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Decomposition of wheat and barley straw treated with urea-sulfuric acid

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Summary. Wheat straw treated with 0.5 or 1.0 ml/g urea-sulfuric acid (1:1 acid in water v/v) and incubated in Protneuf or Woodburn silt loam soils in the laboratory decomposed faster than nontreated straw the first 4–6 weeks but at 12 weeks the nontreated straw had decomposed 25%–45% more. In a field experiment, urea-sulfuric acid treated straw, removed at 40-day intervals over 160 days, decomposed faster than nontreated straw. The differences were attributed to salt buildup in the laboratory samples, where electrical conductivities up to 17.6 dS/m were observed. In the field, leaching removed the excess salts. Nitrification produced up to 1875 mg NO_3^--N/kg Portneuf silt loam soil in the laboratory, indicating that nitrifying bacteria were not suppressed by the salt. Total plate counts with no straw were 1.8×10^6 microorganisms/g and with urea-sulfuric acid treated straw were 15.7×10^6/g soil after 14 days incubation. The respective actinomycete counts were 0.3×10^6 and 6.7×10^6/g for the no straw and straw-treated soils, respectively. The urea-sulfuric acid treatments suppressed straw decomposition in the laboratory and accelerated straw decomposition in the field.

Key words: Wheat – Barley – Urea – Sulfuric acid – Straw decomposition

Soil moisture and temperature are major factors controlling crop residue in the field. Another factor of major importance in crop residue management is N fertilization. Nitrogen addition to crop residues has been attributed to hasten decomposition in N-deficient soil systems and to retard decomposition in systems with adequate to excessive N (Allison and Murphy 1963). Reviews by Bartholomew (1965) and Smith and Peterson (1982) report the past and current status of corp residue decomposition research, with many citations supporting various theories and factors affecting residue decomposition. With present levels of fertilizer application on most farms, added N seldom accelerates crop residue decomposition because N is usually adequate for the needs of soil microorganisms. Other factors such as temperature and moisture can limit decomposition to the extent that N is not a controlling factor. Soil and plant additives have been promoted in the past for increasing crop residue decomposition and soil microorganism activity but most have been ineffective (Smith et al. 1961; Weaver et al. 1974). In the western United States, urea has been reacted with sulfuric acid to form a product less corrosive than sulfuric acid. This product with several formulations that contain 10%–28% N is marketed for spraying on cereal grain straw and other crop residues to aid in digestion and decomposition of the organic residues.

This paper reports the effects of urea-sulfuric acid on decomposition of cereal straw in controlled experiments in the laboratory, decomposition evaluations of the material on straw in the field, and the effects of the compound on total numbers of microorganisms and on actinomycetes in the laboratory.

Materials and methods

Straw decomposition in the laboratory. Fieldwin soft white spring wheat straw (*Triticum aestivum* L.) was treated with 1:1 v/v urea sulfuric acid in water at 0.5 or 1.0 ml/g straw. The urea-sulfuric acid had 1 mol urea reacted with 1 mol sulfuric acid and contained

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15% N and 17% S. The 0.5 ml/g application was the least that would wet the surface of the ground (<2 mm) straw. A theoretical N application on a field basis could be as follows: With 5 mg straw/ha, treated with 0.5 ml 1:1 urea-sulfuric acid in water where the original urea sulfuric acid contained 170 g N/kg, would provide approximately 300 kg N/ha. The straw was mixed in Portneuf silt loam (course-silty, mixed, mesic, Durixerollic Calciorthids) at rates of 0.5, 1.0, or 1.5 g straw/100 g air dry soil. The urea-sulfuric acid was mixed with the straw and the appropriate weight of treated straw was added to the soil to provide the straw weights desired. The 100-g soil samples containing the straw were placed in 1/2-l-bottles, wetted with 18 ml distilled water, and incubated at 26 °C. The moisture content of the soil represented about 80% of 33 kPa (0.33 bar) tension. The flasks were continuously aerated with CO_2-free air passing over the soil surface. Carbon dioxide was captured in bottles containing standard 0.1 *N* NaOH solution. The NaOH solutions were removed weekly from the incubator, treated with 10 ml 10% $BaCl_2$ solution, titrated with standard 0.1 *N* H_2SO_4 solution, and CO_2 evolution calculated. All treatments were replicated 3 times. An air blank was used to determine the small amount of CO_2 in the air supply. Airflow through the sample flasks was regulated with capillary tubes in the air tubes to the flasks.

The soil samples were removed after 12 weeks, air dried, extracted, and analyzed for NO_3^- using a specific ion electrode (Milham et al. 1970). The pH and electrical conductivity of a saturated paste extract were measured.

A second experiment almost identical to the first was run on a noncalcareous Woodburn silt loam soil (fine-silty, mixed, mesic, Aquultic Agrixerolls) from Corvallis, Oregon. Each flask received 21 ml water, representing about 80% 33 kPa tension as above. Differences between treatments were determined by analysis of variance according to LeClerg (1957).

Field experiments. Greer, soft white winter wheat (*Triticum aestivum* L.) and a mixture composed of 90% Mal, 10% Hesk, winter barley (*Hordeum vulgare* L.) straws were coarsely ground through a 1-cm screen in a Wiley mill. Twenty-five-gram samples were treated with 0, 0.5, or 1.0 ml urea-sulfuric acid in a 1:1 v/v mixture with water, and placed into fine mesh nylon cloth bags. The treatments were replicated 3 times. The bags were buried 20 cm in Portneuf silt loam soil at Kimberly, Idaho, into which 5 mg straw/ha had been incorporated by rototilling to about 20 cm with no N treatment. Burial was on 3 May 1985. The bags were removed from the field plots on 12 June, 22 July, 30 August and 10 October 1985. Adhering soil was removed from the surface of the bags and the bags were dried in an oven at 60 °C for several days. The straw was removed from the bags and weighed for decomposition measurement by weight loss. The straw was analyzed for total N by the Kjeldahl procedure of Carter et al. (1967). Differences in decomposition were determined by analyses of variance (LeClerg 1957).

Microorganism numbers. Fielder, soft white spring wheat straw (*Triticum aestivum* L.) was treated with urea-sulfuric acid 1:1 (v/v) with water at the rate of 0.5 ml acid/g straw and mixed with 100 g Portneuf silt loam in 1/2-l flasks. Straw was added to the soil at rates of 0, 0.5, 1.0, and 1.5 g/flask. The soil and straw mixture was wetted with 18 ml distilled water plus 1 ml/g straw. This was equivalent to 80% of 33 kPa moisture tension. The flasks were incubated at 26 °C with a one hole stopper inserted in the neck for aeration. A 10-g soil sample was removed weekly from each of 3 replicate flasks, an appropriate dilution series was prepared, and the total plate count for microorganisms was made according to Wollum (1982). Actinomycetes were enumerated by the method of Williams and Wellington (1982). Differences in microorganism numbers were determined by analysis of variance (LeClerg 1957).

Results and discussion

Straw decomposition in the laboratory

Straw decomposition as measured by CO_2 evolution in the laboratory was stimulated by treatment with urea-sulfuric acid during the 1st–4th weeks in Portneuf silt loam soil (Fig. 1). When 1.0 ml acid was added per gram straw, decomposition was more rapid than when 0.5 g urea-sulfuric acid/g straw was added. After the initial stimulation period, the nontreated straw decomposed at a more rapid rate than the treated straw. The crossover in total C evolved occurred in the 4th –6th weeks, with final decomposition at 12 weeks being 25%–45% greater for the nontreated straw than for the two treated straws. The same results were observed for straw decomposition in the Woodburn silt loam soil except that crossover occurred between the 5th and 8th weeks (Fig. 2). Analyses of variance showed differences to be significant at the 95% probability level for acid treatments after the 2nd or 3rd week. The accumulative C differences with time were also different. Curves reported in Fig. 1 and 2 are values derived for acid treatments. The three straw applications are not presented separately because of the similarity in curve shapes.

After 12 weeks of incubation, the soil was removed from the flasks and extracted for nitrate and electrical conductivity determinations. In both soils, the nitrate

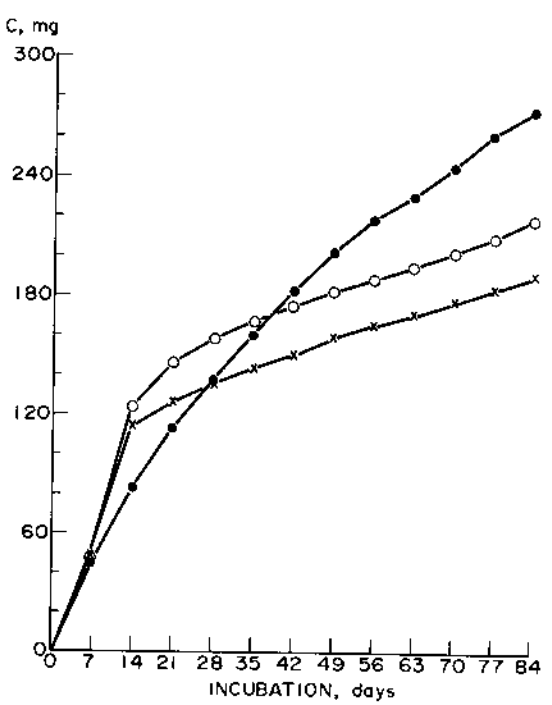

Fig. 1. Carbon dioxide evolved from wheat straw decomposing in Portneuf silt loam soil in the laboratory. ●: no acid; ×: 0.5 ml acid; ○: 1.0 ml acid

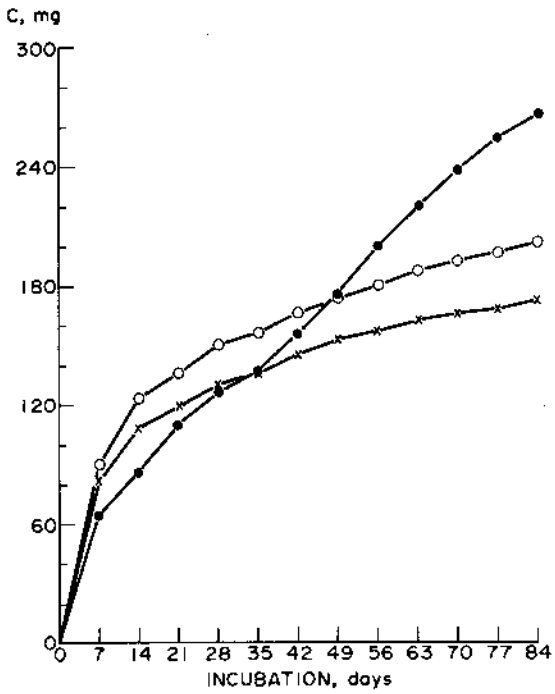

Fig. 2. Carbon dioxide evolved from wheat straw decomposing in Woodburn silt loam soil in the laboratory. ●: no acid; ×: 0.5 ml acid; ○: 1.0 ml acid

Table 1. Soil nitrate and electrical conductivity of Portneuf and Woodburn soils following 12 weeks incubation of urea-sulfuric acid treated wheat straw in the laboratory

Straw (g)	Acid (ml/g straw)					
	NO_3^--N (mg/kg)			EC (dS/m)		
	0.0	0.5	1.0	0.0	0.5	1.0
Portneuf silt loam soil						
0.5	50	326	755	1.24	5.83	9.66
1.0	51	640	1370	1.21	8.11	14.87
1.5	23	923	1875	1.22	11.37	17.63
Soil control	67			1.47		
Woodburn silt loam soil						
0.5	24	190	162	0.60	3.77	5.13
1.0	11	182	81	0.51	5.13	7.06
1.5	4	74	25	0.55	6.65	10.23
Soil control	38			0.78		

values in soils without urea-sulfuric acid treated straw showed a slight to fairly large immobilization of nitrogen (Table 1). In the Portneuf soil, both urea-sulfuric acid treatments provided a large amount of N that was mineralized and appeared as nitrate.

Nitrogen was immobilized in the Woodburn soil when treated with straw alone but nitrification occurred to a limited extent in response to urea-sulfuric acid treatment. Nitrification was severely limited by acid in the Woodburn soil with pH decreasing from 5.1 to 4.3 in response to urea-sulfuric acid treatment. In contrast, nitrification in the calcareous Portneuf soil with pH of about 7.5 was not decreased by the acid treatment.

The electrical conductivity in the Portneuf soil initially was 1.47 dS/m and it increased incrementally with increasing acid-straw treatments to 17.6 dS/m. In the Woodburn soil the original EC was 0.78 dS/m and it increased to 10.23 dS/m with increments of acid straw.

Decomposition of the added straw was decreased overall in both soils by the urea-sulfuric acid treatments. In the Portneuf soil, nitrification was not decreased by the urea-sulfuric acid straw treatments. In the Woodburn soil were the pH was decreased by the urea-sulfuric acid treatments, nitrification was limited. However, it is difficult to separate the effect of the urea-sulfuric acid treatment directly from the overall pH change that occurred in the soil as a result of the acid straw treatments. It is also probable that accumulated soluble salts decreased microbial activity and straw decomposition in the latter part of the incubation, as evidenced by the large increases in observed electrical conductivity. An EC near 18 limits almost all crop plant growth and it is likely that microbial respiration is also severely limited by electrical conductivity values observed here (Handbook 60).

Straw decomposition in the field

Greer soft white winter wheat straw decomposition in the field for 160 days was about 48% for nontreated straw. Straw that was treated with either 0.5 or 1.0 ml urea-sulfuric acid per gram straw decomposed significantly faster than the nontreated straw, with 58% decomposition occurring in the same time. There were no differences between the urea-sulfuric acid rates on decomposition (Fig. 3). The barley straw that was not treated decomposed about 50% in the 160-day incubation. Urea-sulfuric acid treatment increased straw decomposition to about 60% and again there were no differences between the two acid treatments (Fig. 4).

Microorganism counts in incubated soil

Total plate counts and actinomycetes were enumerated weekly in soils amended with four rates of straw treated with urea-sulfuric acid to determine if soil microorganisms numbers were suppressed by the treatments (Table 2). The analysis of variance showed highly significant differences. Both total and actinomycetes counts increased as the straw addition rate increased at nearly all of the sampling dates. Bacteria

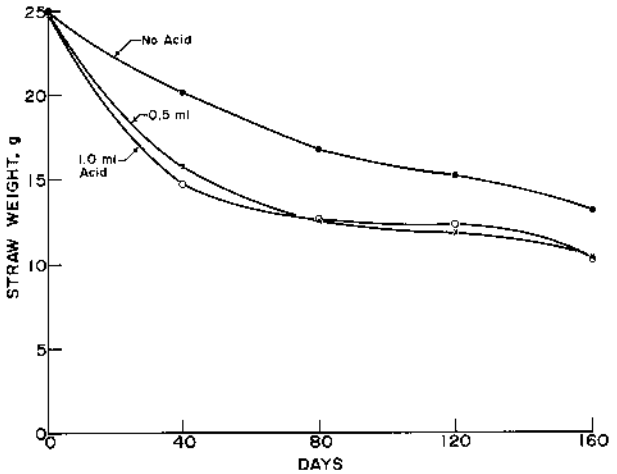

Fig. 3. Weight loss in winter wheat straw decomposing in the field for 160 days in the summer

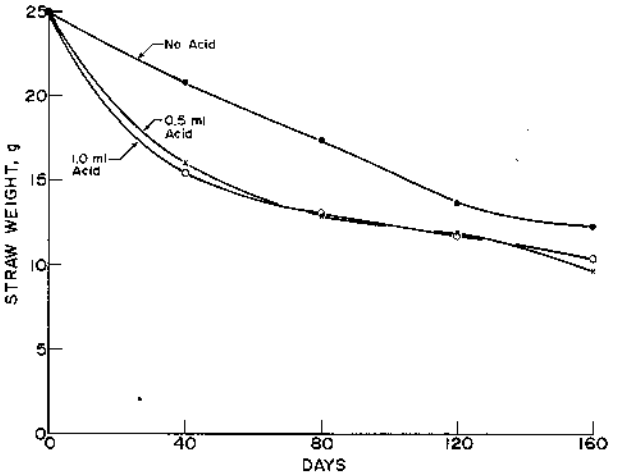

Fig. 4. Weight loss in winter barley straw decomposing in the field for 160 days in the summer

Table 2. Total plate counts and actinomycetes in Portneuf silt loam soil treated with urea-sulfuric acid treated straw, incubated in the laboratory

Acid-treated straw in soil (g/kg)	Incubation days									
	14	21	28	35	42	58	71	85	100	$\bar{X}$
Total plate counts[a]										
0	1.8	1.2	2.2	1.0	1.9	0.3	1.4	0.8	0.6	1.2
5	6.6	7.0	8.8	8.3	3.8	7.0	9.4	7.3	6.0	7.1
10	9.6	8.2	11.0	9.5	9.0	5.8	9.4	7.8	7.9	8.7
15	15.7	14.7	17.0	11.3	11.8	7.0	8.3	10.7	9.9	11.8
Actinomycetes[a]										
0	0.3	0.6	0.6	0.7	1.2	1.0	1.4	0.9	0.6	0.8
5	0.3	1.2	1.3	1.8	1.4	1.3	2.1	1.6	0.2	1.2
10	0.4	1.5	1.8	1.8	2.6	1.7	2.5	1.6	1.8	1.7
15	6.7	2.2	2.2	2.7	3.2	1.7	2.0	2.0	2.0	2.7

[a] For microorganisms per gram dry soil multiply by 10^6

ANOVA	Total plate counts	Actinomycetes
	F	*F*
Straw	178.57***	2219.97***
Dates	7.66***	14.86***
Straw × dates	3.10***	35.21***
Rep	1.03	1.20

*** F values are significant at 99.9% probability

as measured in the total plate count increased from 1.8 to 15.7 million/g soil during the 1st week of incubation. During the same time actinomycete counts increased from 0.3 to 6.7 million/g soil with incremental straw additions. No straw without acid treatments was included in the experiment because of laboratory limitations. Therefore, no direct comparisons could be made of microorganism numbers in straw with and without urea-sulfuric acid. But the relatively high numbers of microorganisms that were found indicated that the straw and soil mixtures were populated with large numbers of microorganisms. The high nitrification that was observed in the Portneuf silt loam soil incicated that nitrifying microorganisms were not limited in the calcareous soil.

Conclusions

Laboratory experiments showed that urea-sulfuric acid accelerated straw decomposition initially but at 12 weeks decomposition was slower than in nontreated straw. The slowing of decomposition was probably caused by salt accumulation in the soil from the acid. In the field urea-sulfuric acid enhanced straw decomposition throughout the 160-day experiment in the summer. Nitrification was not limited by the acid treatments in calcareous Portneuf soil but was slowed in Woodburn slightly acid soil. Total plate counts for soil microorganisms and numbers of actinomycetes were greatly increased in soil treated with urea-sulfuric acid treated straw. Test data indicate than the acid treatment was not particularly damaging to the soil microorganisms. While the treatment of straw with urea sulfuric acid may not be an economically feasible method of accelerating straw decomposition in the field, the treatments work rather satisfactorily, even though more N is applied than is desirable in applying sufficient acid to wet the surface of the straw. A wider ratio of urea-sulfuric acid to water, 1:5 or 1:10, would wet the straw with less nitrogen being applied and would be a more economical treatment that should be evaluated. Finally, this experiment demonstrates that care must be exercised in extrapolating laboratory experiments to field conditions.

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