



Carbon to Nitrogen Ratios in Cropping Systems

Introduction

Carbon to Nitrogen ratio (C:N) is a ratio of the mass of carbon to the mass of nitrogen in a substance. For example, a C:N of 10:1 means there is ten units of carbon for each unit of nitrogen in the substance. Since the C:N ratio of everything in and on the soil can have a significant effect on crop residue decomposition, particularly residue cover on the soil and crop nutrient cycling (predominantly nitrogen), it is important to understand these ratios when planning crop rotations and the use of cover crops in agricultural systems.

Microbial C:N Ratio Feeding Soil Microorganisms

Soil microorganisms have a C:N ratio near 8:1. They must acquire enough carbon and nitrogen from the environment in which they live to maintain that ratio of carbon and nitrogen in their bodies. Because soil microorganisms burn carbon as a source of energy, not all of the carbon a soil microorganism eats remains in its body; a certain amount is lost as carbon dioxide during respiration. To acquire the carbon and nitrogen a soil microorganism needs to stay alive (body maintenance + energy) it needs a diet with a C:N ratio near 24:1, with 16 parts of carbon used for energy and eight parts for maintenance. It is this C:N ratio (24:1) that rules the soil!

If foodstuff such as mature alfalfa hay (C:N ratio of 25:1) is added to the soil (see Table 1), the soil microorganisms will consume it relatively quickly with essentially no excess carbon or nitrogen left over. The hay has an almost perfect balance of carbon to nitrogen that soil microorganisms (24:1) need.

What would happen if we added a foodstuff with a higher C:N ratio to the soil (see Table 1), such as wheat straw with a C:N of 80:1? Since wheat straw contains a greater proportion of carbon to nitrogen than the 24:1 perfectly balanced diet soil microorganisms require, the microbes will have to find additional nitrogen to go with the excess carbon to consume the wheat straw. This additional nitrogen will have to come from any excess nitrogen available in the soil. As soil microorganisms tie

up excess nitrogen (immobilization), this situation could create a deficit of nitrogen in the soil until some of them die, decompose, and release nitrogen (mineralization) contained in their bodies, or some other source of nitrogen becomes available in the soil.

Conversely, what would happen if we added a foodstuff with a lower C:N ratio, such as a hairy vetch cover crop with a C:N of 11:1? Since the vetch contains a lesser proportion of carbon to nitrogen than the 24:1 perfectly balanced diet soil microorganisms need, the microbes will consume the vetch and leave the excess nitrogen in the soil. This surplus nitrogen in the soil will be available for growing plants, or for soil microorganisms to use to decompose other residues that might have a C:N ratio greater than 24:1.

Everything else being equal, materials added to the soil with a C:N ratio greater than 24:1 will result in a temporary nitrogen deficit (immobilization), and those with a C:N ratio less than 24:1 will result in a temporary nitrogen surplus (mineralization). This is why composting operations strive to achieve a blend of materials with a C:N ratio of about 30:1... so the resident microbes can readily decompose the compost pile leaving a little food and structure left over to feed and shelter the microbes after the compost is applied to the soil.

Next, let's examine C:N ratios from a practical perspective for crop production and soil health.

C:N Effects on Soil Cover

The faster crop residues are consumed by soil microorganisms the less time those residues will be covering the soil surface. Crop residues on the soil surface are important for protecting soil aggregates from the destructive force of raindrops hitting the soil, conserving soil moisture, and providing habitat for arthropods that shred crop residue and eat weed seeds. While it is important to maintain soil cover, it is also essential that those same residues decompose to release plant nutrients and build soil organic matter. Therefore, it is important to pay attention to crop residue C:N ratios to maintain soil cover when desired, yet allow the cover to ultimately break down and be recycled.

A cropping system of continuous no-till wheat certainly provides good soil cover, as wheat produces a fair amount of residue with a relatively high C:N ratio (80:1) that decomposes relatively slowly. However, such a cropping system does not allow the crop nutrients in the wheat straw to become readily available to soil microorganisms or plants. By adding a relatively low C:N ratio crop such as hairy vetch (11:1) to the rotation, nitrogen will be available to the soil microorganisms, thus allowing them to break down the wheat straw more quickly. Likewise, a cropping system of continuous no-till peas would result in very little soil cover as soil microbes would consume the pea residue (C:N of 29:1) relatively quickly, as not much additional nitrogen would be necessary for decomposition of the residue to take place.

C:N Effects on Nutrient Cycling

It should now be apparent from the discussion of C:N ratios and soil cover that management choices must strike a balance between crop residues covering the soil and nutrient cycling. An awareness of crop C:N ratios is necessary to select crop types and keep a cropping sequence on the right path toward sustainability, that of the ultimate C:N ratio of 24:1 that supports soil microorganisms.

Managing residues so they cover the soil when a growing crop is not providing soil protection requires some planning and experimentation to achieve a proper balance. If crops with high C:N ratios are grown too frequently in the rotation, residues will accumulate on the soil surface, and nitrogen for crop growth may be scarce unless supplemented with other sources of nitrogen. This may result in poor crop performance during times when soil microorganisms tie up nitrogen while working to decompose high C:N ratio crop residues.

Influence of Cover Crops

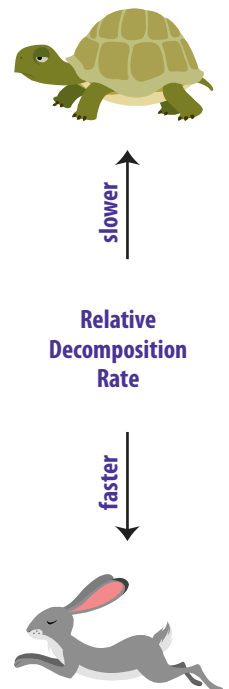
Cover crops added to a cash crop rotation can help manage nitrogen and crop residue cover in a cropping sequence. A low C:N ratio cover crop containing legumes (pea, lentil, cowpea, soybean, sunn hemp, or clovers) and/or brassicas (turnip, radish, canola, rape, or mustard) can follow a high C:N ratio crop such as corn or wheat, to help those residues decompose, allowing nutrients to become available to the next crop. Similarly, a high C:N ratio cover crop that might include corn, sorghum, sunflower, or millet can provide soil cover after a low residue, low C:N ratio crop such as pea or soybean, yet decompose during the next growing season to make nutrients available to the following crop.

Conclusion

Understanding carbon to nitrogen ratios of crop residues and other material applied to the soil is important to manage soil cover and crop nutrient cycling. Providing quality habitat for soil microorganisms should be the goal of producers interested in improving soil health. Soil is a biological system that functions only as well as the organisms that inhabit it.

Table 1. Carbon to nitrogen ratios of crop residues and other organic materials

Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	24:1
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1



References

Brady, N.C. and R.R. Weil. 2002. *The Nature and Properties of Soils*, 13th edition, Prentice Hall.

Howell, J. 2005. *Organic Matter: Key to Soil Management*. Available at http://www.hort.uconn.edu/ipm/veg/croptalk/croptalk1_4/page8.html. [verified 1.19.11]

USDA NRCS. 1977. *Conservation Agronomy Technical Notes, No. 30: Relationships of carbon to nitrogen in crop residues*. Available at <http://www.nm.nrcs.usda.gov/Technical/tech-notes/agro/AG30.pdf>. [verified 1.19.11]

Wortman, C.S., C.A. Shapiro, and D.D. Tarkalson. 2006. *Composting Manure and Other Organic Residues*. NebGuide G1315. Available at <http://www.ianrpubs.unl.edu/e-public/pages/publicationD.jsp?publicationId=567>. [w 1.19.11]