

Title: Kentucky Bluegrass Straw Utilization: Genetic and Management Factors Influencing Pulping Requirements and Papermaking Properties

Objectives:

The main goal of this interdisciplinary project is to stimulate an integration of the PNW paper and agricultural industries for improving their environmental and economic sustainability.

Specific research objectives were to:

1. evaluate Kentucky bluegrass straw as a potential raw material for papermaking and soil amendments/fertilizers.
 - assess variations in straw characteristics related to fiber quality among commercial cultivars used in the PNW.
 - relate fiber characteristics to paper making quality of the pulp derived from bluegrass
 - evaluate pulping liquor byproducts from Kentucky bluegrass straw as potential soil amendments/fertilizers.
2. optimize straw pulping, fiber blending and black liquor processing for producing paper medium, molded paper products, soil amendments and hydroseeding products.
3. Contribute above-generated research results to ongoing feasibility and engineering studies for commercial crop residue pulping in eastern Washington.

Investigators:

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Abstract:

This project was not renewed after the first year of phase II. In light of the discontinuation of funding, projects were culminated, summarized and publications were finalized. Commercial pilot studies on making molded paper products were successfully executed with wheat and bluegrass straw by UW. Bluegrass straw black liquor's strong alkalinity increases soil pH, has modest effects on soil EC, increases K availability and plant K uptake, while improving soil microbial activity, soil aggregation and overall quality.

Results

Bluegrass straw fiber evaluation, pulping process development and pilot trials

Evaluation of new fiber sources for paper manufacturing typically includes measurements of paper compression, tensile and burst strength. Short span compression involves holding paper sample between two clamps located with a very narrow gap. The test relates to strength of fibers when placed under a compression load.

Tensile test (breaking load and tensile energy absorption(TEA)) relate to paper strength when placed under tensile load. The resulting stress-strain curve provides two useful sets of information. The load at failure relates to ultimate paper tensile strength. The TEA, also called

toughness shows the tendency of the paper to stretch under a load up until the point of total failure. TEA is the total area located under the stress-strain curve. Burst is a test intended to simulate the resistance to puncture and burst failure of a container subjected to side loading during transit. It is influenced by both the fiber strength and the fiber-fiber bonding in paper.

Significant findings thusfar include: 1) pulping liquor can be recycled numerous times without detrimental effects on fiber strength properties, 2) while initial experiments suggested NaOH was superior to KOH in yielding high quality fiber, it has since been demonstrated that increasing alkali charge with KOH can result in pulped fiber of equal quality to that obtained with NaOH. In addition, it has also been demonstrated that alum does not enhance the pulping process, as originally perceived. These results are good news in terms of developing usable soil amendment byproducts out of the black liquor, since it is detrimental to add Na and Al to soil systems.

Molded paper products were commercially produced on a pilot trial basis from bluegrass and wheat straw. Flower pots were produced at Willamette Valley with Western Pulp Products, and apple trays, berry trays were produced by Keyes Fiber at Wenatchee, WA. However, grass seed straw fibers are shorter than other straw fibers. They have an issue with slow drainage thereby slowing down productivity. They also have a high water retention value which makes it difficult to dry. Na-based pulping produced superior pulp to K-based pulping, but some combination of the two could satisfy fiber quality goals while producing a land-applicable black liquor, as suggested by results from a plant growth trial. Products were of excellent quality and commercial producers were highly satisfied. Plans are continuing for the restart of the Wallula recycling mill that could be retrofitted for pulping crop straw as well as recycling newspaper.

Field experiments

The GxE field experiment was plagued by late planting and dry fall conditions, in the first year and the WSU mandated removal of the plots in 2004 to make room for a road project. Insufficient data were collected from this experiment to meet the objectives of this part of the project.

Black liquor characterization and evaluation as a potential soil amendment

Black liquor is rich in lignin, hemicelluloses sugars and ash minerals (Table 1) that stimulate microbial activity. Soil structure is an important indicator of soil quality. Application of KOH based black liquor and fine fiber with high K and beneficent nutrients may improve soil quality. The effect of KOH based bluegrass straw pulping black liquor (BL) and fine fiber (FF) on soil macroaggregates in a semi-arid soils weak in soil structure was examined in incubation experiments over 30 days. Nine treatments were established in combination with BL and FF at a rate of 1.5 g C kg⁻¹ soil and treatments with fungicide (captan), bactericide (oxytetracycline) and both biocides to evaluate the relative efficiency of microbial (fungi and bacteria) activity in improving soil macroaggregates. Both BL and FF had similar effect in increasing soil wet stable macroaggregates. By 30 days of incubation, amended soils with BL or FF resulted in an increase in wet stable macroaggregates by 14% compared with non-amended control (Fig. 1). Addition of BL or FF increased soil microbial activities in terms of soil respiration (Fig. 2) and soil enzyme (dehydrogenase, β -glucosidase, and arylsulfatase) activities (Fig. 3). Soil respiration reached maximum level 2 days following addition of BL or FF, but maximum macroaggregates occurred in 20 days of incubation, and then were stable. BL or FF in combination with fungicide decreased wet stable macroaggregates compared with BL or FF alone, and did not

result in any differences in wet stable macroaggregates compared with the non-amended control, but when in combination with bactericide, BL or FF increased soil wet stable macroaggregates compared to non-amended control or corresponding BL or FF alone, suggesting that increases in soil wet stable macroaggregates of soils receiving BL or FF were attributable to the fungal activity, and particularly to the proliferation of fungi hyphae. Separate microscopic studies confirm the rapid growth of fungal hyphae with the application of KGB BL to soils (Table 2). A second year field experiment with similar K-based black liquor generated from wheat straw was conducted at IAREC in Prosser, WA. Soil aggregation and soil microbial activities increased with both fall and spring applications of black liquor.

Hydroseeding, hydromulching

Greenhouse experiments were initiated in fall 2004 to evaluate the potential for using chopped or chemically pulped bluegrass straw in hydromulching and hydroseeding. The plans for field hydroseeding experiments with pulped bluegrass straw were aborted when funding was discontinued. Chemically pulping bluegrass straw has promise for producing hydroseeding material since it densifies the material, reduces its hydrophobicity and increases its water holding capacity.

Publications:

Xiao, C., M. Fauci, D. F. Bezdicek, W. T. McKean and W. L. Pan. 200_. Soil aggregation and microbial responses to straw pulping byproducts. *Soil Sci. Soc. Am. J.* (in review).

Xiao, C., R. Stevens, M. Fauci, R. Bolton, M. Lewis, W.T. McKean, D. F. Bezdicek and W. L. Pan. 2006. Soil microbial activity, aggregation and nutrient responses to straw pulping liquor in corn cropping. *Biol. Fert. Soils* on-line link: DOI 10.1007/s00374-006-0153-y; (in press).

Camberato, J.J., B Gagnon, O A Angers, W. L. Pan. 2006. Pulp and paper mill byproducts as plant nutrient sources and soil amendments. *Can. J. Soil Sci.* 86: 641-653.

Xiao, C., M. Fauci, D. F. Bezdicek, W. T. McKean, and W.L. Pan. 2006. Soil microbial responses to potassium-based black liquor from straw pulping. *Soil Sci. Soc. Am. J.* 70: 72-77.

Xiao, C, R. Bolton, W. L. Pan. 2006. Lignin from rice straw kraft pulping: effects on soil aggregation and chemical properties. *Bioresource Technology* 00:00. (In press).

Table 1. Selected characteristics of KGB black liquor and fine fiber (Mean values, determined on triplicate samples)

Properties	Black liquor		Fine fiber	
	Properties	Components added	Properties	Components added
pH	10		10	
EC (dS m ⁻¹)	39		39	
	---- g L ⁻¹ ---	----- g kg ⁻¹ soil -----	--- g kg ⁻¹ --	----- g kg ⁻¹ soil -----
Solid content	95	4.2	122	4.0
Total organic C	34	1.5	46	1.5
Total N	1.1	0.05	1.5	0.048
Polysaccharides	23	1.01	49	1.59
Lignin	6.3	0.28	11	0.36
Total K	21	0.93	22	0.72
Total Na	2.1	0.09	2.7	0.088
Total P	0.26	0.011	0.054	0.018
Total Ca	0.063	0.03	0.06	1.9 x 10 ⁻³
Total Mg	0.021	9 x 10 ⁻³	0.03	1 x 10 ⁻³
Total Si	0.11	5 x 10 ⁻³	0.037	0.012
Total Fe	5 x 10 ⁻³	0.044	0.017	6 x 10 ⁻⁴
Total Cu	7 x 10 ⁻⁴	3 x 10 ⁻⁵	1 x 10 ⁻³	3 x 10 ⁻⁵

Table 2. The length of fungal hyphae as influenced by amendments over incubation days

Treatment	-----Incubation days -----						
	1	2	5	10	15	20	30
	----- Fungal hyphae length (µm mm ⁻² petri dish) -----						
Control	0.0 c [†]	0.0 c	45.3 b	476 b	381 b	537	695 a
BL	633 b	770 b	0.0 c	698 b	525 b	361	263 bc
BL + F	0.0 c	0.0 c	0.0 c	777 b	982 a	373	22 c
BL + B	1043 a	1261 a	605 a	639 b	477 b	680	186 c
BL + F + B	0.0 c	283 c	680 a	1357 a	1076 a	673	513 a
L.S.D. _{0.05}	127	288	117	407	302	NS	256
p values	<0.0001	<0.0001	<0.0001	<0.0007	<0.0001	0.074	<0.0001

[†] Different letters mean significant differences among treatments at the same day of incubation at $p \leq 0.05$; NS represent no significant differences.

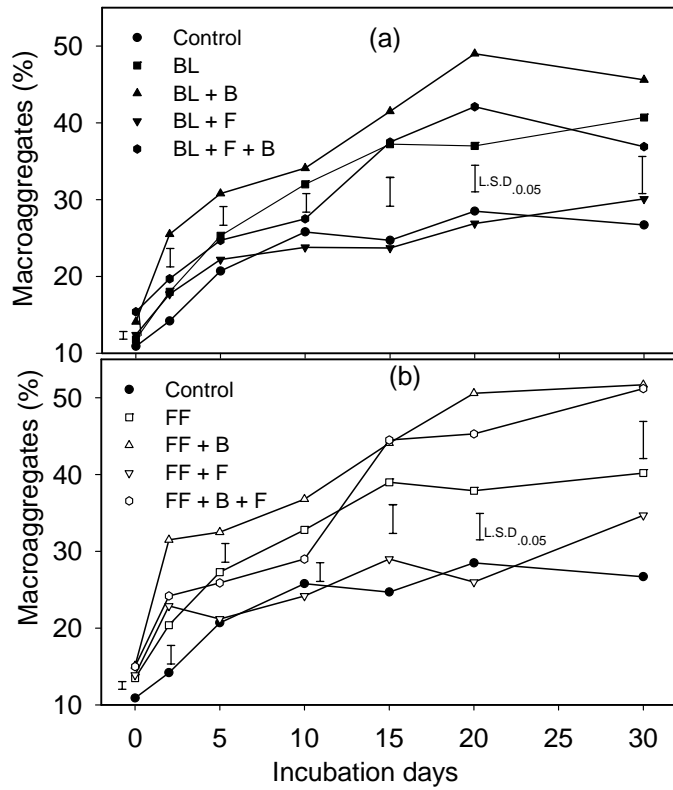


Fig. 1. (a) and (b) Wet stable macroaggregates in soils receiving BL or FF treated with biocides. I: L.S.D._{0.05} bars, significant differences among treatments at each incubation date at p ≤ 0.05.

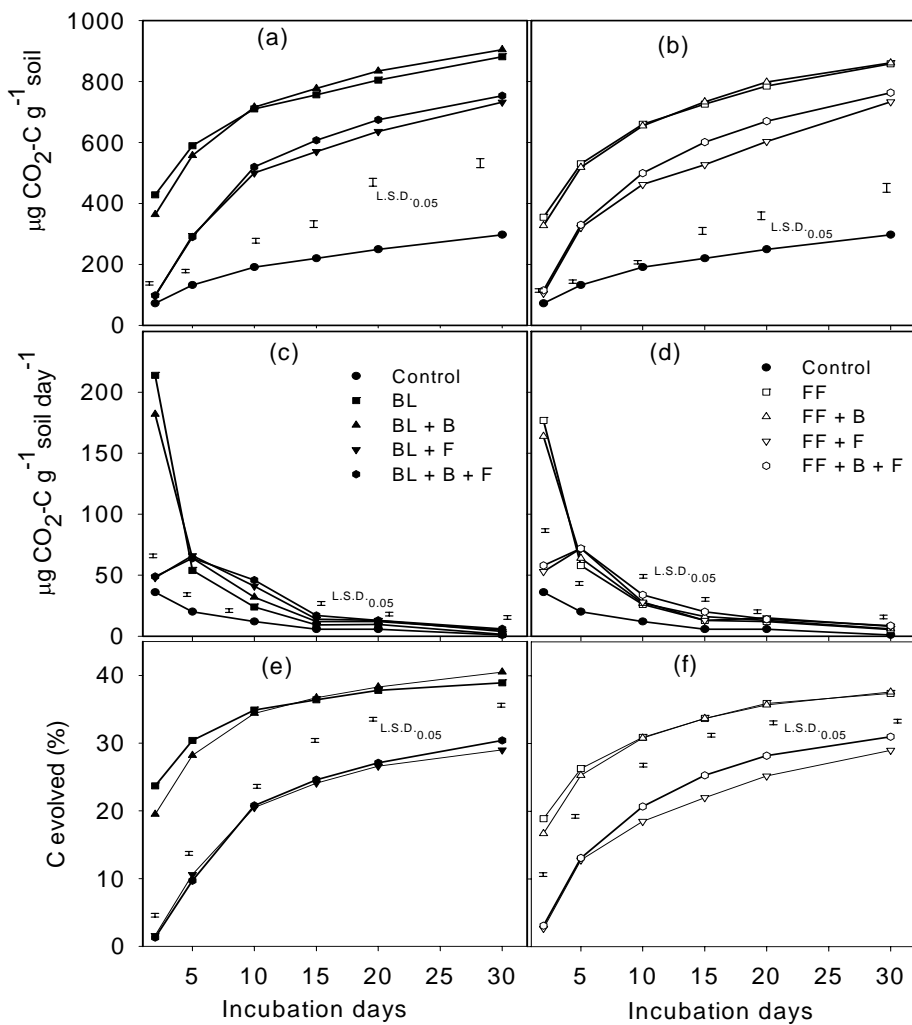


Fig. 2. (a) and (b) Cumulative CO₂, (c) and (d) CO₂ evolution rate, and (e) and (f) Cumulative apparent percentage of BL- or FF-derived C evolved in soils receiving BL or FF treated with biocides. I: L.S.D._{0.05} bars, significant differences among treatments at each incubation date at $p \leq 0.05$.

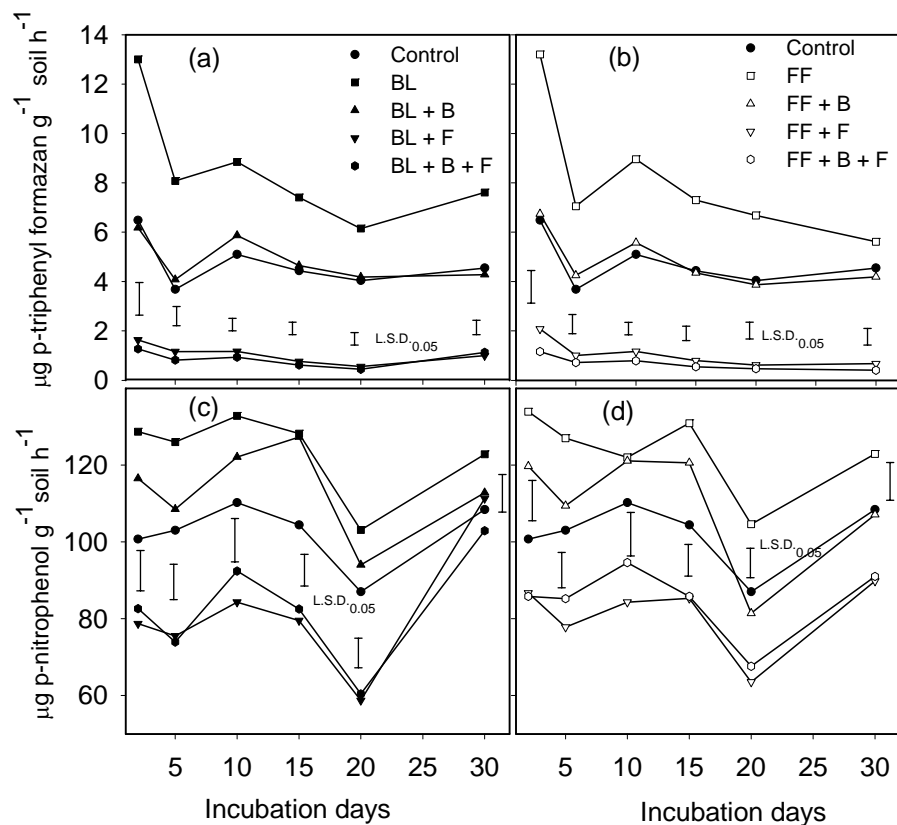


Fig. 3. (a) and (b) dehydrogenase, and (c) and (d) β -glucosidase activities in soils receiving BL- or FF-treated with biocides. I: L.S.D._{0.05} bars, significant differences among treatments at each incubation date at $p \leq 0.05$.