PREDICTING CROP RESIDUE DECOMPOSITION

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Abstract. The Douglas/Rickman model was used to simulate decomposition of spring wheat (*Triticum aestivum* L.) straw and alfalfa (*Medicago sativa* L.) hay, based on air temperature, initial nitrogen content, and residue placement. Model predictions were compared with results from an experiment conducted in 1991-92 on the long-term chemical fallow site at Melfort, Saskatchewan. Overall, model predictions agreed well with measured results for surface and buried wheat and alfalfa residue.

INTRODUCTION

The successful adoption of conservation tillage systems by farmers will partially depend on accurate predictions of the rate and extent of decomposition of surface crop residues for efficient residue management. Residue management in these tillage systems is particularly important for crop production because surface-placed residues affect soil cover, nutrient availability, soil structure, soil temperature, water infiltration and evaporation, pest populations, and microbial activity (Douglas et al. 1980; Stroo et al. 1989; Collins et al. 1990). Effective residue management in conservation tillage systems strives to maintain sufficient crop residues at or near the soil surface to minimize erosion, yet not in excessive amounts that impede planting operations or subsequent crop seedling emergence and establishment.

Residue decomposition proceeds at a rate determined by the most limiting environmental, soil, residue, or management factor (Parr and Papendick 1978; Tanaka 1986). Microbial degradation is mainly responsible for crop residue decomposition (Parr and Papendick 1978; Douglas and Rickman 1992), although physical breakdown, removal by wind or water, or use by soil fauna also can significantly affect residue loss (Stott et al. 1990). Environmental factors are temperature and precipitation (Parr and Papendick 1978). Soil factors include available nutrients, pH, and aeration (Smith and Douglas 1968; Tanaka 1986). Residue factors include N content (C/N ratio), chemical composition, size, age, and species or cultivar type (Smith and Douglas 1968, 1971; Parr and Papendick 1978; Douglas et al. 1980; Smith and Peckenpaugh 1986; Collins et al. 1990). Janzen and Kucey (1988) concluded that the rates of decomposition of cereal, oilseed, and pulse crop residues were primarily influenced by their N content. Generally, residues with low N content or high C/N ratios have slower decomposition rates (Parr and Papendick 1978). Management practices affect residue placement or degree of incorporation in soil (Smith and Douglas 1968, 1971; Parr and Papendick 1978). Retention of crop residues on the soil surface decreases the rate of decomposition compared with residues that are partially or completely buried. Brown and Dickey (1970) and Douglas et al. (1980) have shown that surface residue disappears at approximately one-third the rate of buried residue. Residues that are partially or completely buried are subject to greater mechanical disruption and more intimate soil-straw contact than surface residues, which favours microbial decomposition (Douglas et al. 1980).

Degree days (DD) (heat units) recently have been used to quantify crop residue decomposition (Douglas and Rickman 1992), similar to growing DD used to measure the rate of development of annual and perennial crops. Cumulative degree days (CDD) are calculated by summing, for each day, the average daily air temperature minus a base temperature of 0 C. The authors found that the relationship between cereal residue decomposition and CDD was the same at nearly all locations evaluated in the United States. Good agreement was obtained between model predictions and measured results of residue decomposition, using CDD computed from air temperature, and initial N content and placement of the residue. However, the model has not been evaluated in western Canada nor has it been evaluated for predicting residue decomposition of forage legumes, which have a high N content. Therefore, the objective of this paper is to evaluate the Douglas/Rickman model for predicting decomposition of surface (simulated zero tillage system) and buried (simulated intensive tillage system) spring wheat (*Triticum aestivum* L.) straw and alfalfa (*Medicago sativa* L.) hay, using data from an experiment conducted in 1991-92 on the long-term chemical fallow site at Melfort, Saskatchewan.

MATERIALS AND METHODS

A crop residue decomposition study was initiated in 1991 on the long-term chemical fallow site (established in 1969) at the Agriculture Canada Research Station at Melfort, Saskatchewan. The soil at the site is a Melfort silty clay (Orthic Black Chernozem) with 9.5% organic matter content and pH 6.0. The long-term experiment is arranged in a randomized complete block design with four replications per treatment. The two year crop rotation consists of spring wheat (Katepwa) alternating with fallow. The tillage treatments for the fallow phase are herbicides only, herbicides in combination with two tillage operations, and tillage alone. The dimensions of individual plots are 4.3 by 30.5 m.

Unweathered Katepwa wheat straw and alfalfa hay were collected in 1990, immediately after harvest. In the spring of 1991, weathered (over winter) wheat straw also was collected. The residues were oven dried at 60 C for 48 h. The initial N contents of the unweathered and weathered wheat straw and alfalfa hay were 0.41, 0.23, and 2.77%, respectively. Twenty-five grams of each residue were placed in nylon mesh (1 mm) bags (25 by 25 cm). The residue bags were placed on the soil surface and buried at 12-cm depth in the fallow plots on July 11 in 1991. Bags were removed from the field on August 12, September 11, October 11, November 12, and May 14 in the following year. The latter sampling date was included to estimate over winter surface residue losses. After removal from the field, residue was sieved (1 mm) to remove loose soil, oven dried, and weighed. The residue was ground to pass through a 1-mm sieve, and a subsample was ashed at 500 C in a muffle furnace over night to determine the soil content within the residue. Residue weights were expressed on an ash-free, dry matter basis. Values for surface and buried residue at each sampling date are means of the four replicate bags per tillage treatment averaged over the three treatments. Results were averaged across the tillage treatments because the model does not distinguish between the treatments when residue bags are used to measure decomposition. In this study, residue placement represents two tillage extremes, either surface-placed with no soil incorporation (simulated zero tillage) or completely buried (simulated intensive tillage).

The residue decomposition model is described in detail by Douglas and Rickman (1992). Four equations are used in the model to estimate decomposition of crop residues based on CDD calculated from daily mean air temperature. Each is based on the general equation:

$$Rr = Ir \exp(fN\, fW\, k\, CDD)$$

where Rr = the residue remaining, Ir = the initial residue, fN is an N coefficient based on initial residue N content, fW is a water coefficient based on a combination of residue and field management, and k is a general decomposition coefficient. Simulation of residue decomposition using air temperature is based on the premise that, regardless of location, the natural logarithm of the fraction of residue remaining (Rr/Ir) is linearly dependent on the daily mean temperature. Two modifying factors are included in the equation. Firstly, fN, to account for the fact that residues with higher N contents decompose faster than those with lower N contents and secondly, fW, to express the difference in decomposition rate under wet vs. dry conditions.

RESULTS AND DISCUSSION

The relationship between CCD and time is shown in Figure 1. The CDD increased linearly with time during the first 90 days, with few DD occurring after mid-October until the latter part of April. Thereafter, CDD increased at a rate similar to that of the first 90 days.

Measured and predicted decomposition of surface-placed unweathered and weathered wheat straw and alfalfa hay, expressed as percent organic matter remaining as a function of CCD, is shown in Figure 2. There was good agreement

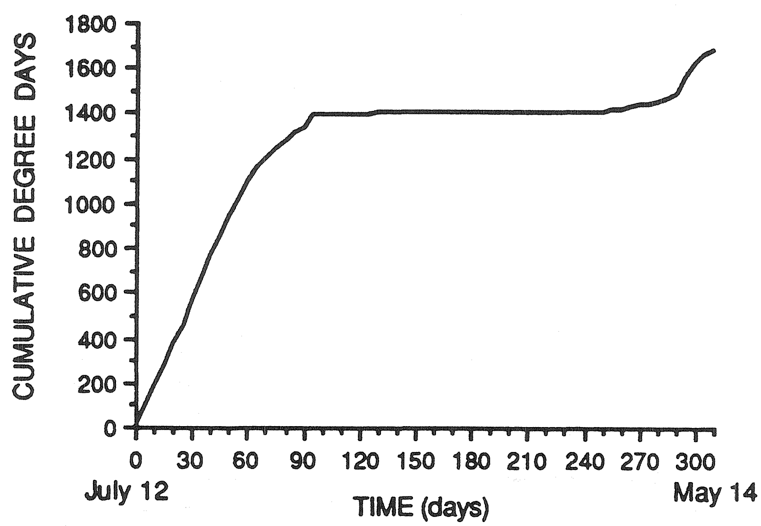

Figure 1. Relationship between CCD and time in 1991-92 at Melfort.

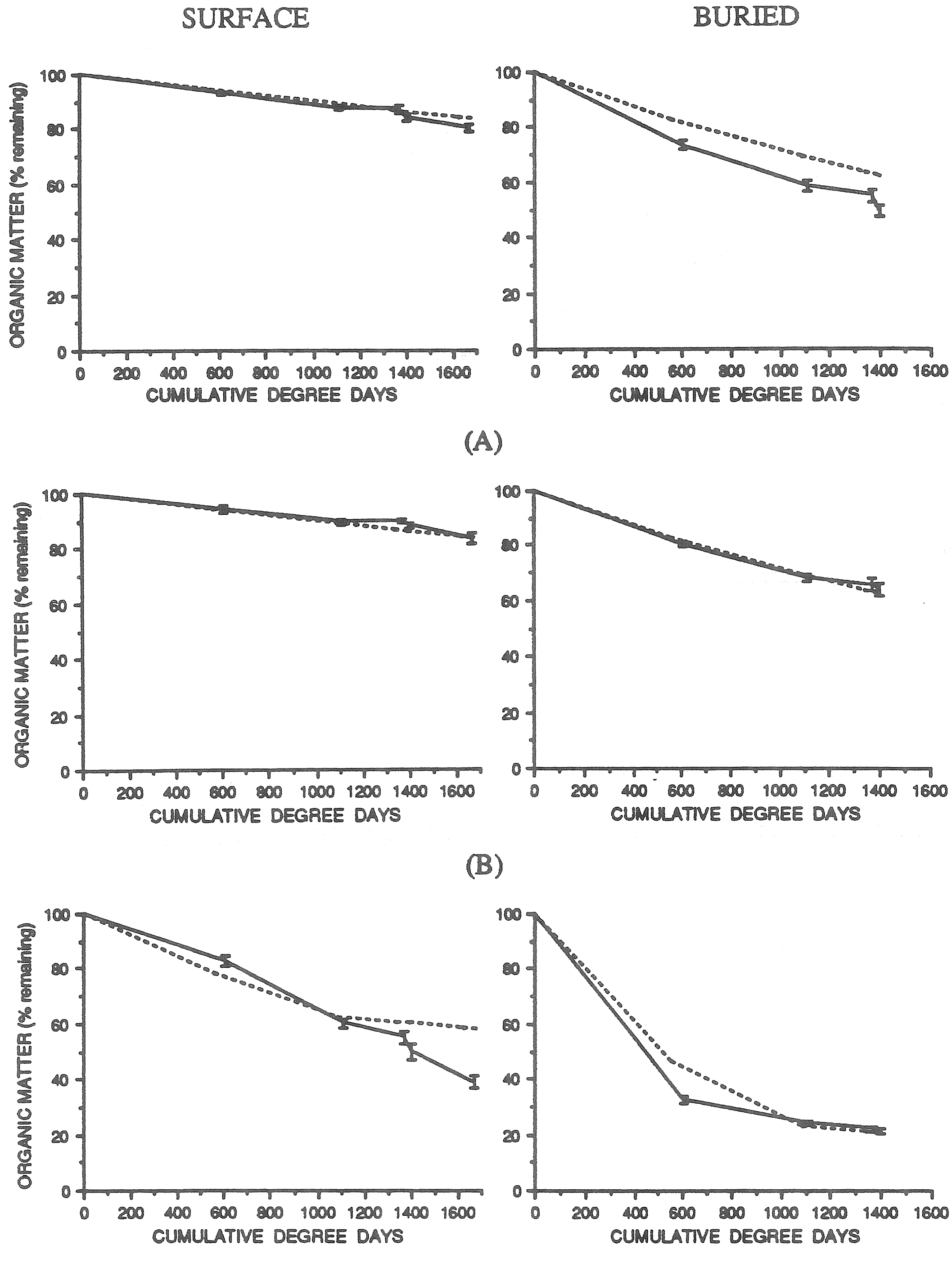

Figure 2. Decomposition of surface and buried unweathered (A) and weathered (B) wheat straw and alfalfa hay (C) as a function of CDD in 1991-92 at Melfort. Measured results: solid line with error bars; predicted results: dashed line.

between measured and simulated decomposition of surface unweathered and weathered wheat straw. Both residues decomposed at the same rate. Predicted losses were the same for both residues, since their initial N contents were less than 0.55%, which the model specifies as the boundary separating low N from high N residue. Therefore, the same N coefficients were used in model simulations. Both measured and predicted results indicated that decomposition was linear with respect to CDD. After 308 days, similar amounts of unweathered and weathered wheat straw had decomposed - 80 and 84%, respectively (Table 1). As expected, alfalfa hay, with a high initial N content (2.77%), decomposed faster than wheat straw. After 308 days, only 39% of initial residue remained. After the first 60 days, model predictions diverged from measured results, so that by the end of the experiment, the model had underestimated decomposition by 49%. Part of this divergence may be due to physical breakdown, which was visibly evident. The model does not account for this type of loss and therefore may underestimate decomposition of surface-placed alfalfa. Measured results indicated that overwinter losses of surface wheat residue were only 4%, whereas loss of alfalfa residue was 11%.

The model slightly underestimated decomposition of buried unweathered wheat straw, but predicted decomposition of buried weathered straw with good accuracy. As expected, unweathered wheat straw decomposed slightly faster than weathered residue, likely due to leaching losses and microbial utilization of the more readily decomposable soluble components prior to commencement of the experiment. After 124 days, 50 and 64% of unweathered and weathered residue, respectively, remained compared with model predictions of 63% for both residues. There was close agreement between measured and predicted buried alfalfa hay decomposition. After 124 days, measured and simulated amounts remaining were 21 and 20%, respectively. For all three types of buried residue, decomposition was curvilinear with respect to CDD. Measured results for surface-placed and buried residue indicate that the former decomposed at two-thirds the rate of the latter. In contrast, other workers in the United States have indicated that surface residue decomposes only one-third as fast as buried residue.

Table 1. Measured and simulated crop residues remaining after 308 days (surface) and 124 days (buried) at Melfort (standard errors in parentheses).

	Surface		Buried	
Residue	Measured[a]	Simulated	Measured[b]	Simulated
	% remaining			
Wheat (unweathered)	80(2)	83	50(2)	63
Wheat (weathered)	84(2)	83	64(3)	63
Alfalfa	39(2)	58	21(1)	20

[a]Surface residue decomposition was measured from July 12 to May 14, 1992.
[b]Buried residue decomposition was measured from July 12 to Nov. 12, 1991.

In conclusion, there was generally good agreement between measured and simulated decomposition of surface and buried wheat and alfalfa residue, indicating that predictions based on air temperature, initial N content, and placement are sufficiently accurate to describe decomposition. Further testing of the model across years and with other types of residue is required before it can be recommended for use in the Black soil zone. However, because of the good agreement between simulated and measured results, this model has the potential to assist producers or extension workers with crop residue management decisions.

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LITERATURE CITED

Brown, P. L. and Dickey, D. D. 1970. Losses of wheat straw residue under simulated field conditions. Soil Sci. Soc. Am. J. 34:118-121.

Collins, H. P., Elliott, L. F. and Papendick, R. I. 1990. Wheat straw decomposition and changes in decomposability during field exposure. Soil Sci. Soc. Am. J. 54:1013-1016.

Douglas, C. L., Jr., Allmaras, R. R., Rasmussen, P. E., Ramig, R. E. and Roager Jr., N. C. 1980. Wheat straw composition and placement effects on decomposition in dryland agriculture of the Pacific Northwest. Soil Sci. Soc. Am. J. 44:833-837.

Douglas, C. L., Jr. and Rickman, R. W. 1992. Estimating crop residue decomposition from air temperature, initial nitrogen content, and residue placement. Soil Sci. Sci. Am. J. 56:272-278.

Janzen, H. H. and Kucey, R. M. N. 1988. C, N, and S mineralization of crop residues as influenced by crop species and nutrient regime. Plant Soil 106:35-41.

Parr, J. F. and Papendick, R. I. 1978. Factors affecting the decomposition of crop residues by microorganisms. p. 101-129 *in* W. R. Oshwald (ed.) Crop Residue Management Systems. Spec. Pub. 31. A.S.A., Madison, WI.

Smith, J. H. and Douglas, C. L. 1968. Influence of residual nitrogen on wheat straw decomposition in the field. Soil Sci. 106:456-459.

Smith, J. H. and Douglas, C. L. 1971. Wheat straw decomposition in the field. Soil Sci. Soc. Am. J. 35:269-272.

Smith, J. H. and Peckenpaugh, R. E. 1986. Straw decomposition in irrigated soil: comparison of twenty-three cereal straws. Soil Sci. Soc. Am. J. 50:928-932.

Stott, D. E., Stroo, H. F., Elliott, L. F., Papendick, R. I. and Unger, P. W. 1990. Wheat residue loss from fields under no-till management. Soil Sci. Soc. Am. J. 54:92-98.

Stroo, H. F., Bristow, K. L., Elliott, L. F., Papendick, R. I. and Campbell, G. S. 1989. Predicting rates of wheat residue decomposition. Soil Sci. Soc. Am. J. 53:91-99.

Tanaka, D. L. 1986. Wheat residue loss for chemical and stubble-mulch fallow. Soil Sci. Soc. Am. J. 50:434-440.