Understanding how tannins affect soil organic matter and nutrient cycling may be important in silvopastures.

Tannins Reduce Recovery of Water Soluble-C & -N from Soil

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Introduction: Tannins are common plant-derived polyphenolic compounds that comprise up to 40% of the composition of leaves and bark of some species. Tannins precipitate proteins and react with other biomolecules and are thought to influence a number of important soil ecosystem processes. However, basic information on the effects of tannins on SOM and nutrient cycling is limited. Tannins should affect soil C- and N-cycles because they can form precipitates or complex with many substances and affect microorganisms.

Objectives: Improve understanding of the role of plant-based polyphenolic compounds, such as tannins, on soil processes. These studies were designed to determine:

1) If tannins and related phenolic compounds influence the recovery of soluble soil-C and –N from soil.

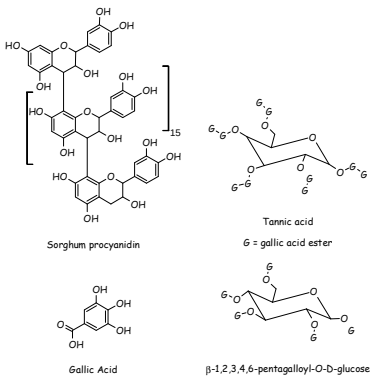
2) If tannin effects can persist.

3) If tannin effects are additive.

Methods: Phenolics/Tannins: Compounds used in these experiments included condensed tannin purified from sorghum, tannic acid (TA), penta-galloyl-glucose (PGG) purified from TA, and gallic acid (GA) (Figure 1). These were selected because of their postulated role on plant nutrient cycling and because they vary in complexity. Condensed tannin from sorghum is a flavinoid-based proanthocyanidin; tannic acid is a readily available, but imprecisely defined, commercial mixture of hydrolyzable tannins; PGG is a simple hydrolyzable tannin; and GA is a relative simple phenol and one of the building blocks of hydrolyzable tannins.

Water Soluble-C & -N: Water-soluble carbon (WSC) and nitrogen (WSN) were extracted with variations of a sequential cool and hot water procedure. The desired tannin/phenol (10 mg g^{-1} soil) was added as solution to soil at room temperature (23°C). After shaking for 1 hour, samples were centrifuged, decanted, and analyzed with a Shimadzu TOC-VCPN equipped with a TNM-1 module. Deionized water was added and samples were incubated in a hot water bath (80°C) and re-assayed. Total values are the sum of cool and hot extractions. Net values were calculated by subtracting the C or N added in the compounds. Error bars are the standard error of the mean.

Figure 1. Chemical structures for condensed tannin from sorghum, tannic acid (TA), gallic acid (GA), and penta-galloyl-glucose (PGG).



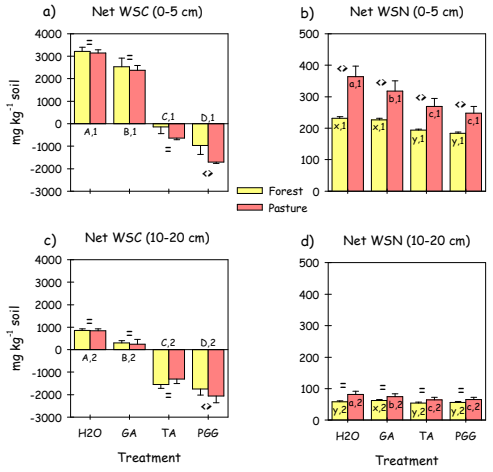


Figure 2. Treatment with TA reduced net total WSC and WSN in West Virginia soils (n=5) suggesting that TA-C sorbed on soil and interacted with labile soil-N. A purified gallotannin, PGG, inhibited extraction more than TA while GA, a non-tannin phenolic, had less effect.

Would soils from other locations be similarly affected?

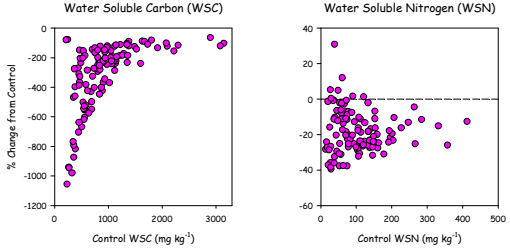


Figure 3. Treatment with TA affected soil samples collected from 17 ARS locations through the U.S. (n=91). Average total WSC and WSN were reduced by 352.9 and 18.5% compared to the control (extraction with H_2O). Greatest responses for WSC were associated with samples with less soluble-C. The effects of tannic acid seem to vary with management and depth when viewed in detail .

Figure 4. Effects of a single application of TA or PGG on WSC and WSN persisted through 12 washings with water (80°C). Extractions were not affected by GA.

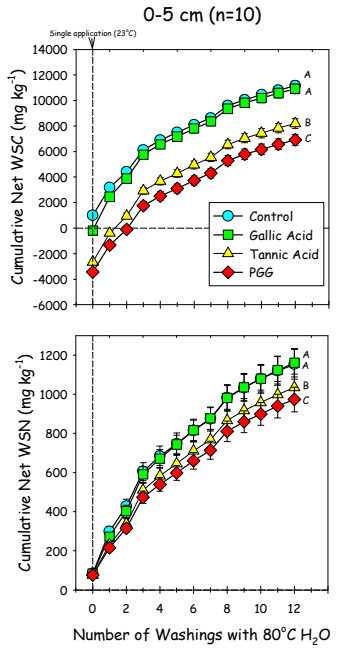
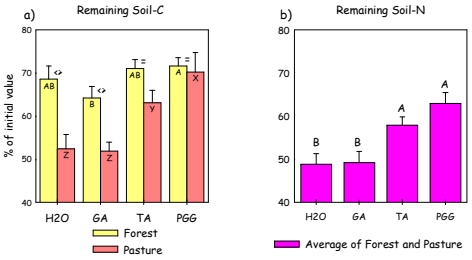


Figure 5. After the final wash, remaining total soil C varied among treatments and by use. Total soil N varied by treatment.



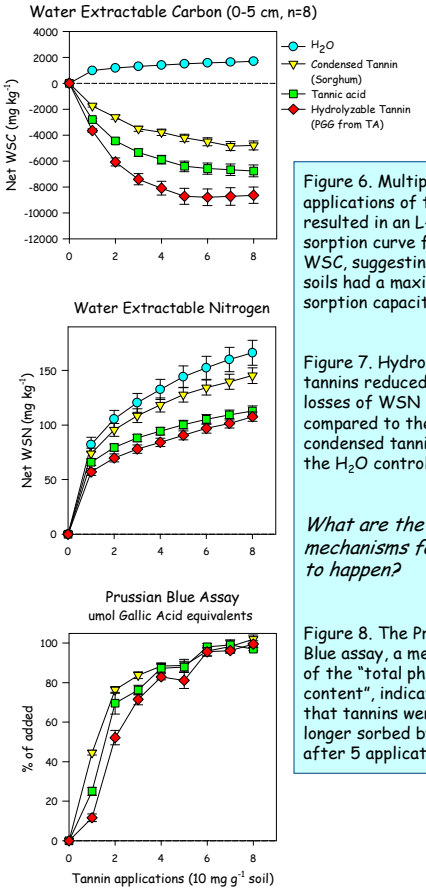


Figure 6. Multiple applications of tannins resulted in an L-type sorption curve for WSC, suggesting that soils had a maximum sorption capacity.

Figure 7. Hydrolyzable tannins reduced the losses of WSN compared to the condensed tannin or the H_2O control.

What are the mechanisms for this to happen?

Figure 8. The Prussian Blue assay, a measure of the "total phenolic content", indicates that tannins were no longer sorbed by soil after 5 applications.

Conclusions

- These studies indicate that reactions between some tannins and soil organic matter might rapidly decrease the solubility of labile soil C and N.
- However, further research is needed to determine mechanisms of interactions between tannins and related compounds and soil organic matter including:
  1. Methods to measure biological and chemical activity of tannins in soil systems.
  2. Role of tannins and other plant secondary compounds on formation of stable organo-mineral complexes.
  3. A functional definition of tannins that relates specific chemistry to functions that can be managed.

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