efficiency (%)						
40.8	46.2	46.3	46.7	47.6*	43.5	49.2*
Crop water use, mm						
464	483	484	490	488	483	471
Production efficiency (kg dry matter ha^{-1} mm^{-1})						
15.2	16.4	16.1	15.9	15.8	16.6	17.6

* Significantly different from conventional tillage, Practice A. ($P < 0.05$)
† Practices A through G defined in Table 1.

Data from the deeper sampling definitely shows no-tillage allowed deeper water percolation than the conventional and reduced tillage practices. During these 3 yr, precipitation storage efficiencies in the 3.3-m soil depth were 38.9, 46.7 and 54.3% for the conventional, reduced, and no-tillage practices, respectively. A significant practice-by-year interaction was found, indicating that yearly variation in precipitation distribu-

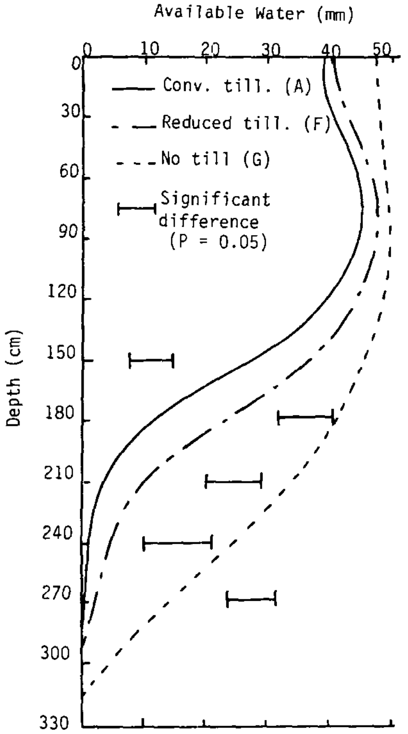

Fig. 1. Average available soil water at seeding to 3.3 m during last 3 yr under conventional, reduced, and no-till fallow management.

Table 3. Grain production, straw production, test weight, and grain protein content as influenced by fallow management practice, Akron, CO.

Fallow management practice†						
A	B	C	D	E	F	G
Grain yield, kg ha^{-1}						
2840	2910	2920	2940	2970	2980	3230*
Straw production, kg ha^{-1}						
4190	5030	4890	4860	4740	5050	5050*
Test weight, kg m^{-3}						
754	758	751	758	756	756	758
Grain protein, g kg^{-1}						
122	125	127	119	122	124	126

* Significantly different from conventional tillage, Practice A. ($P < 0.05$).
† Practices A through G defined in Table 1.

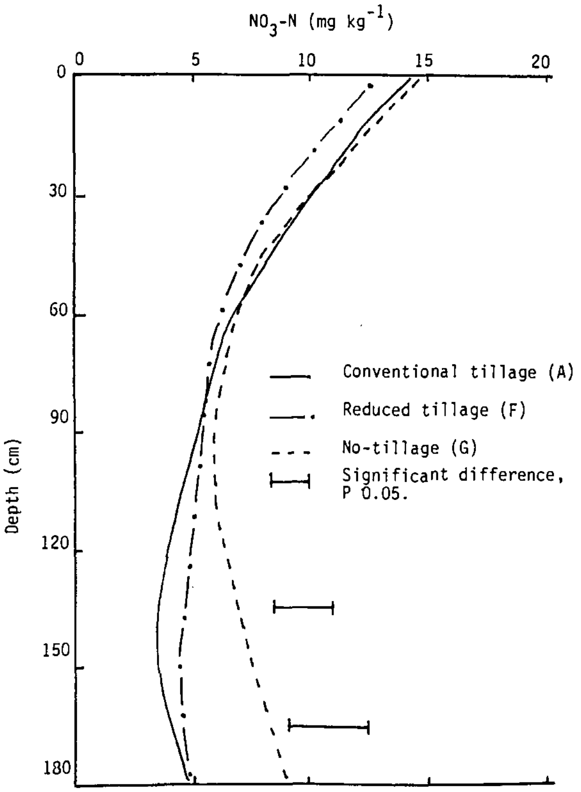

Fig. 3. Average profile distribution of NO_3–N to 1.8 m at seeding for three fallow management practices from 1975 to 1987.

tion and amount influenced soil water storage within individual treatments.

There was a difference in total water storage between conventional tillage and no-tillage, but neither practice was favored by dry, average or wet year. While there was no consistent change in water storage in any of the reduced tillage practices, water storage in Fallow Practices C and D (tillage immediately after harvest and in late fall after harvest, respectively) tended to be better in average or wet years than in dry years.

Total soil nitrate accumulation during fallow varied between practices as the study progressed with time. Nitrate-N accumulation during fallow for all reduced tillage practices was similar in all years, therefore only the data from Practice (F) is presented as representative of all reduced tillage practices. Early in the study the no-tillage practice had less NO_3–N at the end of fallow than the conventional tillage practice (Fig. 2). As the study progressed this pattern changed and, during the last 7 yr, NO_3–N accumulation during fallow was greater with no-tillage than for any of the other practices. However, the difference was significant in only 3 yr. This phenomenon was reported in Nebraska (7) and clearly indicates that time must be allowed for equilibrium conditions to be established when soil management practices are changed. While there was no significant difference in nitrate accumulation during fallow to a depth of 120 cm, there was significantly more nitrate in the soil below 120 cm with no-tillage than with the other practices (Fig. 3). This is probably due to greater accumulation and movement of soil water below 120 cm.

Grain production increased as tillage decreased (Table 3). Production from the reduced tillage practices

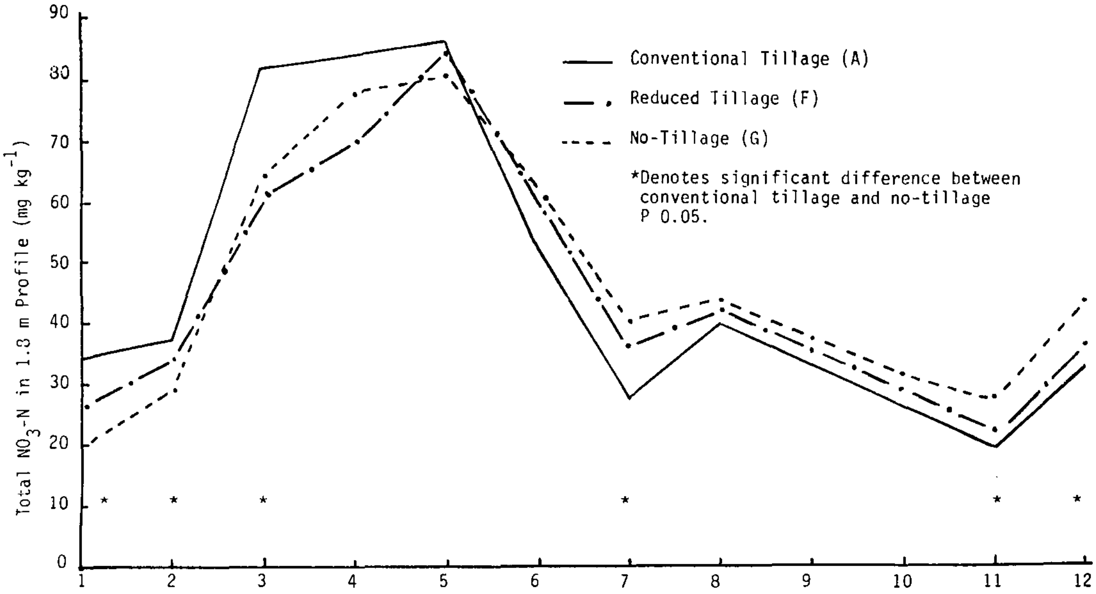

Fig. 2. Total nitrate accumulation to 1.8 m with conventional, reduced and no-tillage fallow for each year from 1975 to 1987.

Table 4. Plant number per unit area, tillers per plant at heading, kernels per head, weight per kernel, tiller producing heads and heads per unit area as influenced by fallow management practice, Akron, CO.

Fallow management practice†						
A	B	C	D	E	F	G
			Plants, no. m^{-2}			
43.0	42.7	43.4	43.2	43.7	43.6	44.6*
			Tillers, no. $plant^{-1}$			
8.4	8.6	8.6	8.5	8.4	8.4	8.5
			Kernels, no. $head^{-1}$			
32.2	32.5	31.3	32.9	32.9	32.4	33.2
			Kernel weight, mg			
30.9	30.5	30.6	30.1	30.3	30.0	30.7
			Head producing tillers, %			
79.7	84.9	84.1	84.7	85.9*	86.0*	85.5*
			Heads, no. m^{-2}			
288	312*	314*	311*	315*	315*	324*

*Significantly different from conventional tillage, Practice A. ($P < 0.05$).
† Practices A through G defined in Table 1.

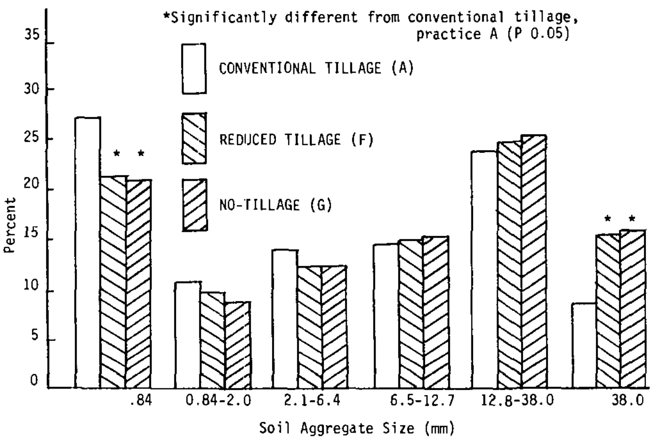

Fig. 4. Soil aggregate distribution in surface 5 cm of soil as influenced by fallow management practice in Akron, CO.

indicates that, in the long term, all reduced tillage practices will perform similarly when receiving a high level of management. Straw production did not reflect any influence of fallow management (Table 3). This would be expected because straw production occurs first and grain yield varies with available water. Test weight of the grain was also not affected by fallow management. Grain protein was also not influenced by fallow management practice, primarily because sufficient N was applied to minimize differences in available NO_3-N between practices.

Fallow management practice did not effect the number of plants per unit area, number of tillers per plant, number of kernels per head or weight per kernel (Table 4). However the number of tillers that produced heads and the number of heads per unit area were significantly greater with reduced and no-till fallow management practices compared to the conventional tillage management practice (Table 4). This increase in tiller survival and larger number of heads is attributed to the more favorable soil water conditions in the reduced and no-tillage fallow management practices compared to the conventional tillage fallow management practice.

Crop water use was not significantly affected by fallow management practice ($P = 0.05$), but there was a trend towards greater water use with reduced- and no-tillage practices (Table 4). Production efficiency (total dry matter production per unit area per mm of water used to a depth of 180 cm), however, was significantly greater with no-tillage fallow management compared to the conventional tillage. This is a direct reflection of the higher grain production from no-till compared to conventional tillage.

While soil aggregation alone is seldom the only factor in minimizing the potential of a soil for erosion, soil aggregate size distribution does contribute to the resistance of a soil to erosion by wind (15). During this study, fallow management practice significantly influenced the percent of soil aggregates in the erodible fraction, <0.84 mm. There was about 5% more erodible aggregates in the conventional tillage fallow management than in any of the reduced and no-tillage management practices (Fig. 4). Since all reduced tillage management practices produced similar results, only the data for Practice F are shown. Conventional tillage fallow management has also had an average of 7% fewer aggregates >38 mm than the other fallow management practices. Though not significant at $P = 0.05$, there was also a trend towards a higher percent of aggregates in the two aggregate size classes just above the erodible size (<0.84 mm) with conventional tillage. This implies there is a potential for an even greater percent of erodible sized aggregates with conventional than with reduced or no-tillage.

While precipitation was above average for the duration of the study, extreme variation occurred, ranging from 264 to 535 mm. Of importance was that, regardless of precipitation level the trend toward better water use, more crop production, and less erodible soil aggregates was always with the reduced and no-tillage fallow management practices. With this consistency, adoption of reduced and no-till fallow practices is feasible with high management. However, there is indication that, with good management, the wheat crop should be followed by a spring-seeded crop when precipitation is favorable. This would minimize or eliminate water accumulation in the deeper depths of the soil profile. Research at the Central Great Plains Research Station has shown that corn (*Zea mays* L.), grain sorghum (*Sorghum bicolor* (L.) Moench), safflower (*Carthanus tinctorius* L.) or millet (*Panicum miliaceum* L.) can be grown successfully the year following winter wheat harvest when no-till practices are used.

REFERENCES

1. Chepil, W.S. 1962. A compact rotary sieve and the importance of drying sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4–6.
2. Fenster, C.R. 1960. Stubble mulching with various types of machinery. Soil Sci. Soc. Am. Proc. 24:518–523.
3. Fenster, C.R., and G.A. Peterson. 1979. Effect of no-tillage fallow as compared to conventional tillage in a wheat-fallow system. Nebr. Agric. Exp. Stn. Res. Bull. 289.
4. Good, L.G., and D.E. Smika. 1978. Chemical fallow for soil and water conservation in the Great Plains. J. Soil Water Con-

serv. 33:89–90.

5. Greb, B.W. 1983. Water conservation: Central Great Plains. *In* H.E. Dregne and W.O. Willis (ed.) Dryland agriculture. Agronomy 23:57–72.
6. Hinze, G.O., and D.E. Smika. 1983. Cropping practices: Central Great Plains. *In* H.D. Dregne and W.O. Willis (ed.) Dryland agriculture. Agronomy 23:287–394.
7. Lamb, J.A., G.A. Peterson, and C.R. Fenster. 1985. Fallow nitrate accumulation in a wheat-fallow rotation as affected by tillage system. Soil Sci. Soc. Am. J. 49:1441–1446.
8. Smika, D.E. 1976. Seed zone soil water conditions with reduced tillage in the semiarid Central Great Plains. p. 37.1–37.6. *In* W. Johansson (ed.) Proc. 7th Conf. Int. Soil Tillage Res., Uppsala, Sweden. 13–18 June 1976. Inst. Markvdaskap, Landbrackets & Hydrotekuik, Uppsala, Sweden.
9. Smika, D.E. 1979. Nonerodible soil aggregated in surface soil as related to tillage practice. p. 147–152. *In* P. Kahnt (ed.) Proc. 8th Conf. Int. Soil Tillage Res. Org., Stuttgart, Germany. 9–12 Sept. 1979. Univ. Hahenheim, Stuttgart, Germany.
10. Smika, D.E. 1983. Soil water change as related to position of wheat straw mulch on the soil surface. Soil Sci. Soc. Am. J. 47:988–991.
11. Smika, D.E., and P.W. Unger. 1986. Effect of surface residues on soil water storage. p. 11–138. *In* B.A. Stewart (ed.) Advances in soil science, Vol. 5. Springer-Verlag, Inc. New York.
12. Smika, D.E., and G.A. Wicks. 1968. Soil water storage during fallow in the Central Great Plains as influenced by tillage and herbicide treatments. Soil Sci. Soc. Am. Proc. 32:591–595.
13. Technicon Industrial Systems. 1973. Nitrate and nitrite in water and wastewater. Industrial method 100-70W. Technicon Industrial Systems, Tarrington, NY.
14. Wicks, G.A., and D.E. Smika. 1973. Chemical fallow in a winter wheat-fallow rotation. Weed Sci. 21:97–102.
15. Woodruff, N.P., Leon Lyles, F.H. Siddoway, and D.W. Fryrear. 1977. How to control wind erosion. USDA-ARS Agric. Info. Bull. 354. U.S. Gov. Print. Office, Washington, DC.