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 Portneuf 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 NO₃-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 1.8×10⁶ microorganisms/g and with urea-sulfuric acid treated straw were 15.7×10⁶/g soil after 14 days incubation. The respective actinomycete counts were 0.3×10⁶ and 6.7×10⁶/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 crop 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 evaluation 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
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 (coarse-silty, mixed, mesic, Durixerollic Calcisols) 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 CO₂-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% BaCl₂ solution, titrated with standard 0.1 N H₂SO₄ solution, and CO₂ evolution calculated. All treatments were replicated 3 times. An air blank was used to determine the small amount of CO₂ 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 NO₃⁻ using a specific ion electrode (Miliham 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, Aquultic Agriolls) 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 CO₂ 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