RESIDUE TYPE AND PLACEMENT EFFECTS ON DECOMPOSITION: FIELD STUDY AND MODEL EVALUATION

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ABSTRACT. *Decomposition of corn (*Zea mays L.*), soybean (*Glycine max [L.] Merr.*), wheat (*Triticum aestivum L.*), grain sorghum (*Sorghum bicolor [L.] Moench*), and cotton (*Gossypium hirsutum L.*) residues and dead roots was studied under field conditions at the Midwest Claypan Experimental Farm located near Kingdom City, Missouri. Residues in fiberglass bags were placed on the soil surface and 0.15 m above and below the surface of a Mexico silt loam (*Udollic Ochraqualf*). Root bags were also buried 0.15 m below the surface. Samples were collected 11 times during the two-year study. Mass losses in one year for above-surface, surface, buried residue, and dead root were 41, 66, 78, and 65%, respectively, for corn; 37, 66, 79, and 51% for soybean; 17, 36, 69, and 64% for wheat; 45, 66, 80, and 76% for grain sorghum; and 40, 58, 76, and 46% for cotton. Decomposition was relatively slow during the second year of the study because of the previous loss of easily decomposed compounds. Decomposition data were used to evaluate a theoretically derived residue decay model. Relationships between predicted and measured mass loss were linear with* r^2 *values > 0.93.*

Keywords. *Decomposition, Field study, Model evaluation.*

Residue is an important crop variable that influences runoff and erosion processes. Meyer et al. (1970) reported that 0.5 and 5.0 Mg/ha straw mulch on the soil surface reduced soil loss to 33 and 95%, respectively, of that with no mulch cover. Lattanzi et al. (1974) concluded that interrill erosion was reduced about 40% by applying a mulch rate of 2 Mg/ha. The Water Erosion Prediction Project (WEPP) Hillslope model predicted that a 10% cover reduced soil loss and runoff by 32 and 28%, respectively. Soil loss and runoff were reduced by 84 and 69%, respectively, with 50% ground cover (Ghidey and Alberts, 1990).

Tillage can greatly reduce surface residue mass and cover, depending on the type of implement used. Residue mass is also lost due to decomposition, even if no tillage is performed. Several studies were previously conducted on the decomposition of residues, particularly for wheat and corn. Most of these studies placed residue samples in fiberglass or cloth bags (Parker, 1962; Brown and Dickey, 1970; Smith and Douglas, 1971; Douglas et al., 1980; Ghidey et al., 1985). Some studies were also conducted under actual (without using fiberglass bags) field conditions (Alberts and Shrader, 1980; Tanaka, 1986; Stott et al., 1990; Collins et al., 1990). All of these studies dealt with the decomposition of surface and/or buried residue of one residue type.

Residue decomposition is affected by temperature, moisture, aeration, pH, available nutrients, lignin content, and age and size of material (Parr and Papendick, 1978). However, data available in the literature indicate that temperature, moisture, C/N ratio, and location on or within the soil are the most important factors (Reddy et al., 1980). Previous researchers have selected factors such as temperature, moisture, or placement in the soil profile and investigated their individual effects on residue decomposition for particular crops (Pal and Broadbent, 1975; Parker, 1962). Brown and Dickey (1970) studied the decomposition of wheat residue and showed that surface residue decayed faster than above-surface residue but slower than buried residue. Parr and Papendick (1978) reported that residues with a low N or high C/N ratio have slow decomposition rates.

Gregory et al. (1985) developed a model that predicts crop residue decomposition. The model was developed in relation to the interaction effects of air temperature, precipitation, and initial C/N ratio of the crop residue. Ghidey et al. (1985) evaluated the decay model and determined the coefficient values required by the equation for corn, soybean, wheat, and sunflower residues placed on the soil surface. However, experimental data were not available to determine the coefficients for buried and above-surface residues, and buried roots.

Objectives of this study were to:

- Compare the decomposition of above-surface, surface, buried residues, and buried dead roots for corn, soybean, wheat, grain sorghum, and cotton.
- Develop regression coefficients required by Gregory's residue decay model for the prediction of above-surface, surface, buried residue, and dead root mass.

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RESIDUE DECAY MODEL

The percent decomposition of residue is predicted using the equation (Gregory et al., 1985)

$$\frac{M_t}{M_{t-1}} = \left(1 - \frac{a}{r_0}\tau\right)^2 \tag{1}$$

where M_t is the present residue (above-surface, surface, or buried), or root biomass (kg/m^{-2}), M_{t-1} is the prior day residue or root biomass, a is a coefficient, r_0 is the initial radius of the residue or root, and τ is the weighted-time variable.

The variable, τ, is calculated from:

$$\tau = \frac{T_a a_m}{C_n} \tag{2}$$

where T_a is the average daily air temperature (° C), a_m is the antecedent moisture index (m), and C_n is the carbon to nitrogen (C/N) ratio of residue and roots at senescence.

Moisture index, a_m, is calculated from (Ligeon and Johnson, 1960):

$$a_m = \sum_{i=1}^{5} \frac{P_i}{i} \tag{3}$$

where P is precipitation depth on a given day (m), and i is the day number with the present day being 1, previous day being 2, etc. The a_m values greater than 0.01 m are set to 0.01 m to reduce the percent decomposition of above-surface and surface residue during high precipitation periods.

Because residue samples contain both stem and leaf materials, r_0 cannot be measured directly. Thus, the constants a and r_0 in equation 1 are combined and replaced by a coefficient α:

$$\frac{M_t}{M_{t-1}} = (1 - \alpha\,\tau)^2 \tag{4}$$

MATERIALS AND METHODS

The decomposition of above-surface, surface, buried residue, and buried root was studied for five crops at the Midwest Claypan Experimental Farm located near Kingdom City, Missouri. Fresh residue and root samples for corn, soybean, wheat, and grain sorghum were collected at senescence from research plots near the experimental site. Cotton residue and root samples were obtained at the Delta Research Center located near Boothill, Missouri.

Approximately 50 g of oven-dried crop residue and 25 g of oven-dried crop roots were placed in fiberglass bags of sizes 0.30 × 0.30 m and 0.15 × 0.30 m, respectively. The initial residue mass in the bags was equivalent to a 5.5-Mg/ha application rate.

Experimental design was a randomized complete block with five replications. Each block consisted of five 11×16 m plots representing the five crop types. Each plot was divided into 11 subplots (1×1.5 m) representing sampling times. Each subplot had a residue bag placed 0.15 m above, on, and 0.15 m below the surface of the soil and a dead root bag buried at the 0.15-m depth. Frames made of 13-mm rigid aluminum conduits were used to hang above-surface residue bags.

Bags containing residues were oven-dried at 65° C for 24 h to obtain initial oven-dry weights before being placed in the field on 27 October 1988. Bags were collected 11 times during the two-year study.

The first sampling date was on 15 December 1988, when the air temperature had decreased to about 4° C. The second sampling date was 14 April 1989, when the air temperature started to get warmer (> 10° C). Assuming rapid decomposition from May through August, samples were collected on 25 May, 21 June, 21 July, and 21 August 1989. The last sampling date for the first year of the study was 27 October 1989, one year after the study was initiated. To provide a soil-water-air environment representative of row-cropping, corn was planted in April 1989 and 1990 on both sides of the rows where residue bags were placed. Assuming that most of the easily decomposed compounds were lost during the first year of the study, samples were collected only four times during the second year of the study (24 April, 25 June, 30 August, and 27 October 1990).

Five residue bags for each crop type and placement were collected at each sampling date. Residue bags were dried at 65° C for 24 h to determine their dry weights. Because most of the bags were contaminated with soil, corrections were made for the addition of soil by analyzing decomposition on an ash-free basis. The procedure described by Parker (1962) was followed in the ash percentage determination. To determine the initial ash percent of each residue and dead root type, five samples (approx. 5 g for each sample) from each treatment were oven dried, ground, and ashed at 600° C for 24 h. The initial ash percent for corn, soybean, wheat, grain sorghum, and cotton were: 8, 11, 7, 13, and 8% for residues and 20, 15, 40, 10, and 4% for dead roots, respectively. At each sampling date, the final ash percent of each sample was also determined. The decomposition loss was calculated using the following equation:

$$R = \frac{W_i A_i - W_f A_f}{W_i A_i} \tag{5}$$

where R is the decomposition loss (fraction), W_i is the initial oven dry weight, A_i is the initial ash percent, W_f is the final oven dry weight, and A_f is the final ash percent.

Daily air temperature and precipitation, and the initial C/N ratio of the fresh residues and roots were required to evaluate the residue decay model. Temperature and precipitation data were obtained from a weather station located within 30 m of the experimental site. Average monthly air temperature and monthly precipitation for the study period are given in table 1. Plant N content was

Table 1. Mean monthly temperature and rainfall for the study period

Month	Year	Mean Monthly Temperature (° C)	Monthly Precipitation (mm)
October	1988	10.3	24.4
November		7.5	118.4
December		1.5	83.8
January	1989	3.8	30.2
February		–4.6	28.7
March		6.5	55.6
April		12.1	45.2
May		16.0	88.9
June		20.4	55.9
July		23.3	86.4
August		21.8	170.9
September		16.5	66.3
October		13.6	12.5
November		7.6	11.2
December		–5.0	18.3
January	1990	4.8	35.1
February		4.4	102.1
March		8.4	122.9
April		12.0	63.8
May		15.3	257.3
June		22.1	248.2
July		23.7	107.2
August		22.6	101.9
September		21.1	42.2
October		12.9	77.2

Table 2. Initial C/N ratio for corn, soybean, wheat, grain sorghum, and cotton residues and dead roots

	C/N Ratio	
Crop Type	Residue	Dead Root
Corn	29.1	19.9
Soybean	27.9	29.8
Wheat	74.1	44.1
Grain sorghum	21.3	36.4
Cotton	23.1	49.2

determined using a Kjeldahl method by the Experiment Station Chemical Lab at the University of Missouri-Columbia (Jones, 1984). Initial carbon contents used for residue and dead root were 40, and 28%, respectively, on a dry weight basis (Buyanovsky and Wagner, 1986). Mean initial C/N ratios for corn, soybean, wheat, grain sorghum, and cotton residues and dead roots are given in table 2.

Statistical analysis of data was done by analysis of variance. The least significance difference (LSD) was calculated and used to compare all simple treatment means.

RESULTS AND DISCUSSION

Residue type and placement effects on the decomposition of corn, soybean, wheat, grain sorghum, and cotton are presented in figure 1. Decomposition of corn, soybean, grain sorghum, and cotton residues was not noticeably different during most of the study period for above-surface, surface, and buried residues. The fact that their initial C/N ratios were not significantly different (see table 2) may have contributed to the similarities in their decomposition. Respective overwinter losses (days 0 through 169) for corn, soybean, grain sorghum, and cotton were: 11.9, 14.3, 10.7, and 13.5% for above-surface; 14.2, 20.7, 19.6, and 19.3% for surface; and 35.6, 41.5, 46.1, and 35.6% for buried residue. Average daily air temperature and total precipitation for this period were 4.8° C and 359 mm, respectively. Mass losses after 12 months for corn, soybean, grain sorghum, and cotton were 41.1, 37.3, 44.5, and 39.8% for above-surface; 65.6, 66.0, 65.8, and 57.6% for surface; and 78.4, 79.2, 80.2, and 75.9% for buried. Broder and Wagner (1988) reported 78 and 86% of mass losses for buried corn and soybean residues, respectively. Total precipitation for the first year was 855 mm, which was 10% lower than the long-term average. Decomposition was relatively slower during the second year of study for surface and buried residue because most of the easily decomposed compounds were gone. Total precipitation during the second year was 1188 mm. Mass loss during the second year was 15 and 7.5% for surface and buried residue, respectively. Approximately 25% of the initial above-surface residue mass was decomposed in the second year.

Alberts and Shrader (1980) in southwestern Iowa studied the decomposition of surface-applied corn stalks and reported a higher (79%) mass loss after one year. The fact that they did not use fiberglass bags in their study may have attributed to the higher mass loss. They also reported a 53% overwinter mass loss, which is much higher than the 14.2% loss observed in this study.

Decomposition of wheat residue was slower than corn, soybean, grain sorghum, and cotton residue. Overwinter losses were 2.9, 7.7, and 32.0% for above-surface, surface, and buried residue, respectively. After one year, 16.8, 35.5, and 69.2% of above-surface, surface, and buried residue had decomposed, respectively. By the end of the second year, above-surface, surface, and buried residue lost 38.3, 51.5, and 82.9% of their original mass, respectively. Decomposition of buried wheat residue observed in this study was similar to the decomposition reported by other investigators. Douglas et al.(1980) in eastern Oregon reported 24.4, 64.5, and 85% mass losses for overwinter, one-year, and two-year exposures, respectively. Brown and Dickey (1970) observed similar values for mass loss in Montana. Surface and above-surface residue decomposition reported by these investigators were lower than those observed in this study. Douglas et al. (1980) reported one- and two-year mass losses of 15.9 and 25.3% for above-surface residue; and 19.2 and 31.0% for surface residue, respectively. Brown and Dickey (1970) reported one- and two-year mass losses of 8.8 and 22.0% for above-surface residue; and 14.3 and 31.2% for surface residue, respectively. The lower residue losses in eastern Oregon and Montana can be attributed to much lower precipitation and relative humidity compared to north-central Missouri. Annual precipitation was 400 and 480 mm for the eastern Oregon and Montana sites, respectively.

Root decomposition was faster than surface and above-surface residue and slightly slower than buried residue. Grain sorghum roots had the most rapid decay, loosing 39.2% of its total mass over the initial 169 days compared with 31.7% for corn, 23.5% for soybean, 22.8% for wheat, and 18.5% for cotton. After one year, root mass losses were 65.2, 50.8, 63.5, 75.7, and 45.9% for corn, soybean, wheat, grain sorghum, and cotton. Cotton roots decomposed the slowest because of their large diameter and high C/N ratio. Wheat roots had C/N ratio similar to that of cotton, but decomposed at a significantly faster rate probably because wheat roots were smaller in diameter, which resulted in more surface area for microbial contact.

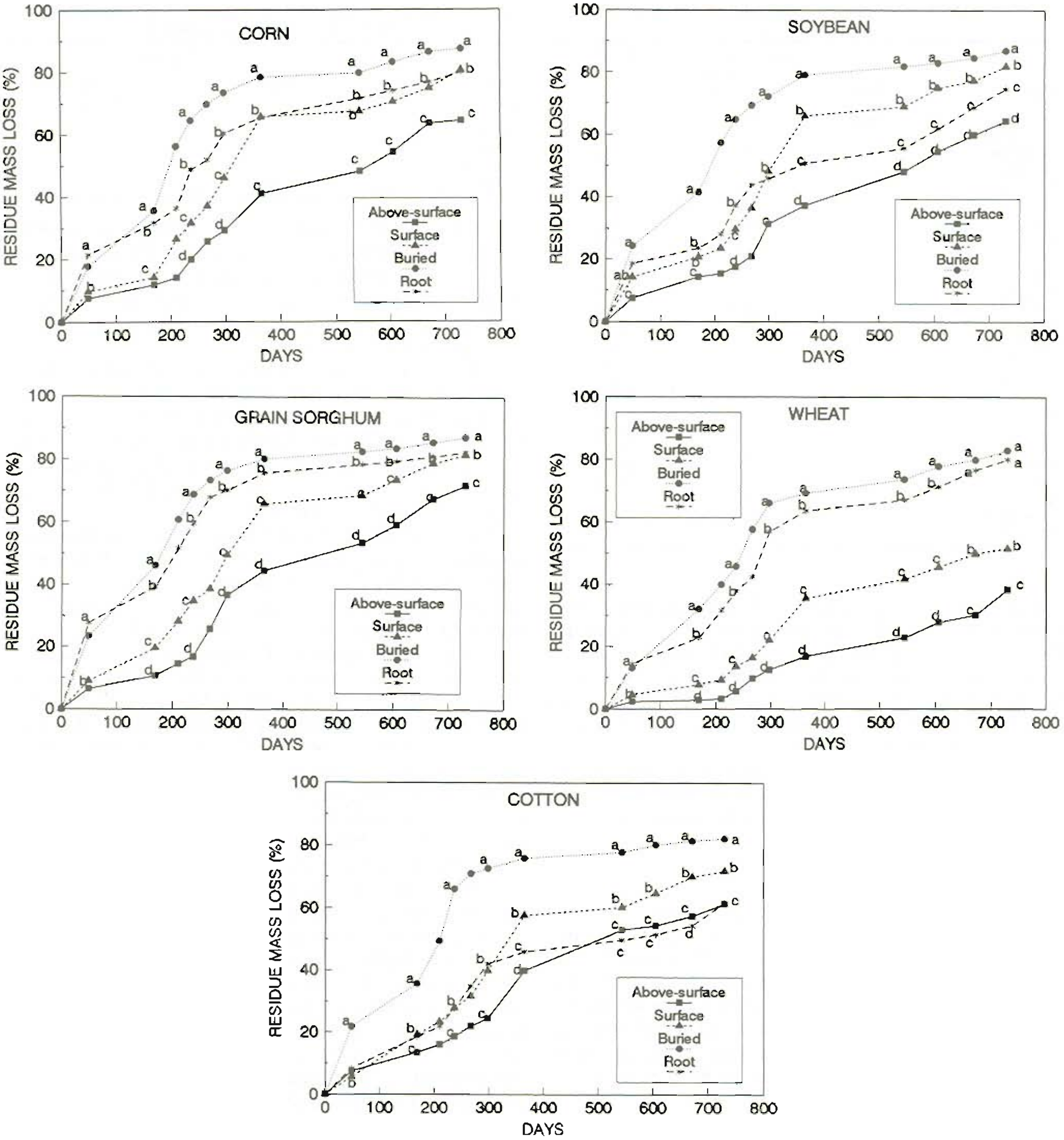

Figure 1–Residue type and placement effects on the decomposition of corn, soybean, wheat, grain sorghum, and cotton residues and roots. At each sampling period, points containing the same letter are not significantly different at 5% level.

After 24 months, corn, soybean, wheat, grain sorghum, and cotton roots lost 79.1, 74.6, 80.0, 82.5, and 61.7%, respectively, of their original mass.

The study has shown that decomposition of buried residue was noticeably faster than surface or above-surface residue. The decomposition of dead roots was faster than above-surface or surface residues but slower than buried residue. The difference in moisture level and the intimacy in contact between the soil and plant material have caused buried residue and dead roots to decay faster than above-surface and surface residues.

Table 3. Coefficient (α) values for residue decay equation*

	Equation Coefficients (α)							
	Standing		Surface		Buried		Root	
Residue Type	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Corn	0.478	0.328	0.730	0.459	1.030	0.328	0.560	0.188
Soybean	0.461	0.309	0.797	0.463	1.078	0.316	0.645	0.225
Wheat	0.377	0.384	0.811	0.658	1.990	0.745	0.960	0.400
Grain sorghum	0.342	0.270	0.578	0.353	0.875	0.245	1.360	0.383
Cotton	0.377	0.258	0.504	0.318	0.823	0.243	0.746	0.297

* Units used to compute α-values were ° C for air temperature, and m for precipitation.

RESIDUE DECAY MODEL EVALUATION

Mean percent decomposition and cumulative τ value at each sampling date were computed for each crop type and placement. Then, equation 4 was rearranged to calculate α. Mean α-values for each residue and placement are shown in table 3. Because α takes into account initial stem radius of the crop, α-values are not the same for different crop residues. If two crops have the same C/N ratio, the one crop with the smaller stem is expected to have a greater α-value and decay faster. For crop residues with different C/N ratios, a greater α-value does not necessarily mean a greater rate of decomposition. For instance, wheat residue, which generally had the highest α-values, actually decomposed slower than the other four crops because of a higher C/N ratio.

Corn, soybean, grain sorghum, and cotton residues had similar decomposition throughout the study and are categorized as group I residues. Wheat, with a decomposition that is significantly slower than that of the group I residues, is categorized as a group II residue.

The α-values vary according to residue type and placement. Buried residues and roots decay faster than surface residues and have greater α-values. Above-surface residues decay slower than surface residues and have smaller α-values. The following relationships were developed for group I residues:

$$\alpha_{s1} = 0.64\ \alpha_{f1}$$
$$\alpha_{b1} = 1.48\ \alpha_{f1} \qquad (6)$$

and for group II residues,

$$\alpha_{s1} = 0.46\ \alpha_{f1}$$
$$\alpha_{b1} = 2.45\ \alpha_{f1} \qquad (7)$$

where α_{s1}, α_{f1}, and α_{b1} are first-year α-values for above-surface, surface, and buried residues, respectively.

Decomposition was slow in the second year of the study; hence, second-year α-values are much smaller than first-year values. For group I residues,

$$\alpha_{s2} = 0.736\ \alpha_{s1}$$
$$\alpha_{f2} = 0.61\ \alpha_{f1}$$
$$\alpha_{b2} = 0.30\ \alpha_{b1} \qquad (8)$$

For group II residues,

$$\alpha_{s2} = 1.00\ \alpha_{s1}$$
$$\alpha_{f2} = 0.81\ \alpha_{f1}$$
$$\alpha_{b2} = 0.37\ \alpha_{b1} \qquad (9)$$

where α_{s2}, α_{f2}, and α_{b2} are second-year α-values for above-surface, surface, and buried residues, respectively.

Decomposition of corn, soybean, grain sorghum, and cotton roots were not similar and cannot be categorized into the same group. For corn, soybean, wheat, grain sorghum, and cotton roots α-value ratios between root and surface residue were 0.78, 0.81, 1.18, 2.35, and 1.48, respectively. Root decomposition was also slow in the second year of the study and α-values obtained were relatively small, compared to the first-year data. Ratios between second- and first-year α-values for corn, soybean, wheat, grain sorghum, and cotton roots were 0.34, 0.35, 0.42, 0.28, and 0.40, respectively.

Applicability of the residue decay model to describe mass loss was tested using decomposition data. Predicted versus measured percent decomposition for all crop residue placements and roots are presented in figure 2. In all cases, model calculations compared well with measured values. Slopes of relationship between predicted and measured values were not significantly different from 1. Most of the data points, except for some buried residue and root data, were close to the 1:1 line.

The model did not predict as well for buried residue and roots as it did for the other placements. The study showed an initial rapid mass loss for buried residues and roots when the average daily air temperature was less than 5° C. The mass losses ranged from 32 to 42% for buried residues and 19 to 39% for dead roots. Once most of the easily decomposed materials were lost, decomposition proceeded slowly even when the conditions were optimum for the process to occur. For this reason, the measured buried residue and root mass losses were significantly higher than the predicted values during the initial period of the study and lower at the later stage. The model was run using daily air temperature and precipitation as inputs. According to the model, if daily average air temperature is low (close to 0° C) or the moisture index (eq. 3) approaches 0, the decomposition process is assumed to be insignificant or slow. This may not be true in the case of buried residue and roots because soil temperature and soil moisture could be higher than the air temperature and surface moisture, particularly during part of the initial overwinter decomposition period.

Although the accuracy of model predictions for buried residues and roots is quite satisfactory for erosion prediction purposes, better results might have been obtained if soil temperature and soil moisture data had been used. Unfortunately, these soil variables were not measured.

SUMMARY

The decomposition of corn, soybean, wheat, grain sorghum, and cotton residues was studied for two years under field conditions using fiberglass bags placed 0.15 m above, on, and 0.15 m below the soil surface. Also, dead root samples from the same crops were placed 0.15 m below the surface. Crop residues with a high C/N ratio (e.g., wheat) decayed at a slower rate than residues with a low C/N ratio (e.g., corn). Buried residue and roots decayed faster than above-surface or surface residues. Above-surface residue decayed slower than surface residue. Information from the residue study was used to determine α coefficients for corn, soybean, wheat, grain sorghum, and cotton residues and roots that predict above-

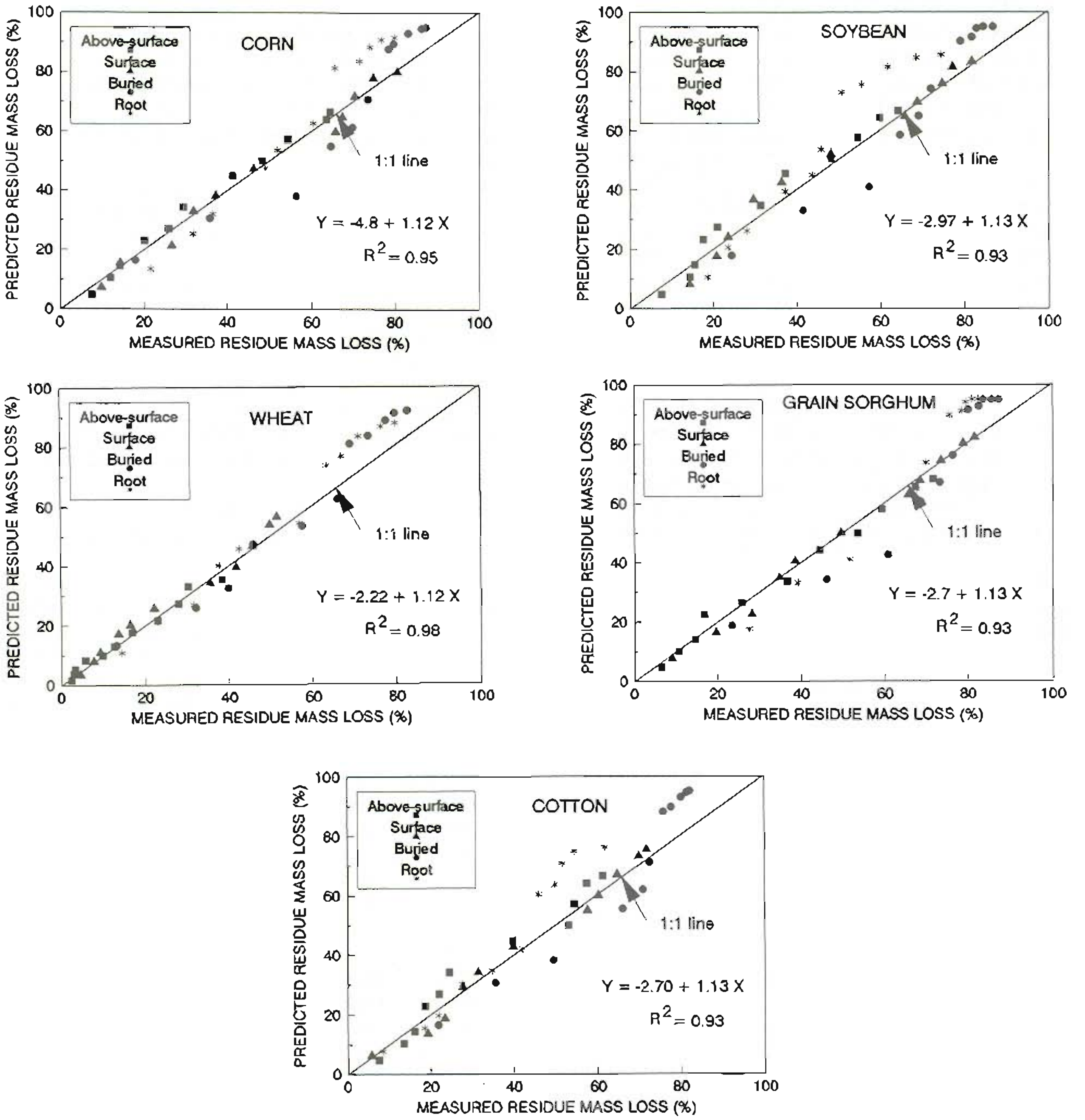

Figure 2–Predicted vs. measured residue mass loss for corn, soybean, wheat, grain sorghum, and cotton residues and roots. Residues were placed above, on, and below the soil surface. Roots were placed below the soil surface.

surface, surface, buried residue, and dead root mass for any crop. These coefficients, which account for differences in residue type and placement, are used in a theoretically derived residue decay model.

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