Straw Decomposition in Irrigated Soil: Comparison of Twenty-three Cereal Straws

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ABSTRACT

The objective of this research was to evaluate field decomposition of 23 cereal grain straws. Straw samples of 'Fieldwin' and 'Owens' soft white spring wheats (*Triticum aestivum* L.); 'Borah' and 'McKay' hard red spring wheat; 'Nugaines', 'Daws', 'Lewjain', 'Stephens', and 'Hill 81' soft white winter wheats; 'Weston'; 'Manning', 'Neeley' hard red winter wheats; 'Advance', 'Steptoe', 'Lud', 'Pirolene', and 'Klages' spring barleys (*Hordeum vulgare* L.); 'Kamiak', 'Boyer', and 'Schuyler' winter barleys; Waid durham wheat (*Triticum durum* Desf.); and 'Flora' and 'Palouse' triticales (*Triticale hexaploide* Lart.); were buried in field plots. The straw bags were removed at intervals during 1 yr and analyzed for the amount of decomposition, and C and N contents. Final decomposition ranged from 54% for the Borah wheat straw to 75% for the Lud barley straw with about half of the straws decomposing 64 or 65%. The hard red spring wheat and triticale straws decomposed the slowest and two spring barley straws decomposed most rapidly, but no completely systematic differences were observed for different genera of straws. The original straw N concentrations ranged from 2.2 to 12.5 g/kg. Nine straws lost N during the incubation period from September to November while eight increased in N concentration during this time. In the next three incubation periods, from November to the following October, nearly every straw sample increased in N concentration. The total N weight in the straw increased to the May sampling and then decreased thereafter. This pattern indicates that the straw was releasing N as it was mineralized and became available for utilization by the growing corn crop. Carbon/N ratios ranged widely in the initial straw samples, becoming more nearly uniform as the decomposition process developed. The C/N ratios remained fairly high avg 41 for the final sampling even though the straw in every case had released N into the soil during the last sampling period. Regression analysis of total decomposition and change in weight of N in the wheat straw samples for the first 67-d incubation in the field showed a linear relationship with decomposition during the year, decreasing with increasing N loss in the early stage.

Additional Index Words: **wheat (*Triticum aestivum* L.) straw, barley (*Hordeum vulgare* L.) straw, triticale (*Triticale hexaploide* Lart.) straw, N, C.**

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CROP RESIDUE DECOMPOSITION studies reported in the literature have been conducted both in the laboratory and the field. In field studies Smith and Douglas (1971) observed 20% straw weight loss in 10 weeks in the fall while soil temperatures decreased from 24 to 4°C. During 56 weeks, 75% straw weight loss occurred. Greb et al. (1974) measured straw remaining in soil following wheat and fallow cycles and found that after two (3 yr) or three (5 yr) cycles at Akron, CO, one-third to two-thirds of the straw remained undecomposed. Adding N did not influence decomposition in either of the above studies but tillage had some impact in the Colorado study. Where crop residues where mixed in the soil, decomposition increased. Allison (1973) also indicated that N addition seldom influenced plant residue decomposition in the field.

Jenkinson (1971) surveyed the literature on plant residue decomposition and reported that the proportion of crop residue decomposed under different climatic conditions with different plant materials was remarkably similar. Excluding acid soils, approximately one-third of the residue remained after 1 yr and one-fifth after 5 yr. He reported that fresh green plant materials behave similarly, contrary to the widespread belief that such residues decompose rapidly and completely in the soil.

Field experiments by Brown and Dickey (1970) on nonirrigated soils in Montana showed that 95% of buried wheat straw decomposed in 78 weeks and the N concentration in the remaining crop residue increased from 3 to 12 g/kg without added N. Under field conditions with irrigation or rainfall, leaching, and other factors such as temperature and moisture deficiency, limit decomposition decreasing the amount of N needed for maximum decomposition below previously accepted values.

Some of the earliest studies on crop residue decomposition and N immobilization related these factors to carbon-nitrogen (C/N) ratios (Salter, 1931; Hutchings and Martin, 1934). However, the C/N ratios have not always correlated well with decomposition rates and better explanations are needed. Reinertsen et al. (1984) leached straw samples with cold water, extracted water soluble C and N, and studied decomposition of the leached and nonleached straws. They postulated from these studies that the microbial biomass production and the wheat straw decomposition rates in the early stages were largely dependent on the size of the water soluble C pool. They also suggested that N immobilization was directly related to the available C in the straw. This differentiates between the total C/N ratio in favor of a C/N ratio based on available C and N. Crop residue decomposition based on available C and N seems to relate more closely to field observations than decomposition based on total C and N.

In recent years, many new cereal grain varieties have been released, and come into prominent use. An interest has developed in evaluating crop residue placement, retention, and decomposition in relation to conservation tillage and fertilizer use efficiency. Some of the more recently released cereal grain varieties produce high grain and straw yields. Decomposition characteristics are important in managing and utilizing cereal grain residues for erosion control in conservation tillage and in evaluating fertilizer requirements for efficient nutrient utilization. The research reported here was conducted to evaluate decomposition characteristics in the field of 23 spring and fall wheat (*Triticum aestivum* L. and *T. durum* Dest.), barley (*Hor-*

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Table 1. Soil temperatures and precipitation at Kimberly, ID from September 1983 through October 1984.

Date	10-cm depth Max	Min	Mean	20-cm depth Max	Min	Mean	Precipitation
	°C						mm
September 1983	21.0	14.3	17.6	19.3	16.9	18.2	24
October	12.4	7.9	10.2	11.8	10.0	10.9	20
November	6.3	4.2	5.2	6.8	5.6	6.2	67
December	0.5	0.4	0.4	1.2	0.9	1.0	80
January 1984	0.1	0.0	0.0	0.3	0.2	0.2	8
February	−0.3	−0.4	−0.4	−0.1	−0.3	−0.2	42
March	3.6	1.1	2.4	2.6	1.3	2.0	12
April	10.2	4.4	7.3	7.8	5.2	6.5	19
May	16.8	8.9	12.8	12.9	10.2	11.6	27
June	19.9	12.3	16.1	17.1	14.3	15.7	44
July	24.4	17.4	20.9	22.4	19.6	21.0	8
August	25.2	18.9	22.0	23.9	21.2	22.6	23
September	20.2	13.0	16.6	19.0	16.2	17.6	13
October	10.7	6.6	8.6	10.7	8.9	9.8	31

deum vulgare L.), and triticale (*Triticale hexaploide* Lart.) straws.

MATERIALS AND METHODS

A crop of 'Fielder' soft white spring wheat was harvested in the fall of 1983 at Kimberly, ID. After harvest, the remaining straw was baled and removed and the stubble and chaff burned. The plot area, which was part of a crop residue management experiment, was disked and Fielder soft white spring wheat straw containing 3.5 g N/kg was applied at 5 Mg/ha and rototilled into the soil. Straw samples from 23 varieties of cereal grains were enclosed in fiberglass cloth bags and buried about 15-cm deep in the field plot. The plot soil was a Portneuf silt loam (coarse-silty, mixed, mesic, Durixerollic Calciorthids). The 25-g straw in each bag approximated the straw application rate of the 5 Mg/ha plot treatment. No nitrogen was added to the straw in the bags or to the plot in which the bags were buried.

Straws that were used were as follows; soft white spring wheat, 'Fieldwin' and 'Owens'; hard red spring wheat, 'Borah and McKay'; soft white winter wheat, 'Nugaines', 'Daws', 'Lewjain', 'Stephens', and 'Hill 81'; hard red winter wheat, 'Weston', 'Manning', and 'Neeley'; spring barley, 'Advance', 'Steptoe', 'Lud', 'Priolene', and 'Klages'; winter barley, 'Kamiak', 'Boyer', and 'Schuyler'; durham wheat, 'Waid'; and triticale, 'Palouse' and 'Flora'. The spring wheat, triticale, and spring barley straws were obtained from a cereal nursery located on a farm near Burley, ID. The winter wheat, durum wheat, and barley straws were obtained from a cereal nursery from the Univ. of Idaho Research and Extension Center at Parma, ID. The straw samples were coarsely ground in a Wiley mill through a 1-cm screen and mixed prior to weighing and bagging.

Two hundred seventy-six straw bags were buried 16 Sept. 1983, which provided three replications per straw variety for each of four sampling dates. The first set of straw bags was removed from the plots on 22 Nov. 1983 when the soil temperature at the 10 cm depth had decreased to 4°C (Table 1). The second set was removed on 22 Mar. 1984 when the soil temperature had increased to 4°C. The third set of straw samples was removed from the plots on 18 May 1984, just prior to planting the plot area to silage corn (*Zea mays* L.). The fourth and final set of straw bags was removed from the plots on 4 Oct. 1984 after the corn silage crop was harvested.

Soil samples were removed from the top 15 cm of the plot area where the straw bags were buried on 20 June 1984 and analyses for NO_3^- showed 7 g N/Mg soil. The plot area was furrow irrigated as needed to grow the corn crop. The irrigation furrows were spaced at 0.76-m intervals. Water was applied to alternate furrows for about 16 h at approximately 10-d intervals. With each irrigation the water soaked to or beyond the two adjacent corn rows. At midseason the irrigations were changed to the dry furrows for subsequent irrigations. Irrigations were based on locally determined evaporative demands for water.

Upon removal of the straw bags from the plots, adhering soil was removed by brushing the surface, the bags were dried at 60°C, and decomposition was determined by weight loss. Straw from the first sampling was relatively clean of soil but later samplings contained some soil that required removal before obtaining accurate straw weights. The straw was placed in a pneumatic seed cleaner where the straw and soil were easily separated. Plant roots were removed from the straw if any were found in the last sampling. The straw was ground and analyzed for total N by a Kjeldahl method (Carter et al., 1967) and for total C by combustion at 900°C. Decomposition percentage, N percentage, N weight, and C/N ratios were calculated for each straw sample. Soil temperatures and precipitation for Kimberly, ID for the study period are presented in Table 1. Additional details about the fiberglass bags and moisture considerations were published in an earlier paper (Smith and Douglas, 1971). The data were tested for mean separations by Duncan Multiple Range Test (LeClerg, 1957).

Table 2. Straw weights during decomposition in the field at four sampling dates.

Variety	Type	22 Nov. 1983	22 Mar. 1984	18 May 1984	4 Oct. 1984	Decompos. 4 Oct. 1984
		g				%
Borah§	HRSW†	21.3bcd	19.1bcd‡	16.9cd	11.4a	54
Palouse	Trit.	21.2cdef	19.4bc	16.2efg	10.5b	58
Flora	Trit.	21.9a	20.3a	17.4ab	10.4bc	58
McKay	HRSW	20.8fgh	19.4bc	16.2efg	10.4bc	58
Owens	SWSW	20.4hi	18.0f	16.3efg	10.1bc	60
Manning	HRWW	21.0efg	18.3ef	16.9cd	9.9c	60
Kamiak	WB	21.0efg	19.5b	17.0bcd	9.5d	62
Weston	HRWW	20.8fgh	19.2bc	17.5a	9.1e	64
Fieldwin	SWSW	18.2klm	16.5h	15.1h	9.0ef	64
Advance	SB	17.2n	16.4h	14.4i	9.0ef	64
Klages	SB	19.0i	17.5g	15.4h	9.0ef	64
Boyer	WB	21.6abc	19.5b	16.6de	9.0ef	64
Nugaines	SWWW	20.4hi	19.1bcd	15.9g	8.9efg	64
Neeley	HRWW	21.0efg	18.7de	16.4ef	8.9efg	64
Daws	SWWW	20.2i	19.5b	17.1abc	8.8efg	65
Stephens	SWWW	20.4hi	19.0cd	17.5a	8.7efgh	65
Schuyler	WB	21.7ab	19.2bc	16.0fg	8.6fgh	65
Steptoe	SB	18.2klm	15.8i	13.9j	8.5ghi	66
Lewjain	SWWW	20.8fgh	19.5b	17.1abc	8.3hi	67
Waid	DW	18.4k	17.4g	15.2h	8.1i	68
Hill 81	SWWW	20.7gh	19.0cd	17.0bcd	7.5j	70
Pirolene	SB	17.8lm	15.7i	14.1ij	7.2j	71
Lud	SB	17.6m	15.4i	13.5k	6.2k	75
Means		20.1	18.3	16.1	9.0	64

† HRSW = hard red spring wheat, HRWW = hard red winter wheat, Trit. = Triticale, SWSW = soft white spring wheat, SWWW = soft white winter wheat, SB = spring barley, WB = winter barley, DW = durham wheat.

‡ Duncan Multiple Range Test, weights in each column followed by the same letter or letters are not different at the 1% significance level.

§ Straws are ranked according to increasing decomposition for the last sampling. The beginning weight of all straw samples was 25 g.

RESULTS AND DISCUSSION

Decomposition of the 23 cereal straws during the 384 d in the field ranged from 54% for the Borah hard red spring wheat straw to 75% for the Lud spring barley straw (Table 2). Approximately one-half of the straw varieties decomposed 64 to 66%, very near the

Table 3. Nitrogen concentrations in straw decomposing in the field.

Variety	Straw sampling dates: 16 Sep. 1983	22 Nov. 1983	22 Mar. 1984	18 May 1984	4 Oct. 1984
	nitrogen, g/kg				
Borah	12.5	3.5c†	3.9a	6.7f	8.6d
Palouse	3.9	4.0de	5.2ef	7.0hi	7.3b
Flora	2.4	3.2ab	3.9a	5.2cd	7.5b
McKay	7.1	3.4bc	3.7a	7.3i	8.8e
Owens	9.9	3.8d	4.8c	5.7e	8.0c
Manning	5.0	4.3fg	5.6g	7.0gh	8.8e
Kamiak	3.6	4.5gh	4.5b	5.1bc	8.4d
Weston	3.6	4.6h	5.3f	6.8fg	8.1c
Fieldwin	8.9	6.4k	6.6j	7.9j	8.9ef
Advance	11.8	7.6l	7.1k	8.4l	9.4hi
Klages	8.0	5.9j	6.2i	7.0gh	6.9a
Boyer	2.9	3.8d	5.0de	7.1hi	8.8e
Nugaines	5.1	5.0i	5.2ef	8.3kl	11.6m
Neeley	3.4	4.6h	6.0hi	7.3i	9.6ij
Daws	3.0	4.3fg	4.5b	6.6f	9.7i
Stephens	4.0	4.1ef	4.7bc	4.9ab	10.3k
Schuyler	4.2	3.8d	5.3f	8.1jk	8.8e
Steptoe	8.9	7.8l	9.1m	10.7o	10.8l
Lewjain	2.6	3.0a	3.8a	5.4d	9.0ef
Waid	6.1	6.2k	5.9h	7.3i	9.3g
Hill 81	2.2	4.0de	4.8cd	4.7a	9.1fg
Pirolene	10.3	7.8l	8.3l	9.4m	9.1fg
Lud	9.0	8.7m	8.2l	9.9n	10.2k
Means	6.0	5.0	5.6	7.1	9.0

† Duncan Multiple Range Test, concentrations in each column followed by the same letter or letters are not different at the 1% significance level.

Table 4. Nitrogen weight in straw decomposing in the field.

Variety	Straw sampling dates: 16 Sep. 1983	22 Nov. 1983	22 Mar. 1984	18 May 1984	4 Oct. 1984
	nitrogen, mg				
Borah	312.5	74.1b†	73.8a	113.8fgh	102.2j
Palouse	97.5	85.7de	100.3ef	116.0ghi	77.2cde
Flora	60.0	70.4b	78.8b	90.0cd	78.2de
McKay	177.5	70.8a	72.1a	117.5hij	92.0i
Owens	247.5	78.2c	86.2c	93.5d	80.9efg
Manning	125.0	90.5fg	103.3f	117.7hij	82.7fgh
Kamiak	90.0	93.6gh	98.2e	86.7bc	79.3def
Weston	90.0	94.9h	101.6ef	118.0hij	73.6c
Fieldwin	222.5	116.0j	108.7g	117.4hij	81.0efg
Advance	295.0	131.3i	116.8h	121.1j	84.1gh
Klages	200.0	111.6j	109.4e	106.4g	62.1a
Boyer	72.5	81.9cd	98.3e	118.5ij	79.4def
Nugaines	127.5	101.4i	98.5e	131.9k	101.4j
Neeley	85.0	95.5h	112.8g	119.9ij	86.0h
Daws	75.0	86.8ef	88.6cd	112.2fg	84.1gh
Stephens	100.0	84.4de	89.5cd	84.4b	90.0i
Schuyler	105.0	81.5cd	101.9ef	130.4k	76.2cd
Steptoe	222.5	141.3n	145.0j	148.0l	90.4i
Lewjain	65.0	61.8a	74.1ab	93.3d	73.2c
Waid	152.5	113.0jk	102.4ef	110.9f	73.6c
Hill 81	55.0	83.1de	91.3d	80.4a	67.1b
Pirolene	257.5	138.5m	129.8i	131.5k	65.8ab
Lud	225.0	153.1o	127.1i	134.1k	63.0ab
Means	154.4	97.4	100.4	112.8	80.2

† Duncan Multiple Range Test, N weights in each column followed by the same letter or letters are not different at the 1% significance level.

two-thirds loss reported by Jenkinson (1971). The hard red spring wheat and triticale straws decomposed the slowest while two of the spring barley straws decomposed the fastest.

Nitrogen concentrations were evaluated by ranking the varieties in Table 3 the same as Table 2, which was for increasing decomposition at the final sampling. High N concentration in straw has frequently been suggested to stimulate rapid straw decomposition, but that was not observed in this experiment. The Borah hard red spring wheat contained 12.5 g N/kg at the time of incorporation into the soil. The N concentration in the Borah straw decreased to 3.5 g/kg at the first sampling on 22 Nov 1983. This same phenomenon was observed with eight other straws, although to a lesser extent than with Borah. We can therefore assume that some of the N in the relatively high N straw was in a soluble form and was leached out of the straw by fall rainfall. Cumulative fall precipitation was 111 mm before the November sampling (Table 1). This observation is consistent with the Reinertsen et al. (1984) observation of water soluble fractions of plant material that are easily extracted and presumed to decompose rapidly. Following the November sampling, the N concentration in the straw increased with each sampling to the time of the October sampling. An average of 9.0 g N/kg was observed for the final straw sampling in October 1984. One of the most rapid decomposing cereal straws was Hill 81, a soft white winter wheat. The initial N concentration was 2.2 g/kg, which was the lowest of any straw used in this experiment. Nitrogen was immobilized, the concentration increased during the decomposition period, and the final N composition was 9.1 g/kg.

With the 3.5 g N/kg straw that was applied to the treatment block where the straw bags were buried, N immobilization by microorganisms probably was similar to that of some of the bagged straw samples with similar initial N concentrations. The Kamiak and Weston straw increased from 3.6 to 4.6 g N/kg in the first sampling period to November 22. The average N concentration in all of the straw samples at the November 22 sampling date following 67 d in the field was 5.0 g/kg. With 3.5 g N/kg straw the blanket straw application that was mixed in the soil for the plot area probably had little effect on either decomposition or N immobilization or release from the straw in the bags.

The weight of N in the straw samples was calculated initially and for each of the sampling dates when straw samples were removed from the field (Table 4). In 16 of the 23 straws, the weight of N decreased from the time the straw was placed in the soil until the first sampling in November. The average N decrease for the 23 straws was 37%. Net N immobilization then occurred in the bagged straw and the weight of N increased in the straw, a small amount in the winter months and somewhat more during the spring. This total increase in N weight averaged about 16% for the 23 straws. During the summer while the corn crop was growing, weight of N decreased in every straw sample, indicating that the straw could be a source of N for the growing corn crop. The average N weight decrease during this period of almost 24 weeks was about 29%. A large number of significant differences were found between N weight in straw samples at the various sampling dates (Table 4).

The discussion above relates to net N immobilization or mineralization. Yoneyama and Yoshida (1977) studied N mineralization and immobilization in rice (*Oryza sativa* L.) residue decomposition using ^{15}N as

Table 5. Carbon content and C/N ratios in straw samples decomposing in the field.

Variety	Straw sampling dates: 16 Sep. 1983	22 Nov. 1983	22 Mar. 1984	18 May 1984	4 Oct. 1984
	C/N ratio				
Borah	33	119m†	109o	58h	43h
Palouse	103	97i	76ij	55fg	45jkl
Flora	165	125n	104n	74j	60m
McKay	68	121m	118p	54f	46kl
Owens	41	108l	88lm	69i	47l
Manning	82	91h	70g	58h	42ghi
Kamiak	112	89gh	88lm	75j	39def
Weston	118	87g	75hi	57gh	44ijk
Fieldwin	46	64d	65e	51e	41fgh
Advance	34	53b	57d	48d	41fgh
Klages	52	71e	67ef	58h	60n
Boyer	143	104k	77ij	57gh	36bc
Nugaines	79	79f	78j	44c	28a
Neeley	125	87g	66ef	54f	37cd
Daws	135	91h	89m	58h	37cd
Stephens	102	98i	86kl	85l	37cd
Schuyler	96	105k	73h	47d	34b
Steptoe	45	54b	45b	37a	38cde
Lewjain	158	134o	107o	70i	40efg
Waid	66	61c	68fg	53ef	39def
Hill 81	199	101i	85k	82k	38cde
Pirolene	40	54b	32a	43c	42cde
Lud	46	47a	49c	40b	38cde
Means	90	89	77	58	41
	carbon, g/kg				
Mean	409	405	403	376	365

† Duncan Multiple Range Test, ratios in each column followed by the same letter or letters are not different at the 1% significance level.

a tracer. They reported that both immobilization and mineralization occurred at the same time even in the early stages of decomposition when N concentrations were low and only immobilization could be observed without tracer N.

Carbon/N ratios were calculated for each of the straw varieties initially and after each straw sample was removed from the field plot. Carbon/N ratios have been used in the past as indications of the crop residue potential for immobilizing or releasing N into the soil system in which the residue decomposed. Carbon/N ratios varied from 33 to 199 in the straw samples as they were buried in the field plots (Table 5), and their initial C/N ratios had little relationship to either decomposition rates or N availability or immobilization. From the sample burial on September 16 to the first sampling on November 22, almost half of the straw samples' C/N ratios increased, while the other half decreased. In the following decomposition periods in the field, the ratios generally decreased and the range and variability of the ratios decreased greatly. During the summer months while the corn grown on the plots reached maturity and was harvested, the C/N ratios of the straw decreased from an average of 58 to 41. During this same time, even though the C/N ratios remained relatively high, the straw samples were a source of mineralized N that could be utilized by the growing corn crop. Carbon/N ratios were of limited value in this study in determining the N immobilization and mineralization potential of cereal grain straw.

Carbon concentrations of the straw samples as determined on each sample were not statistically different for any sampling date. Therefore, the mean C contents for all samples on each sampling date are reported in Table 5. Changes in C/N ratios did not occur because of simultaneous changes in C and N but resulted predominantly from immobilization or mineralization of N.

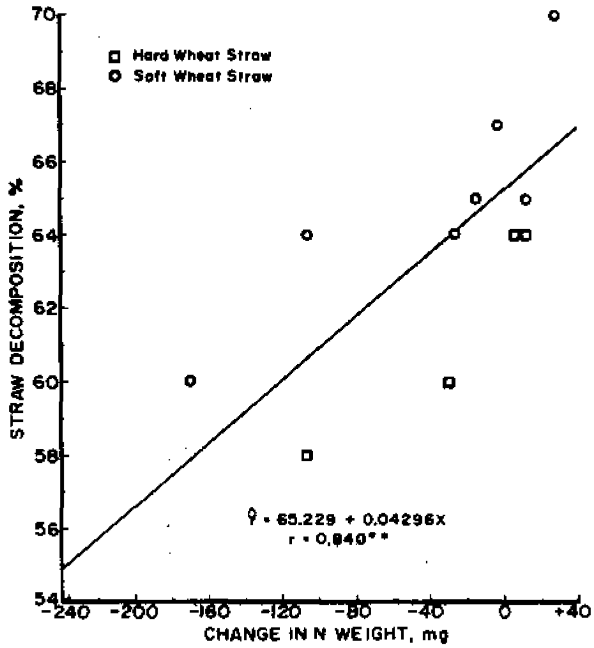

Fig. 1. Regression analysis of total decomposition and change in weight of N in straw samples for the first 67-d incubation in the field with wheat straw samples.

Reinertsen et al. (1984) reported a water soluble component of crop residues that appeared to be readily decomposible. Several of the straws observed in this experiment also had a water soluble component or other readily decomposable fraction that changed considerably during the first 67 d of incubation in the field, resulting in sizeable decreases in N percentage and N weight for Borah and several other straws. Regression analyses between straw decomposition in the field for 384 d and the change of N weight in the first 67 d incubation showed significant correlations for the soft and hard wheat straws (Fig. 1). The relationship is represented by $\hat{Y} = 65.229 + 0.04296\ X$, and $r = 0.840^{**}$. Those straws that lost the most N during the first 67 d, decomposed the least during the remaining months in the field and conversely, those that lost the least N or immobilized N decomposed fastest overall.

The structure and composition of the straws that allows large losses of N through leaching, denitrification, or decomposition of the straw in the early incubation phase merits further study. Where large losses of N occur in the early incubation period, the residual straw becomes depleted of N and water soluble, readily decomposable components. Subsequent decomposition is therefore slower because the available substrate has been depleted. The full significance of the large N losses during initial decomposition and subsequent slow decomposition in several of the straws needs further investigating. This same pattern was not seen in barley straw decomposition. While several of the barley straw samples decomposed 20% or more and lost a large amount of N in the first 67† incubation, subsequent decomposition was not greatly retarded as it was in the wheat straw samples. Too few triticale straw samples were included in the experiment to observe a pattern.

The results indicate that there are different decomposition patterns among straw varieties. In the present study, hard red wheat and triticale straws decomposed slower than the soft white wheat and barley straws. Further characterization of the straws, comparing wheat, barley, and triticale or other cereals, in concentration of water soluble components, lignin, cellulose, silica, or other components, may be useful in determining decomposition rate differences and patterns. These investigations are beyond the scope of this research project. The results of this study indicate that most of the small grain straws decompose rapidly in the field if they are buried in soil that receives sufficient moisture and has high enough temperature for the microbiological processes to proceed.

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