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Wheat Straw Decomposition in the Field[1]

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ABSTRACT

Wheat (*Triticum aestivum*) varieties 'Nugaines' and 'Lemhi' were grown on Portneuf silt loam soil with three nitrogen and three irrigation treatments in 1967. After harvest, 84 kg N/ha was applied to half of each plot before plowing. Uniform straw samples were enclosed in fiberglass cloth bags and buried in the plots September 7. The straw placed in N-treated plots received sufficient N in solution to increase the straw N from about 0.29 to 1.5%. Straw samples were recovered November 15, after the soil had cooled below 4C, and at three later sampling dates to October 3, 1968, after a bean crop (*Phaseolus* spp.) was harvested. Weight loss and total N were determined on all samplings and total C on the first sampling. Decomposition was greater with N than without it for the November sampling and the March sampling for Nugaines but not at other samplings for both varieties. The weight of N in both N-treated straw varieties decreased 55% by November 15, while in the non-N-treated Nugaines and Lemhi straw, N weight increased 12 and 32%, respectively, by March 22. Later, N moved out of all the straw samples when the N percentages were much lower than the theoretical equilibrium value.

Additional Key Words for Indexing: **N immobilization, C/N ratios.**

THE INFLUENCE of nitrogen and C/N ratios on straw decomposition has been investigated extensively (1, 8, 9, 10, 12). Bartholomew (3) reported in a review that the application of inorganic N to plant residues has both hastened and retarded decomposition. Addition of N to low-N residues generally hastened decomposition when conditions for decomposition were favorable, but if low temperature or insufficient moisture limited decomposition, N would not necessarily stimulate decomposition. Added N decreased decomposition of alfalfa residue (*Medicago sativa* L.), maize straw (*Zea mays* L.) containing 1.02% N, and bean husks (*Phaseolus* spp.) containing 2.99% N. Allison and Murphy (2) found that 2% N addition depressed CO_2 evolution from white pine (*Pinus* spp.) and loblolly pine (*Pinus taeda* L.) woods on acid soils. This was attributed to the "increase in acidity and to the salt effect of added N that was not needed." Immobilization of available soil N occurs when crop residues of low N content are incorporated into the soil. Such residues are often fertilized to

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overcome the depression of available N and to hasten decomposition of the residue. Whether or not N addition will hasten decomposition under optimum conditions depends on the nature of the crop residues in characteristics other than C/N ratios, such as toxic resins in some wood varieties, and on the amount of available N in the soil. Allison and Murphy (2) found that nitrogen addition generally did not hasten decomposition of soft woods and barks. This does not mean that no additional N was required, but that the soil provided sufficient N for the microorganisms when decomposition was slow. Smith and Douglas (13) presented evidence that straw decomposes as fast in productive agricultural land without added N as with it. The explanation is similar to Allison and Murphy's in which the needed N was supplied by the soil.

Nitrogen that is immobilized in straw decomposition is not immediately available to plants, but may become available slowly with time (3, 8, 15). However, this immobilized N may never be available with the same recovery efficiency as fertilizer N applied for a crop (4).

Most experiments on plant residue decomposition have been conducted in the laboratory or greenhouse. The experiment reported here was conducted in the field to evaluate the influence of N fertilizer and straw variety on decomposition of wheat straw (*Triticum aestivum*).

MATERIALS AND METHODS

In the fall of 1967, crops of 'Nugaines' and 'Lemhi' wheat (*Triticum aestivum*), soft white winter and spring wheats, respectively, were harvested at Kimberly, Idaho. On August 29, after the wheat was harvested, the soil was sampled. Nitrate content of the Portneuf silt loam soil was about 7 ppm N on all plots. The former wheat plots were split, and 84 kg N/ha was sprayed on half of each plot. The plots were irrigated and the straw residue plowed under. Uniform 25-g straw samples of Nugaines containing 0.27% N, and Lemhi containing 0.29% N were sewed into flat, coarse-weave, fiberglass cloth bags 15 × 30 cm in size. The straw that was to be buried in N-treated plots was treated with ammonium nitrate in solution at the rate of 312 mg N per 25 g straw immediately before burying the bags. Treatments were replicated four times. Four bags were buried in each of 48 plots at a depth of approximately 15 cm on September 7, 1967. One bag was recovered from each plot on November 15, when the soil had cooled to 4C at 10-cm depth; on March 22, 1968, when the soil had warmed to 4C; on May 22 at the time beans (*Phaseolus vulgaris*) were planted; and on October 3, 1968, after the beans had been harvested. Soil temperatures under bare soil for the time of the experiment, obtained from the National Weather Service, Kimberly, Idaho are given in Table 1. Soil moisture was maintained at what appeared to be optimum for the beans by surface irrigation.

Upon removal of the bags from the plots, adhering soil was removed, the bags were dried at 60C, and decomposition was determined by weight loss. Cleanup was easy for the first three samplings, but for the fourth, soil had sifted into the bags with the movement of irrigation water, and the soil was separated with a pneumatic seed cleaner. Bean roots that had grown into the bags were removed before weighing. After removal from the bags, the straw was ground and analyzed for total N by a Kjeldahl method (7) and for total C for the first set by combustion at 900C. Nitrogen percentage, N weight, and C/N ratio were calculated for each of the samples.

Table 1—Soil temperatures at Kimberly, Idaho from September 1967 through October 1968

Date	10-cm depth			20-cm depth		
	Max.	Min.	Mean	Max.	Min.	Mean
		°C			°C	
September 1967	23.8	15.9	19.9	20.4	18.1	19.3
October	14.6	8.3	11.4	13.0	11.0	12.0
November	7.4	3.5	5.4	7.0	5.9	6.4
December	-0.7	-2.0	-1.3	0.3	-0.3	0.0
January 1968	-0.7	-2.4	-1.6	-0.6	-0.9	-0.7
February	2.6	0.5	1.6	1.7	1.0	1.4
March	9.2	2.8	6.0	6.5	4.6	5.6
April	12.0	4.8	8.4	9.0	6.6	7.8
May	17.5	10.3	13.9	14.4	11.9	13.2
June	22.1	15.8	18.9	18.9	17.0	17.9
July	29.3	20.3	24.8	24.2	21.4	22.8
August	22.2	15.6	18.9	19.3	17.3	18.3
September	20.3	13.2	16.7	17.6	15.4	16.5
October	13.9	7.4	10.7	11.8	10.1	11.0

To assess the influence of the fiberglass cloth bag on water movement between the soil and the straw in the bag, a soil column 10 cm in diameter and 30 cm long was instrumented with four tensiometers connected to mercury manometers. A layer of fiberglass cloth from the material used for the bags was inserted horizontally across the center of the column. Tension was applied to the bottom of the column with a tension plate, and soil moisture tensions were determined from saturation to approximately 290 mm Hg.

Soil moisture tension curves from 0 to about 290 mm Hg tension were almost straight lines. In the wet phase of soil drying, the fiberglass cloth between layers of soil did not interrupt water movement enough to cause a discontinuity in the tension curves. The fact that a single layer of cloth did not interrupt water movement in a soil-to-soil system indicates that water movement in the soil-straw-soil system in the field may have been similar with or without the cloth layers. Of course, water movement through the straw was impeded but probably no more than through a straw layer plowed into the soil. In any event, the treatments in the cloth bags were similar enough to each other to be compared. The straw was moist in the bags when removed from the soil. At the last sampling, soil had sifted into the bags and mixed with the straw, decomposition had proceeded to a satisfactory extent, and therefore, it seems plausible to assume that conditions in the bag were similar to field conditions without the cloth bags. The fiberglass bags were inert and did not decompose or enter into the microbiological reactions.

RESULTS AND DISCUSSION

Decomposition of Nugaines wheat straw and nitrogen content of the straw are shown in Fig. 1. Decomposition progressed rapidly during the first period, with about 23% decomposition without added N and 28% decomposition with added N. Decomposition was very slow during the 4 months when soil temperature was below 4C, but it became much more rapid when the soil warmed above 4C. Decomposition at the end of 13 months was about 71% with and 81% without added N. Nitrogen fertilizer applied for the previous wheat crop had no significant influence on decomposition (data not shown).

The change in N content of the straw during decomposition in these field plots was very striking. The initial N content of the N-treated straw was established at about 1.5% to eliminate N deficiency as a limiting factor in decomposition. The sharp decrease in N content of the N-treated straw would not have occurred if the added N had been immobilized in the straw and released at a rate proportional to decomposition of the straw. Apparently much of the applied N was not immobilized in straw decomposition but was moved from the straw by moisture into the surrounding soil. N diffusion from treated straw

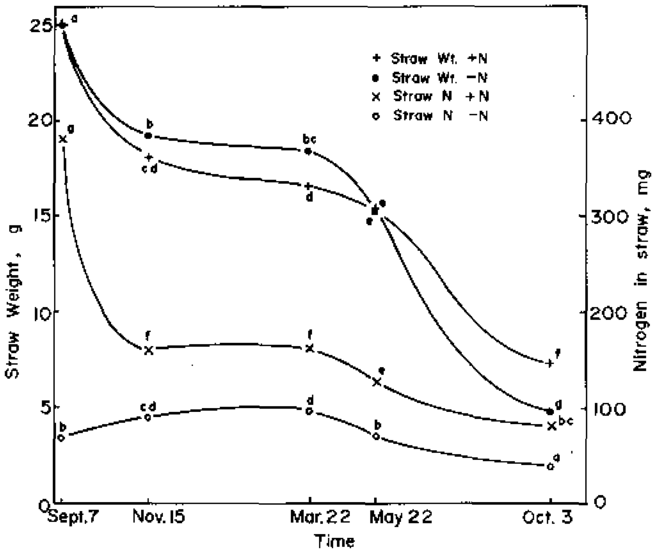

Fig. 1—Weight of Nugaines wheat straw remaining in soil at indicated dates, and N content of straw. Points associated with different letters are different at the .05 significance level (11).

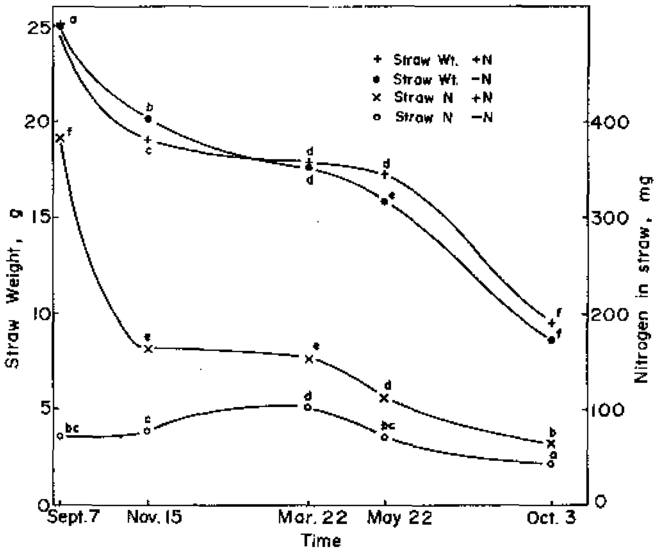

Fig. 2—Weight of Lemhi wheat straw remaining in soil at indicated dates and N content of the straw. Points associated with different letters are different at the .05 significance level (11).

to soil would be expected because of the gradient. This occurred during the time when soil temperatures decreased from approximately 23C to 4C. During the cold season, N contents remained stable, but after the soil warmed and decomposition proceeded, additional N was lost. In the straw samples without added N, the weight of N increased for a time (up to 12% increase) then decreased to the end of the incubation period.

Broadbent and Tyler (5) suggested that ammonium-nitrogen is immobilized to a greater extent than nitrate. If this phenomenon were active in this experiment, part of the N that moved out of the straw was nitrate and could be accounted for by this explanation. Perhaps some of the additional nitrogen above the 50% nitrate was ammonium-nitrogen that was nitrified and subsequently diffused from the straw.

The decomposition pattern for Lemhi wheat straw (Fig. 2) was similar to that of Nugaines. At the first sampling, November 15, the N-treated straw was decomposed more than the nontreated straw. At the March 22 sampling, decomposition of the two straws was not different, and the curves were similar to the end of the experiment in October. The average decomposition at that time was about 64%. The N curves were similar to those for Nugaines straw. Approximately 70% of the added N was gone from the Lemhi wheat by the November 15 sampling date, and was not immobilized or involved in straw decomposition. With both the Lemhi and Nugaines wheat straw, mineralization furnished sufficient N to almost eliminate differences in straw decomposition. There has been considerable speculation that Nugaines straw decomposes slower than Lemhi and other straw varieties. Many observations have been made in the field of straw residue plowed to the surface after being buried in the ground for many months. That this happens more frequently with Nugaines than with Lemhi is probably because Nugaines produces a great deal more straw. In field experiments at Kimberly, Idaho in 1967 and 1968 (14), Nugaines wheat straw yields averaged 10,800 and 6,750 kg/ha, while Lemhi straw yields were slightly more than half as great. Differences in decomposition rate between the varieties with Nugaines decomposing appreciably faster than Lemhi wheat straw under similar conditions and yield differences could have significant influence on management decisions in crop rotations that include these varieties.

In a recent report, Brown and Dickey (6) observed similar straw decomposition to that reported in this paper. Because of several basic differences between Brown and Dickey's and this experiment, these complementary results are especially interesting. Brown and Dickey's experiments were conducted at Bozeman and Huntley, Montana with cooler climate than Kimberly's under dryland conditions, and the plots were not cropped. No N was added to their straw. The experiment at Kimberly, Idaho reported here, was irrigated, and a nitrogen variable was included as well as comparison of two straw varieties. The magnitude of decomposition was similar in Montana and Idaho for the same time intervals, and the maximum nitrogen content of

Table 2—Nitrogen percentage and C/N ratios of Nugaines and Lemhi wheat straw decomposing in the field

Treatment	Sept. 7	Nov. 15	Mar. 22	May 22	Oct. 3
		Nitrogen Percentage			
Nugaines					
N added	1.52 g*	0.90 de	0.98 de	0.83 d	1.14 f
No N added	0.27 a	0.46 b	0.57 c	0.46 b	0.81 d
Lemhi					
N added	1.54 h	0.87 g	0.87 g	0.66 ef	0.69 f
No N added	0.29 a	0.39 b	0.58 de	0.45 bc	0.51 cd
		C/N Ratios			
Nugaines					
N added	26 a	43 cd	40 c	47 d	34 b
No N added	145 g	84 f	68 e	84 f	48 d
Lemhi					
N added	26 a	47 b	47 b	62 cd	59 c
No N added	142 h	105 g	70 de	91 fg	80 ef

* Numbers in each pair of rows not followed by the same letter or letters are different at the .05 significance level (11).

the straw did not in any case reach the theoretical equilibrium values observed in laboratory studies in the range of 1.5 to 1.7%.

The N percentages and C/N ratios for the two straw varieties used in this experiment are shown in Table 2. With the addition of N, both straw varieties contained approximately 1.5% N. As was observed with weight of N in both varieties, the N percentage decreased sharply during the first incubation period to approximately 0.9%. In the Nugaines wheat straw, the N percentage then increased to 1.14% by October of the next year. During this time, the N percentage in the Lemhi straw decreased to 0.69%. When N was not added to Nugaines straw, the N percentage increased from 0.27 to 0.81% during the incubation period. The nitrogen percentage in the Lemhi straw during the same time increased from 0.29 to 0.51%. Nitrogen percentages of the treated and nontreated straw samples were statistically different at each sampling date but the differences decreased with time and would be expected to disappear eventually when the system reached "equilibrium."

Two observations from these data are of particular interest. One is the dramatic decrease in N percentage with approximately 55% decrease in N weight in both N-treated straw varieties during the first incubation period. In view of the N-concentration gradient between the treated straw and the soil, this perhaps should not be startling. Many references have been made to N immobilization during straw decomposition in which N percentages increased to 1.5% or higher. It was because of this anticipated need that the N percentage of the treated straw was adjusted to 1.5%. The decrease in N percentage observed and the apparent immobilization in straw of only 27% of the added N was surprising. The other interesting observation is the relatively rapid decomposition that occurred at relatively low N percentage and wide C/N ratios in the straw. There was very little difference in decomposition between the N-treated and nontreated straw samples throughout the 13 months in the field. The N loss during the first incubation period may have minimized decomposition differences, and the soil provided N to the low-N samples, yet the C/N ratios were wide with nontreated straw and fairly narrow where N was added. The N sources from which the straw derived the additional N (both fertilizer and mineralized N) were not organic nor similar to natural straw N, so it may not be very meaningful to discuss C/N ratios in these terms. The implication is that C/N ratios under field conditions do not provide as good a guide to N requirement for straw decomposition as they do in laboratory experiments.

Under field conditions many of the factors regulating decomposition are not optimum. Unfavorable temperature during part of the fall, the winter, and some of the spring limited decomposition. This and other factors may have been limiting. Therefore, decomposition proceeded at a rate that was maximum for the limiting factor with less N than would be required if all factors were optimum. Because of limiting factors, a lower equilibrium N percentage may exist under field conditions than would be anticipated. These data indicate that this is the case and that straw will decompose at a fairly rapid rate with relatively low N percentage. Nitrogen was also released from straw with much lower N percentage than had been previously indicated. This released N should be available for crop utilization providing fertilizer value from straw at an earlier decomposition stage and at lower N percentage than would be expected. Under field conditions, of course, N immobilization does occur, but the extent and duration of immobilization under the conditions of this experiment were less than would be calculated using the equilibrium constants derived from laboratory experiments.

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