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Cultural Strategies Reduce Weed Densities in Summer Annual Crops[1]

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Abstract: Producers in the central Great Plains are seeking alternative strategies to manage weeds because of herbicide resistance, narrow profit margins, and a lack of registered herbicides in some crops. Thus, we evaluated the impact of cultural systems in winter wheat and tillage on weed dynamics in corn, sunflower, and proso millet planted the year following wheat harvest. Weed seedling densities were 25 to 30% lower in a no-till system compared with minimum-till with a sweep plow. With no-till, cultural systems that produced more crop residue reduced weed densities an additional 15 to 30%, compared with the conventional system. Cultural system effect was eliminated in dry years and by tillage. Weed biomass was 10-fold less in proso millet than in corn. Crop residue management, critical for successful cropping in semiarid regions, also will help weed management by reducing weed density in summer annual crops, especially in no-till systems.

Nomenclature: Corn, *Zea mays* L.; proso millet, *Panicum miliaceum* L.; sunflower, *Helianthus annuus* L.; winter wheat, *Triticum aestivum* L., 'TAM 107,' 'Lamar.'

Additional index words: Crop residue, preventive strategies, systems approach, tillage.

INTRODUCTION

Producers in the central Great Plains are changing their crop rotations because of minimum- and no-till systems (Peterson et al. 1996). Instead of winter wheat–fallow, producers include summer crops such as corn, proso millet, or sunflower in rotation with winter wheat. Land productivity can be doubled with alternative rotations (Anderson et al. 1999), which improves net returns (Dhuyvetter et al. 1996) and long-term sustainability of soil (Peterson et al. 1993).

As producers develop weed management systems for these new rotations, they are faced with three major concerns. First, herbicide-resistant weeds such as kochia [*Kochia scoparia* (L.) Schrad.] and Russian thistle (*Salsola iberica* Sennen & Pau) are now common (Lyon et al. 1996). Especially alarming is resistance to herbicides that inhibit the acetolactate synthase enzyme, because these herbicides are currently used in winter wheat, corn, and proso millet.

Secondly, producers operate within a narrow profit margin because grain yields in this semiarid region are relatively low (Anderson et al. 1999); thus, economic restrictions often limit herbicide choices. A third concern is that some crops, such as proso millet, have few herbicides registered for in-crop use because of their limited hectarage.

Scientists are exploring herbicide options to address these concerns; however, producers question whether these concerns can by solved by focusing so strongly on herbicides (Radosevich and Ghersa 1992). An alternative approach is to devise strategies that improve the inherent strengths of a cropping system and subsequently minimize weed populations (Holtzer et al. 1996; Lewis et al. 1997); this approach emphasizes weed prevention (Jordan 1996). For example, semiarid rotations can be designed to minimize weed interference; weed biomass is reduced fourfold by growing two summer crops in 4 yr compared to two summer crops in 3 yr (Anderson 1998b).

A second promising strategy for weed prevention is crop residue management. Crop residue can suppress weed emergence (Teasdale et al. 1991) by reducing light penetration and soil temperature fluctuations (Teasdale and Mohler 1993). This suppression is related to residue quantity, with 3,000 kg/ha being the minimum quantity needed for suppression (Crutchfield et al. 1986; Vander Vorst et al. 1983).

Winter wheat cultivars commonly grown in the central Great Plains usually produce between 4,000 and 4,500 kg crop residue/ha (Smika 1990). Over winter, 30% of wheat residue decomposes (Stott et al. 1990; Tanaka 1986); thus, residue quantities are usually near or below the 3,000-kg/ha threshold when planting summer crops the next year. However, cultural systems in winter wheat, designed to minimize jointed goatgrass (*Aegilops cylindrica* Host) and feral rye (*Secale* spp.) seed production

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(Anderson 1997), can produce > 6,000 kg/ha crop residue (R. L. Anderson, unpublished data). Thus, cultural systems may enable producers to suppress weeds with crop residue.

Maintaining crop residue on the soil surface is critical for semiarid crop production because it improves water use efficiency and crop yield (Peterson et al. 1996). To conserve surface residue, producers rely on two tillage systems, minimum-till (with a sweep plow) or no-till. The sweep plow consists of V-shaped blades that sever plant roots with low soil disturbance at a tillage depth of 5 to 8 cm; each operation buries only 10 to 15% of crop residue, in contrast to 60 to 75% residue burial with a tandem-disk harrow (Good and Smika 1978). A disadvantage of the sweep plow, compared to no-till, is that shallow tillage may increase weed seedling emergence by burying weed seeds (Anderson 1998a; Egley 1986).

Our goal at the Central Great Plains Research Station is to develop ecologically based cropping systems that emphasize the systems' inherent strengths. To achieve this goal, we are examining the effect of cultural strategies on weed dynamics during various segments of alternative cropping systems. We hypothesized that cultural systems in winter wheat, designed to control winter annual grass weeds (Anderson 1997), also would reduce weed densities in summer crops planted the next year. To test this hypothesis, we monitored weed seedling densities in corn, sunflower, and proso millet as affected by cultural systems in winter wheat. We also compared the two prevalent tillage systems, minimum-till and no-till, for impact on weed emergence.

MATERIALS AND METHODS

Site Description. The study was conducted from 1994 to 1998 near Akron, CO. The long-term yearly precipitation is 419 mm; average precipitation during the summer growing season (May–September) is 290 mm. Average air temperature during the growing season is 18.9 C and ranges from 13.5 C in May to 22.9 C in July. Soil was a Platner loam (Aridic Paleustoll). In all years, study sites were initiated in the fallow phase of a winter wheat–corn–fallow rotation and were located in different areas of the field.

Cultural Production Systems in Winter Wheat. Three production systems were established during September 1994, 1995, and 1996: (1) the prevalent system for this region: 'TAM 107,' a semidwarf cultivar, planted at 45 kg/ha in 30-cm rows with 66 kg N/ha applied broadcast 2 wk before planting (designated as System A); (2) TAM 107 planted at 73 kg/ha in 18-cm rows with 50 kg N/ha applied broadcast 5 mo before planting followed by 16 kg N/ha placed in a band on the soil surface, above the wheat row (System B); and (3) 'Lamar,' a tall cultivar, planted at 73 kg/ha in 30-cm rows with 66 kg N/ha applied broadcast 5 mo before planting (System C). Design of Systems B and C was guided by previous research on cultural systems in winter wheat for winter annual grass control (Anderson 1997). Nitrogen fertilizer formulation was ammonium nitrate.

Table 1. Cultural practices for establishing corn, proso millet, and sunflower at Akron, CO.

Cultural data	Corn	Proso millet	Sunflower
Cultivar	Pioneer 3732	Sunup	Triumph 546
Planting date range	May 3–12	June 5–12	June 1–5
Seeding rate (seeds/ha)	37,600	2 million	39,500
Row spacing (cm)	76	20	76
Nitrogen rate (kg/ha)	65	35	45

Tillage Treatments After Wheat Harvest. Two tillage treatments (no-till and minimum-till) were initiated within 3 d after wheat harvest each year. Glyphosate [*N*-(phosphonomethyl)glycine] at 0.56 kg ai/ha controlled weeds in the no-till system, whereas a sweep plow with 76-cm blades controlled weeds in minimum-till. Three operations of either tilling or spraying, two in the fall after wheat harvest and one before planting the summer annual crops the next year, occurred in each system.

Summer Annual Crop Production Practices. Corn, sunflower, and proso millet were established with conventional practices (Table 1) in the stubble of cultural production systems in 1996, 1997, and 1998. Nitrogen as ammonium nitrate was applied broadcast before planting of all crops. The last operation (tillage or herbicide) in each tillage system eliminated weeds present at planting; weeds that emerged after planting were not controlled.

Experimental Design. Cultural wheat production systems were arranged in a randomized complete block design with four replications. Each cultural system treatment was split by the three summer crops, with the crops randomized within each cultural system plot. Plot size for cultural systems was 15 by 20 m, with split plots for summer crops being 5 by 20 m. Each replication was split by tillage in a split-block design, with tillage perpendicular to summer crop alignment. Tillage plots were 10 by 45 m.

Weed Seedling Density and Biomass Measurements. Four 0.33-m² permanent quadrats were randomly estab-

Table 2. Weekly precipitation during the weed emergence period for corn, sunflower and proso millet in 1996, 1997, and 1998 and the long-term average at Akron, CO.

Week (ending date)	1996	1997	1998	91-yr average
	mm			
May 5	2	5	0	14
May 12	21	0	10	13
May 19	1	0	1	17
May 26	61	44	8	18
June 2	31	21	1	23
June 9	2	20	3	21
June 16	34	8	0	16
June 23	12	2	6	12
June 30	16	39	0	10
July 7	29	2	21	14
July 14	18	2	12	15
July 21	1	7	16	17
July 28	17	13	31	16
Total	245	163	109	206

lished in both tillage subplots of each summer annual crop. Weed seedling emergence was recorded weekly, starting 1 wk after planting and continuing for 8 wk in corn and sunflower and for 6 wk in proso millet. The interval of seedling assessment was determined by the critical weed interference period for each crop (Zimdahl 1980). After counting, seedlings were pulled and removed.

Predominant weed species observed in all crops were kochia #[3] KCHSC; Russian thistle # SASKR; green foxtail, [*Setaria viridis* (L.) Beauv. # SETVI]; witchgrass, (*Panicum capillare* L. # PANCA); and redroot pigweed (*Amaranthus retroflexus* L. # AMARE). Sources of weed seeds were the indigenous soil seedbank, plus seeds of kochia, Russian thistle, green foxtail, and redroot pigweed spread on the soil surface in November after winter wheat planting in each year. Broadcast rate for each weed species was 200 live seeds/m^2, based on germination tests.

After the last emergence assessment for each crop, weed biomass from an additional set of randomly placed 0.33-m^2 quadrats, four in each tillage system, was collected. Samples were oven dried at 56 C for 48 h, then dry weights were determined.

Data Analyses. Weed seedling density and biomass data were averaged across subsamples and converted to seedlings or grams per square meter. Treatment effects were similar with individual weed species and weed community emergence; thus, only community data are presented. Initial ANOVA indicated that a four-way interaction

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds,* Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence KS 66044-8897.

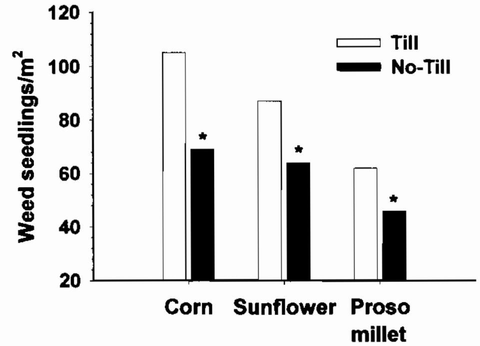

Figure 1. Tillage effect on weed densities in corn, sunflower, and proso millet. Means were averaged across cultural systems and years. An asterisk indicates that means within a crop differed, as determined with LSD.

occurred among cultural systems, crop, tillage, and year. Therefore, we analyzed cultural systems by tillage by year for each crop because of different planting dates and data collection intervals among crops. If interactions did not occur among factors for a crop, data were pooled across factors. Treatment means were compared with either least significant differences (LSD) or Duncan's new multiple range test at the 0.05 level of probability.

RESULTS AND DISCUSSION

Precipitation. Precipitation varied among years during the seedling assessment periods in May, June, and July (Table 2). Precipitation was favorable for seedling emergence in 1996; by contrast, precipitation was 84% less in May and June of 1998. The first 3 wk of May in 1997 also were dry. This variation caused a year by cultural system interaction with weed emergence (to be discussed later).

Tillage Effect on Weed Density. Tilling with the sweep plow increased weed density in all crops (Figure 1). For example, tillage increased seedling density in corn from 69 to 105, a 52% increase compared to no-till. Similar trends occurred in sunflower and proso millet, with seedling density 35% greater in minimum-till. The sweep plow buries weed seeds shallowly, which increases emergence of broadleaf (Zorner et al. 1984) and grass weeds (Anderson 1998a).

Tillage with the sweep plow also eliminated the cultural system effect on weed emergence in all crops (data not shown), most likely because of weed seed burial and residue loss. The sweep plow buries 10 to 15% of surface residue with each operation (Good and Smika 1978). The three tillage operations, along with 30% residue decomposition over winter (Stott et al. 1990; Tanaka 1986), probably reduced residue quantities to near

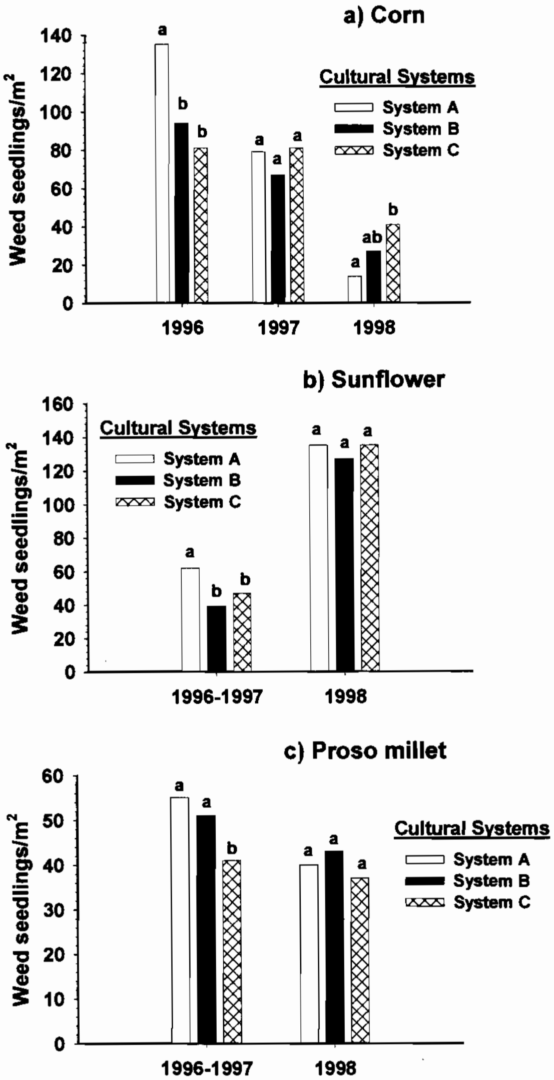

Figure 2. Weed densities in (a) corn, (b) sunflower, and (c) proso millet, as affected by cultural systems for wheat production. Data are from no-till treatments. Cultural System A is TAM 107 planted at 45 kg/ha in 30-cm rows with 66 kg N/ha broadcast at planting; System B is TAM 107 planted at 73 kg/ha in 18-cm rows, with 50 kg N/ha applied broadcast 5 mo before planting followed by 16 kg N/ha placed in a band above the wheat row; and System C is Lamar planted at 73 kg/ha in 30-cm rows with 66 kg N/ha applied 5 mo before planting. Bars with identical letters within a year do not differ, as determined with Duncan's new multiple range test.

the 3,000-kg/ha suppression threshold (Crutchfield et al. 1986).

Cultural System Impact on Weed Density in the No-Till System. *Corn.* Cultural system effect on weed densities varied among years. In 1996, when precipitation was favorable, weed density was 135 plants/m^2 in System A, the conventional system; in contrast, weed density in System C was 81 plants/m^2, a 40% reduction (Figure 2a). System B performed similarly, as weed density was 30% less than in the conventional system.

In 1997, when precipitation was low in May but normal in June, weed densities did not differ among cultural systems. When the entire measurement interval was dry in 1998, seedling density was highest in System C, which included the tall cultivar Lamar. With favorable moisture, higher residue systems suppressed weed emergence by physical or chemical factors (Crutchfield et al. 1986), whereas under dry conditions, residue most likely increased the number of favorable microsites for weed emergence (Teasdale and Mohler 1993). However, total emergence was less in the dry year as weed density in 1998, averaged across systems, was only 27% of weed density in 1996.

Sunflower. The high residue Systems B and C reduced weed densities 37 and 24%, respectively (Figure 2b), when favorable precipitation occurred during June and July in 1996 and 1997 (Table 2). Weed densities did not differ among systems in 1998 when precipitation was low in June, again suggesting residue can ameliorate dry conditions that affect weed germination (Teasdale and Mohler 1993). Weed densities were twofold greater in 1998 than in the first 2 yr (Figure 2b), which contrasts with results in corn (Figure 2a). We attribute this response to precipitation pattern in July 1998, because precipitation > 10 mm occurred every 5 to 7 d the first 3 wk, which favored extensive weed emergence.

Proso millet. Cultural system effect on weed densities in proso millet also reflected the impact of precipitation. With favorable precipitation in 1996 and 1997, System C reduced weed density 26% compared with System A (Figure 2c). Surprisingly, System B did not affect weed density, which we cannot explain. As observed with sunflower, dry conditions in 1998 eliminated the cultural system effect on weed emergence.

Treatment Effect on Weed Biomass. *Tillage and cultural systems.* Weed biomass was reduced in treatments with fewer weeds. Tilling with the sweep plow, which increased weed densities (Figure 1), also increased weed biomass 22–30% among the three crops (data not shown). Similar trends occurred with cultural systems among crops. For example, in 1996, Systems B and C reduced weed biomass in corn approximately 40% compared with System A, the conventional system (data not shown), reflecting the lower weed densities (Figure 2a).

Crop. When averaged across cultural systems in no-till, weed biomass in corn was almost 10-fold greater than in proso millet and three-fold greater than in sunflower (Figure 3). Row spacing and canopy closure probably contributed to this biomass difference between corn and the other two crops. Proso millet was planted in 20-cm

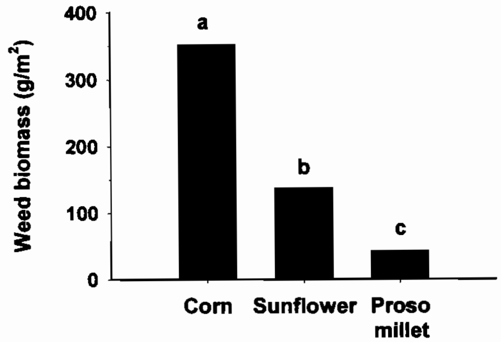

Figure 3. Weed biomass in corn, sunflower, and proso millet. Means are averaged across cultural systems in no-till for 3 yr. Bars with identical letters do not differ, as determined with Duncan's new multiple range test.

rows compared with 76-cm rows for corn and sunflower. Furthermore, proso millet begins stem elongation 4 wk after planting, which enhances its competitiveness with weeds. Sunflower shades the soil more than corn because of its broad leaves, thus reducing weed growth more than corn (Forcella et al. 1992). Another contributing factor may have been the later planting dates of sunflower and proso millet (Anderson 1994).

Management Guidelines. Residue management is a key component in semiarid cropping systems because water is the most limiting resource (Peterson et al. 1996). With no-till systems, producers are now including alternative crops in rotation with winter wheat. Maintaining crop residue on the soil surface will favor weed management in these alternative crops, if used in a no-till system; weed densities can be reduced 25 to 50% with cultural systems designed to increase residue production. Another factor possibly contributing to reduced weed densities is that increased competitiveness of winter wheat in cultural systems may reduce weed seed production in winter wheat, hence reducing the soil seedbank (Wicks et al. 1994).

An intriguing finding in our study is the difference in weed biomass among crops, which was 90% less in proso millet compared with corn (Figure 3). Previously, it was found that weed biomass in proso millet could be reduced several-fold by rotation design (Anderson 1998b). Furthermore, we are examining cultural systems for weed control in proso millet (R. L. Anderson, unpublished data) in our efforts to develop ecologically based cropping systems. Initial results indicate that cultural systems can reduce weed biomass 75 to 90% in proso millet.

One strategy for managing herbicide resistance in weeds is to favor susceptible biotypes in the population (Maxwell et al. 1990). Our results suggest that integrating rotation design and residue management with cultural systems in proso millet may reduce weed interference such that herbicides could be eliminated without losing yield. This approach would favor susceptible weed biotypes in 1 yr of the rotation, and it would supplement strategies such as rotating herbicides (Holt and LeBaron 1990) and minimizing use of long-residual herbicides (Gressel 1992) to delay development of resistant weed populations.

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