Acknowledgements

We gratefully acknowledge Stephen M. Haller (U.S. Department of Agriculture Agricultural Research Service) and Carol H. Williams (Mississippi State University) for their technical assistance in this research.

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Soil coverage by residue as affected by ten crop species under no-till in the northern Great Plains

S.D. Merrill, J.M. Krupinsky, D.L. Tanaka, and R.L. Anderson

ABSTRACT: Soil coverage by residue protects soil and land resources from erosion, conserves soil water, and maintains soil quality. No-till and chemical weed control are management practices that increase soil coverage by residue. On the other hand, crop diversification in dryland agriculture in the northern Great Plains promotes the use of crops that produce significantly less soil coverage by residue than small cereal grains. Within a 10 x 10 crop sequence project under no-till in south-central North Dakota [409 mm (16.1 in) mean annual precipitation], all two-year crop sequence combinations of ten crops (barley, canola, crambe, dry bean, dry pea, flax, safflower, soybean, spring wheat, and sunflower) were evaluated at two adjacent sites. Soil coverage by residue was measured by transect and photographic techniques following spring wheat seeding. Soil coverage ranged from 98 to 89 percent following crop sequences that included spring wheat and barley. Soil coverage values were intermediate for spring wheat—alternative crop sequences, 97 to 62 percent. Crop sequences not including spring wheat with alternative crops for two years had values ranging from 86 to 35 percent. Soil coverage values after two consecutive years of sunflower or dry pea (two years of data) and two years of dry bean or safflower (single year of data) were in a lower range, 48 to 35 percent. Soil erosion hazards were evaluated with equations based on residue effects alone that were taken from the Revised Universal Soil Loss Equation (RUSLE) water erosion and Revised Wind Erosion Equation (RWEQ) wind erosion models: calculated soil loss ratio values (SLR = 1 with no residue protection) for 35 percent coverage following a sunflower-sunflower sequence were 0.29 for water erosion and 0.21 for wind erosion. Even with use of no-till, especially on more fragile soils, producers should consider planting a higher residue-producing crop (e.g., wheat, flax) the year before seeding lower residue-producing crops in order to assure adequate protection of soil and land resources.

Keywords: Crop residue, diverse cropping system, no-till, water erosion, wind erosion

The use of crop residue-conserving management practices, such as conservation tillage, no-till, and chemical weed control, has enabled dryland soil-crop production systems in the Great Plains to diversify and use soil water more efficiently. Traditional summer-fallowing practices in dryland cropping were characterized by low precipitation-use-efficiency, but adoption of so-called continuous cropping and the use of conservation tillage practices has significantly increased water-use-efficiency (Farahani, 1998). Adoption of residue- and water-conserving soil-crop management practices has facilitated the ability of producers to adopt

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the principles of dynamic cropping systems (Tanaka et al., 2002), whereby crop and soil management decisions are adjusted annually to meet changing exigencies of climate, economics, and environmental care.

Diversification of rainfed soil-crop production systems has increased the use of crop species, which leave considerably less residue cover on the soil than do small cereal grains. In addition, residue from alternative crops such as sunflower and pulse legumes (e.g., dry pea and dry bean) is less durable and effective compared to small cereal grains. Preliminary reports concerning soil coverage by residue under no-till management (Merrill et al., 2002, 2003) showed that soil coverage in the spring after seeding could be significantly lower following sunflower and dry pea compared to spring wheat, barley, and some other species.

Soil-crop management practices that conserve crop residue on the soil surface maintain or improve soil quality (increased organic matter and improved aggregation), protect soil from erosion, and conserve soil water. Above ground crop residue protects the soil and supports decomposition of below-ground residue. Decomposition products in turn create favorable soil structure for plant growth (Dormaar and Carefoot, 1996). Black (1973) has shown that the rate at which wheat straw was returned to or withheld from the soil surface in a winter wheat - summer - fallow crop rotation positively affected the degree of dry aggregate size distribution.

Considering that the level of residue coverage directly affects soil erodibility, some of the most accessible and comprehensive information about soil coverage by residues is available in U.S. Department of Agriculture Agricultural Research Service (USDA-ARS)-developed soil erosion models. The Revised Wind Erosion Equation (RWEQ) model (Fryrear et al., 1998; see Merrill et al., 1999 for concise summarization) documents and integrates research information concerning the dynamic cycle of surface residue including: the degree of crop growth and the manner of its harvesting (e.g., height of harvest cutting); residue durability and climatic influences which determines the rate of decay; as determined by the conversion of standing to flattened residue; and the effect of tillage (where seeder passage is the principal or only disturbance in a no-till system). The rate of residue decay and other residue dynamics are also predicted by the Revised Universal Soil Loss (RUSLE) model (Renard et al., 1997), which deals with water erosion.

The basic theory of residue decay indicates that the rate of decay is a function of crop species, and the extent of decay depends on the accumulated product of time during which the soil is wet from precipitation and temperature greater than some threshold (Fryrear et al., 1998; Schomberg and Steiner, 1997). The rate constant of residue decay has also been shown to depend on the initial residue density present—the greater the density of initial residue, the lower is the rate constant (Steiner et al., 1999; Stott et al., 1990).

The documentation of soil erosion models brings together and summarizes comparative information about soil coverage by residues of various crop species. The RUSLE model (Renard et al., 1997) predicts that the rate of non-standing residue decay varies among crops, with soybean > sunflower > wheat. The RWEQ model (Fryrear et al., 1998) combines prediction of residue production at harvest with residue decay so that soil coverage among crops is in the order spring wheat and barley > soybean > sunflower. Comparative information about crops outside of major species is sparse. Guy and Gareau (1998) show that crops in the mustard family (canola, mustard, etc.) result in considerably more coverage than the pulse legumes pea and lentil.

The principal objective of the research reported here was to determine the comparative levels of springtime post-seeding soil coverage following a diverse array of crop species and crop sequences managed under no-till. The research was conducted as part of a crop sequence experiment, in which all possible two-year sequences of ten diverse crop species were under observation.

Table 1. Sequence of crop types and residue coverage measurement operations. There were four replication blocks at each site. The sites were contiguous in the same field.

	Site 1		Site 2	
Year	Crop(s) seeded	Near seeding-time residue cover measurements	Crop(s) seeded	Near seeding-time residue cover measurements
1997	Winter wheat			
1998	10 residue crops		Barley	
1999	10 matrix crops	Dataset A	10 residue crops	
2000	Spring wheat	Dataset B	10 matrix crops	Dataset C
2001			Spring wheat	Dataset D

Materials and Methods

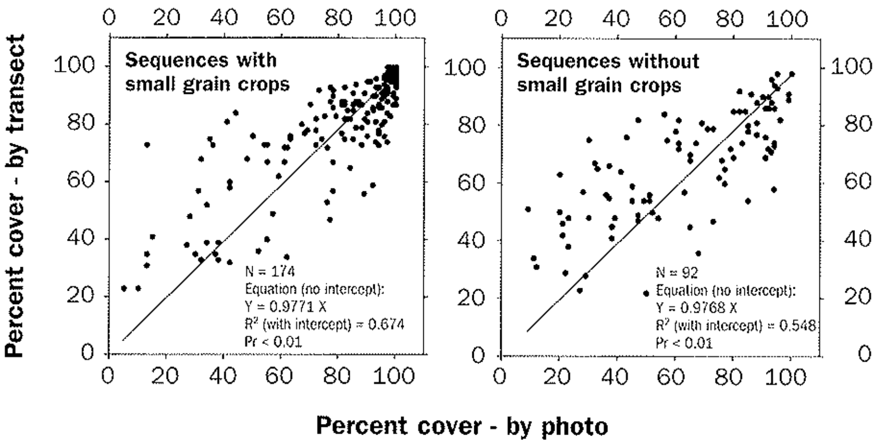
This research was carried out as part of a crop sequence project conducted by the USDA-ARS-Northern Great Plains Research Laboratory. Research was conducted at the Area IV Soil Conservation Districts/USDA-ARS Cooperative Research Farm located approximately 7 km (4.4 mi) southwest of Mandan, North Dakota (46° 46' N, 100° 57' W). Soil and land at the site consists of gently rolling uplands (0 to 3 percent slope) with a silty loess mantle overlying glacial till subsoil. The predominant soil type at the location is classified as Wilton silt loam (fine-silty, mixed, superactive frigid Pachic Haplustoll). Mean annual precipitation is 409 mm (16.1 in), 81 percent of which is received during the April to September growing season. Mean annual temperature is 5°C (41°F) and monthly averages range from 22°C (72°F) in July to -12°C (10°F) in January.

The crop sequence project was carried out by formation of a ten crop by ten crop matrix over a two-year period. The ten crops consisted of: barley (*Hordeum vulgare* L.), dry bean (*Phaseolus vulgaris* L.), dry pea (*Pisum sativum* L.), canola (*Brassica napus* L.), crambe (*Crambe abyssinica* Hochst. ex R.E. Fr.), flax (*Linum usitatissimum* L.), safflower (*Carthamus tinctorius* L.), soybean [*Glycine max* (L.) Merr.], spring wheat (*Triticum aestivum* L.), and sunflower (*Helianthus annuus* L.). In the first year, the ten crops (the residue crops) were planted in randomized 9-m (30-ft) wide strips. In the second year, the same ten crops (the matrix crops) were planted in re-randomized strips perpendicular to first set. In this manner, all 100 two-year sequences of the crops could be evaluated. The crop matrix, which had four fold replication, was repeated at a second site immediately adjacent to the first (Site 1 and Site 2). The matrices were preceded by winter wheat (Site 1) or barley (Site 2) crops, and both were followed with spring wheat. The sequence of crops and operations for the project are summarized in Table 1.

No-till management practices were used throughout the project employing regular farming equipment. Crops were seeded with a John Deere 750[1] no-till drill, a coulter type with relatively low soil disturbance. This drill

Figure 1

Comparison of residue cover determinations by a transect technique and nadir-view photographic technique. Graphed equations shown have zero intercepts.



has low residue burial, tending to move residue aside and then back during passage. Row spacing was 19 cm (7.5 in) with 40 to 50 percent surface soil disturbance and narrow vertical disturbance 5 to 8 cm (2 to 3 in) deep. Weeds were controlled with herbicide applications both in pre-seeding and post seeding periods. During seeding of all crops, nitrogen was band applied as NH_4NO_3 at 67 kg N ha^{-1} (60 lb ac^{-1}) at seeding. Phosphorus was also applied with the seed at 11 kg P ha^{-1} (10 lb ac^{-1}) as a 0-44-0 formulation. The only disturbances to the soil and land were: (a) by the drill at seeding; (b) two (or possibly three) trips for most crops per year by tractor-mounted herbicide sprayer; and (c) passage of harvesting combine.

Soil coverage by residue was measured in plots seeded to spring wheat with two techniques. Four datasets of residue measurements were taken in selected plots after seeding but before crop emergence from 1999 through 2001 (Table 1). With the transect technique, residue presence was enumerated at 25 points equally spaced along a 7.6-m (25-ft) cable, which was stretched across each plot four times to count the number of residue contacts for a total of 100 points. All residue visible to the operator at semicircular, 2 mm (0.08 in) diameter areas defined by small metal pieces affixed to the cable was counted. Obviously alive green weeds when encountered were not counted as residue. At each plot, two V patterns were formed by successive layings of the cable, which pointed in the direction of seeding. Separate counts were made with the transect technique for non-wheat residue and for recognizable wheat residue. Soil coverage was also measured with a photographic technique in which a 35-mm camera held by a light frame was used to produce nadir-view film slides from a height of 2 m (6.6 ft). One slide was made for each plot, and the slides were evaluated for residue presence at 50 points on a projector screen.

Results from the transect technique were compared with those from the photographic technique by regression analyses (Figure 1). Separate analyses for sequences with and without small grain crops (spring wheat and barley) produced no-intercept (forced through zero) regression coefficients with identical values, 0.977. Use of a no-intercept equation facilitates conversion of data taken with one technique into data equivalent to that taken with the other technique. Transect technique data has been preferentially used in this study because data generated by the method represent more soil surface area compared to the photographic technique. Some data taken in 2000 were derived from the photographic technique only, and these data were converted to transect technique-equivalent values. Transect and photographic technique-derived data were not mixed within a given year in a figure or table.

Data for each year and site (see Table 1) were analyzed separately using an analysis of variance model with previous crop as main treatment and replication as model effects. Means separation was assessed with the Student Newman-Keuls multiple comparison tests (SAS Institute, 1990).

Results and Discussion

Residue measurements reflect crop response and especially residue decay dynamics as influenced by climatic conditions in the years 1998 through 2000, which had above average precipitation. Precipitation, a principal limiting climatic variable in a dryland cropping system, impacts residue decay, especially during the growing season. Even though the 1998 monthly precipitation was below average for five out of six months (April through September), the overall seasonal precipitation (371 mm, 14.6 in) was above the long-term average (331 mm, 13.0 in) due to high precipitation in August (161 mm, 6.3 in). Seasonal precipitation was considerably above average in 1999 (551 mm, 21.7 in) and average in 2000 (328 mm, 12.9 in).

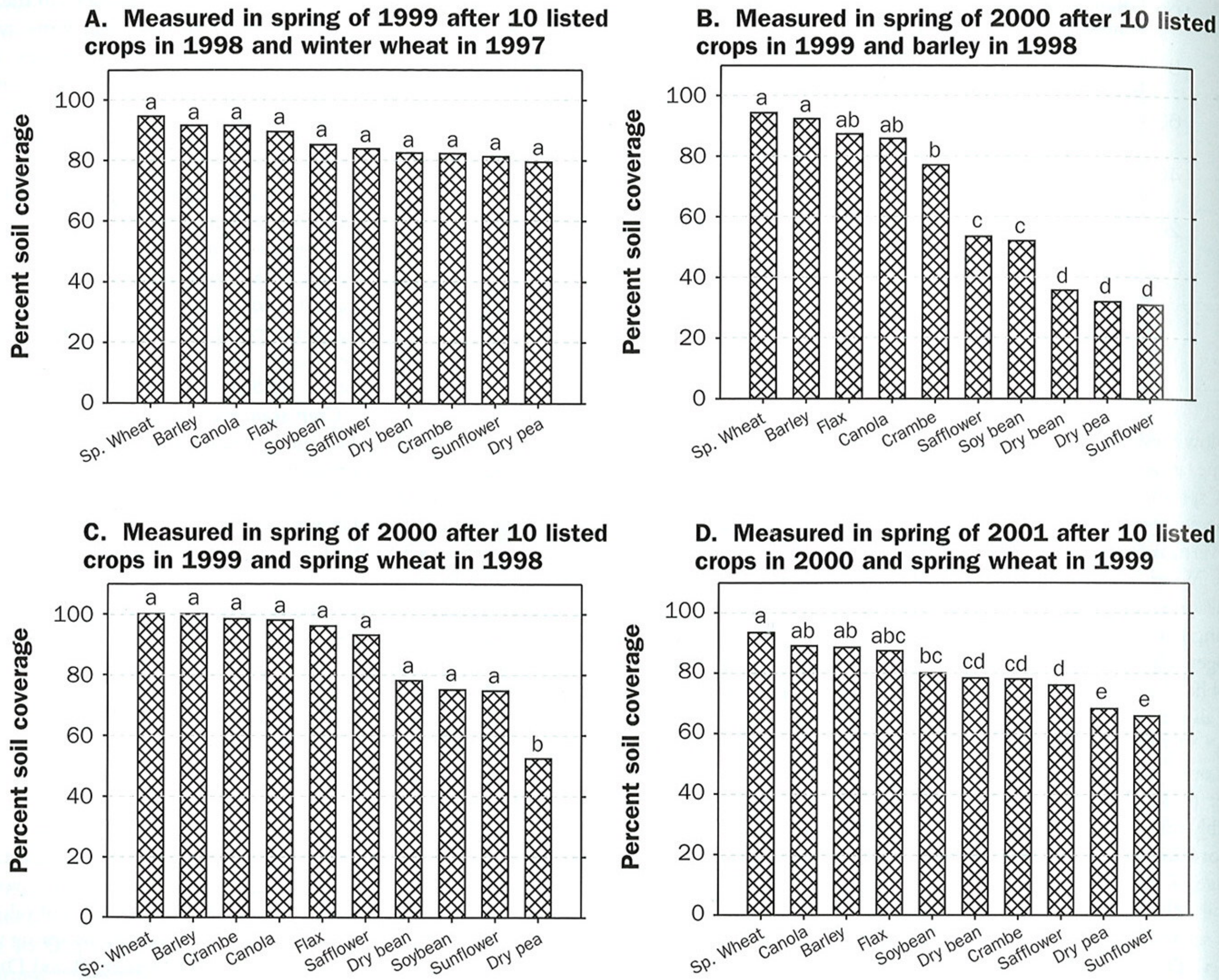
Crop sequence effects on soil coverage. Soil coverage by residue following crop sequences containing a small grain crop the first year and an alternative crop the second year (Datasets A-D, Table 1) was measured (Figure 2). Crop sequences with spring wheat, barley, flax, or canola as the second year crop had the higher values, while crop sequences with dry pea, sunflower, dry bean, or safflower in the second year had the lower values. Crop sequences with dry pea or sunflower in the second year had the lowest coverage levels. Soil coverage values for crop sequences with winter wheat in the first year (Figure 2A, Dataset A) were the highest on average, ranging from 95 to 80 percent, while coverage values for sequences with barley in the first year (Figure 2B, Dataset C) were the lowest, 94 to 31 percent. Ranges of values for two sets of sequences headed by spring wheat (Figures 2C and 2D, Datasets B and D) were intermediate in value, 100 to 52 percent and 94 to 66 percent, respectively.

The soil coverage values for sunflower and dry pea following barley (average 32 percent, measured in 2000, Figure 2B) are lower than values for sunflower and dry pea following winter wheat (average 80 percent, measured in 1999, Figure 2A). One can speculate that differences are due to (a) above average precipitation during the 1999 season, which provided good conditions for residue decay, in contrast to the below average growing season precipitation in 1998 or (b) a differential species effect (winter wheat vs. barley).

For small grain, alternative crop sequences (Figure 2), the lowest coverage values for each site and year occurred when sunflower or dry pea was the second year crop. Such

Figure 2

Soil coverage by residue measured in April or May immediately after spring wheat seeding but before crop emergence in the year following two-year crop sequences consisting of small grains the first year and various alternative crops the second. Values having the same letter are not significantly different at the P ≤ 0.05 level according to the Student Newman-Keuls multiple comparison test. Figure 2A is from Dataset A; Figure 2B is from Dataset C; Figure 2C is from Dataset B; and Figure 2D is from Dataset D (Table 1).

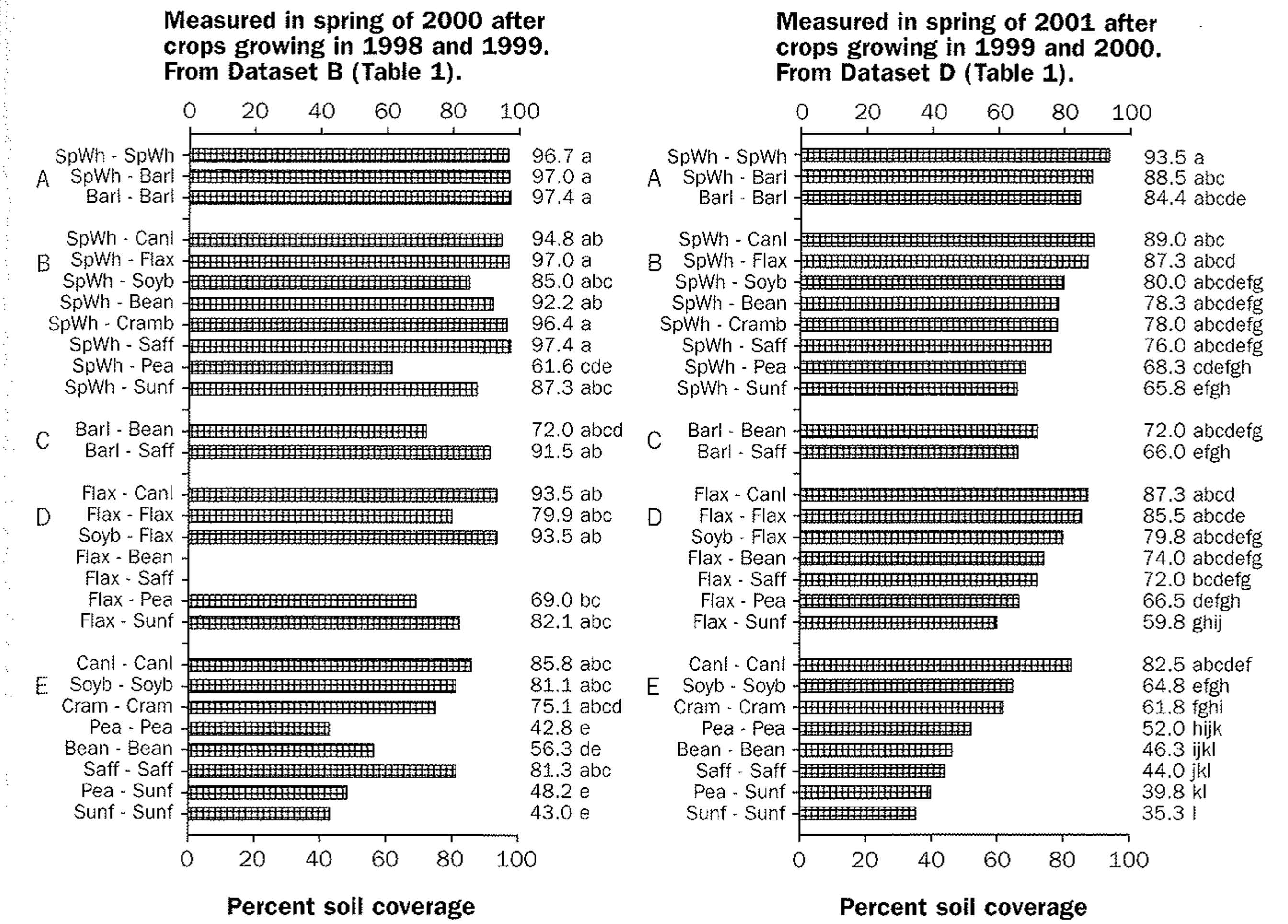


sequences had cover values of 82 and 78 percent when winter wheat was the first crop in the sequence (Figure 2A), ranged from 75 percent following spring wheat - sunflower in 2000, to 52 percent for spring wheat—dry pea in 2000 (Figure 2C), and had lowest values for barley—sunflower and barley—dry pea of 32 and 31 percent, respectively (Figure 2B). The fact that only one year of data is available for all 10 crops with sequences with winter wheat or barley in the first year, limits conclusions that may be drawn regarding particular influences of these species. However, the four groups of data shown in Figure 2 indicate a range of variability possible in the residue decay of lower-residue producing crops such as sunflower and dry pea planted in small cereal grain residue under no-till management.

Soil coverage measured in the spring of 2000 and 2001 for a wide variety of crop sequences (Datasets B and D, Table 1) have been placed into five groups (A-E, Figure 3). Within each group, entries are arranged by the order of their 2001-measured values. For most sequences, soil coverage measured in spring of 2000 was higher than that measured in spring 2001—80.7 percent on average vs. 70.5 percent, respectively. It can be seen that crop sequences composed of small cereal grains, spring wheat and barley (Group A, Figure 3), have the highest values. Crop sequences composed of combinations of either spring wheat and an alternative crop (Group B) or flax and an alternative crop (Group D) have an intermediate range of soil coverage values, while those consisting of two years of the same alternative crop other than wheat or flax (Group E) have the lowest average values.

Crop sequences with spring wheat in the first year and an alternative crop in the second year (Group B, Figure 3) resulted in soil coverage values of 89 and 78 percent in the spring of 2000 and 2001, respectively. This was about 20 percentage points greater than coverage values following crop sequences with two years of the same alternative crop (Group E), which had average values of 68 and 59 percent in spring of 2000 and 2001, respectively. Three of the alternative crop—

Figure 3
Soil coverage by residue measured immediately after spring wheat seeding in the year following two-year crop sequences. Values having the same letter are not significantly different at the P ≤ 0.05 level according to the Student Newman-Keuls multiple comparison test.



alternative crop sequences had values less than 50 percent in spring 2000, and four of them were less than 50 percent in spring 2001, which is of potential concern with respect to soil erosion hazard, an issue discussed below.

Crop sequences with flax in the first year and another alternative crop in the second (Group D) had slightly less average soil coverage values than comparable sequences with spring wheat in the first year (Group B): flax in the first year vs. spring wheat first year, 81 vs. 85 percent, respectively, in 2000 (average of four sequences each, Figure 3, left), and flax first vs. spring wheat first, 74 vs. 78 percent, respectively in 2001 (six sequences each, Figure 3 right).

In general, higher residue coverage is associated with the wheat—alternative crop sequences compared to the alternative crop—alternative crop sequences. This appears to be related to the carryover of wheat residues from the first year of the sequence. For example, high coverage values for various small grain—alternative crop sequences (Figure 2A, Dataset A) appear to be related to the amount of identifiable winter wheat residues measured in 1999 (21 percent to 30 percent, Table 2). Average coverage values for spring wheat—alternative crop sequences were somewhat higher in measurements made in spring of 2000 compared to spring 2001, 85 vs. 79 percent, respectively (Figures 2C and 2D). This result appears to be associated with spring wheat coverage values, which averaged 12 percent in 2000 vs. four percent in 2001 (Table 2). The numerical ordering of two-year average identifiable wheat residue coverage values does not appear to have any easily discernable pattern that could be linked to crop type or agronomic group.

Residue durability and decay. Comparative information about different species' production and durability of residues is included in the documentation of standard soil erosion models. The RWEQ model (Fryrear et al., 1998) predicts standing and prostrate residue biomass from seed yield, and residue decay based on ambient temperature and precipitation pattern. Using seed yield values taken from the same crop sequence project (Krupinsky et al., 2006), we have used RWEQ-embedded algorithms to calculate soil coverage values for those crops included in the model. The calculations assume two levels of accumulation of "decomposition days," which is the product of a specialized version of "growing degree days" (GDD) and number of days that rainfall water is available for microbial activity to occur:

10 decomposition days: barley—82 percent; spring wheat—79 percent; soybean—76 percent; and sunflower—52 percent.

Table 2. Total soil coverage percentage and soil coverage percentage due to identifiable wheat residue measured after spring wheat seeding under no-till management.

	Spring 1999 after various crops 1998, winter wheat 1997		Spring 2000 after various crops 1999, spring wheat 1998		Spring 2001 after various crops 2000, spring wheat 1999		2000 and 2001 average
	Total % coverage	Wheat % coverage	Total % coverage	Wheat % coverage	Total % coverage	Wheat % coverage	Wheat % coverage
Safflower	83.8	30.2	93.0	23.3	76.0	5.7	14.5
Dry bean	82.5	27.9	78.0	19.6	78.3	7.7	13.7
Sunflower	81.3	42.8	74.7	13.4	65.8	5.3	9.4
Canola	91.5	31.1	98.0	16.0	89.0	2.6	9.3
Crambe	82.3	33.8	98.3	12.5	78.0	3.2	7.9
Flax	89.5	25.5	96.3	9.9	87.3	5.1	7.5
Soybean	85.3	33.2	75.0	6.3	80.0	4.4	5.4
Dry pea	79.5	20.8	52.3	3.3	68.3	2.6	3.0
Barley	91.5	21.3	100.0	1.0	88.5	0.0	0.5
Average	85.2	29.6	85.1	11.7	79.0	4.1	7.9

20 decomposition days: barley—78 percent; spring wheat—74 percent; soybean—65 percent; and sunflower—47 percent.

The numerical ordering of these model-calculated values appear to be most comparable to coverage values following spring wheat—alternative crop sequences measured in spring of 2001 (Figure 3):

second year crop of the sequence: spring wheat—94 percent; barley—89 percent; soybean—80 percent; and sunflower—66 percent.

These experimental values have about the same ordering as the model-derived values—spring wheat and barley being the highest and approximately the same, soybean is second, and sunflower has the lowest coverage value. The fact that measured values are 10 or more percentage points higher than the calculated values for 10 decomposition days is probably due to no-till management and/or the more northern geographical position of our study compared to studies from which model parameters were taken.

Evaluation of soil erosion risks. Soil erosion models developed by the USDA-ARS were used to evaluate possible soil erosion hazards inherent for the lower soil coverage values. The RWEQ model (Fryrear et al., 1998) was used for wind erosion, and the RUSLE model (Renard et al., 1997) was used for water erosion. Specific equations within the model, which address prostrate residue effects were used. The equations, which are largely based on either wind tunnel trials or rainfall simulator and soil pan or small plot studies, predict soil loss ratio values directly from soil coverage values. The soil loss ratio is defined as the ratio (as a percentage) of soil loss with residue present to soil loss that would occur without residue under conditions in which other soil factors are in a state of relatively high soil erodibility, such as a dry, smooth soil surface with low soil aggregation. Thus, soil loss ratio = 1 with no residue present, and soil loss ratio = 0 with complete residue coverage. Significantly wind erodible soils have smooth surfaces with low slope, while water erodible soils are sloped.

Ten crop sequences with values ranging from 31 to 48 percent were evaluated (Table 3). Calculated soil loss ratio values for water erosion hazard (RUSLE model) indicate that theoretical soil losses under generally high erodibility conditions would range from 0.19 up to 0.34 of maximum (1.00) soil loss with no residue for measured coverage values ranging from 0.48 down to 0.31. Theoretical, relative soil losses for wind erosion were lesser, ranging from 0.12 up to 0.26 of maximum soil loss (Table 3). These theoretical, calculated soil losses refer to conditions that are generally more erodible than those occurring in typical well-managed no-till soil-crop systems that are not under drought or on marginal, fragile soils.

However, surface residues can float away and/or be covered with soil from rain splash in a heavy shower and/or can blow away in windstorms, and are characteristically subject to all three mechanisms at once in high-wind rainstorms. Even with the practice of no-till management, the use of sequences with sunflower and pulse legumes such as dry pea and dry bean for two consecutive years can result in lack of adequate soil coverage and heightened soil erosion risks under drought conditions. Lack of precipitation at critical times

Table 3. Calculated soil loss ratios (SLR) for measured soil coverage by residue with values less than 50 percent using equations in RUSLE (water erosion) and RWEQ (wind erosion) models. SLR = 1 indicates full theoretical soil loss in complete absence of residue coverage. See text for further explanation.

Prior crop sequence	Year measured	Percent soil coverage	SLR for water erosion*	SLR for wind erosion†
Barley/Sunflower	2000	31.0	.338	.257
Barley/Dry pea	2000	32.0	.326	.246
Sunflower/Sunflower	2001	35.3	.291	.213
Barley/Dry bean	2000	35.8	.286	.208
Dry pea/Sunflower	2001	39.8	.248	.175
Dry pea/dry pea	2000	42.8	.224	.153
Sunflower/Sunflower	2000	43.0	.222	.152
Safflower/Safflower	2001	44.0	.214	.146
Dry bean/Dry bean	2001	46.3	.198	.132
Dry pea/Sunflower	2000	48.2	.185	.121

*Based on RUSLE model (Renard et al., 1997).

†Based on RWEQ model (Fryrear et al., 1998).

can result in stand failure and lack of adequate crop growth for provision of adequate residue coverage during the latter part of the season and the following year. During drought periods, inadequate crop growth and consequent low residue presence will negatively synergize with soil erodibility factors to increase wind erosion risks (Merrill et al., 1999).

Application of results. The principles of dynamic cropping systems (Tanaka et al., 2002) call for producers to respond to changing conditions in a flexible manner. In dryland soil-crop production systems, inadequate precipitation and stored soil water can lead to a decision to summer fallow. Measurements of actual wind erosion were conducted on no-till-managed sunflower stubble land (silt loam soil with spring wheat preceding sunflower) subjected to various degrees of pre-plant tillage treatments, including no-till, medium-till, and heavy tillage (conventional). Then all tillage treatments were subjected to chemical (glyphosate) summer fallowing (Merrill et al., 2004). The combination of tillage and chemical weed control under relative summer dryness resulted in high levels of wind erosion. Even the no-till treatment had moderately elevated measured levels of soil loss under a high-energy windstorm event (Merrill et al., 2004).

Higher soil coverage with residue under no-till has direct beneficial effects in dryland cropping through water conservation, especially under drought conditions (Merrill et al., 1996). Higher residue coverage has positive effects on soil health (Doormar and Carefoot, 1996; Willhelm et al., 2004), including the soil conservation aspects already discussed in this paper. However, there may be a negative side to high residue coverage during cool wet years. Longer season crops (e.g., corn, soybeans) growing in the northern Great Plains may undergo yield losses from combinations of cool, wet spring conditions, lack of sufficient heat units during the season, and early-occurring frosts. It has been reported that the higher residue associated with no-till can delay crop development compared to conventional-till under relatively cooler, wetter conditions, especially with crops such as corn (Carter and Barnett, 1987). In another crop sequence project with predominantly warmer-season crops, growth stages of spring wheat development have been related to levels of residue coverage. For example, high residue levels may slow wheat development (authors, unpublished data).

The results of this study show that producers need to carefully manage crop sequences so that soil resources are adequately protected from erosion, particularly on more erodible and fragile soil and land. Preceding low residue-producing crops with high-residue producing crops such as small cereal grains would reduce erosion risks. Even though other crops such as flax and canola are shown to be relatively high residue-producing crops, producers must be aware of particular negative crop sequential effects of complex soil biological and/or plant pathological origin that can occur with these and other non-small grain crops (Krupinsky et al., 2002; 2005).

Endnotes

Inclusion of product information is for the benefit of the reader and does not imply preference nor endorsement by the U.S. Department of Agriculture, Agricultural Research Service.

Acknowledgements

The authors would like to acknowledge the technical assistance of Ms. Dawn Wetch, Mr. Justin Hartel, Mr. Marvin Hatzenbuhler, and Mr. Delmer Schlenker.

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