Understanding the Carbon-Nitrogen Ratio

by Crow Miller

There are two chemical elements in organic matter which are extremely important, especially in their relation or proportion to each other; they are carbon and nitrogen. This relationship is called the carbon-nitrogen ratio. To understand what this relationship is, suppose a certain batch of organic matter is made up of 40 percent carbon and 2 percent nitrogen. Dividing 40 by 2, one gets 20. The carbon-nitrogen ratio of this material is then 20 to 1, which means 20 times as much carbon as nitrogen. Suppose another specimen has 35 percent carbon and 5 percent nitrogen. The carbon-nitrogen ratio of this material then would be 7 to 1. Anyone who handles organic matter, who mulches, or who composts, regardless of which method is used, should have some idea about the significance of the carbon-nitrogen ratio.

Carbon is important because it is an energy-producing factor; nitrogen, because it builds tissue. We are familiar with carbon in the form of charcoal. In that form it is practically pure carbon. A diamond is another form of pure carbon. In a plant it takes an entirely different form. Limestone is usually over 90 percent calcium carbonate ($CaCo_3$), a compound made up of two partners — calcium and carbon. If you eat a radish or take bicarbonate of soda, you are consuming carbon.

We found that earthworms feeding on oat straw composted with fish meal yielded a carbon-nitrogen ratio from 23 to 11 during a period of two years, while the soil microorganisms alone reduced it to about 18 during the same period. This means that the earthworm is an even more efficient user of nitrogen than microorganisms.

So you can see how widely distributed carbon is. It can be a gas, an acid or other form of compound. I need not say much about nitrogen here; it is a term with which every grower is familiar with. A certain amount of is essential for plant health. Too much is undesirable. When organic matter decays, the carbon is dissipated more rapidly than the nitrogen, thus bringing down the carbon-nitrogen ratio.

Before I go further and cover the significance of this ratio, we should first look at some figures, examples of typical materials and their specific carbon-nitrogen ratios:

Alfalfa hay — 12:1
Composted Manure — 20:1
Cornstalks — 60:1
Straw — 80:1
Sawdust — 400:1

Note the high carbon-nitrogen ratio of sawdust. Such a material would be considered highly carbonaceous, and has a very low nitrogen content. If much of it is put into the soil, there would not be enough nitrogen, the food of bacteria and fungi, which aid in the function of decomposition. They would thus have to consume soil and create a deficiency of nitrogen, thereby depressing the crop yield. The eco-grower who applies organic matter must be conversant with the carbon-nitrogen ratio of the different materials they handle. Generally speaking, the legumes are highest in nitrogen and have a low carbon-nitrogen ratio, which is a highly desirable condition.

There is a difference between the carbon-nitrogen ratio of raw organic matter and that of humus. The nitrogen in a leaf may be only 1 percent, but by the time it turns to humus, the percentage of nitrogen of that more or less refined substance would be about 5 percent. The average nitrogen content of practically all humus is about 5 percent, but in organic matter it fluctuates considerably.

Reprinted from
ACRES USA
A Voice for Eco-Agriculture
April 2000 - Vol. 30, No. 4 - Page 20

With carbon, however, a different condition exists. While decomposing organic matter loses large amounts of carbon as it turns to humus, the percentage of it to the total mass does not seem to go up or down considerably. If you begin with rotted manure that has a 40 percent carbon and 2 percent nitrogen content (which represents a carbon-nitrogen ratio of 20:1), you may wind up with a 10-to-1 ratio when it turns to humus — that is, a 50 percent carbon and a 5 percent nitrogen content. There is always a narrowing down of the carbon-nitrogen ratio when organic matter decomposes. The content of carbon in humus does not vary much. It averages about 50 to 53 percent.

We have seen that raw organic matter has a higher carbon-nitrogen ratio than humus or of the average soil. Now, as we study the of the microorganisms of the soil, we find there a much lower level than in the organic matter humus or soil. The average carbon-nitrogen ratio of the bodies of bacteria and fungi falls between 4:1 to 10:1. Why is their carbon-nitrogen ratio always less than the humus in which they work? The answer is that they require more protein than carbohydrates. Protein is needed primarily for tissue building, while carbon of carbohydrates is for energy.

Humus is made up to a great extent of lignins and other high-carbon material. Or in other words, humus has more carbohydrates than the bodies of microbes, which are extremely high in protein. Since about 16 percent of protein is nitrogen, we can see that the microbes bodies will have a very high proportion of nitrogen to carbon. Usually the tissues of bacteria are richer in protein than fungi.

When a lot of raw organic matter is applied to a soil, the microorganisms will multiply rapidly, but in the process of working they have to consume nitrogen. That is an absolute necessity to their existence. If the material that is tilled under has a low carbon-nitrogen ratio (that is, it is low in nitrogen), the soil organisms decomposing it will have to look for their nitrogen in places other than in the decomposing substances. They will draw on the soil's store of nitrogen, thus depleting it, with a depressing effect on the crop yield. But their bodies, now gorged with nitrogen, will die or be consumed by other predators and thus return the element to the soil. This shows that when tilling under highly carbonaceous organic matter, a sufficient period of time should elapse before the crop is planted. It will give the soil organisms time to pass on their nitrogen caches. Also, one should try to use organic materials with a low carbon-nitrogen ratio, which means a high nitrogen content.

We discovered that where the carbon-nitrogen ratio of added organic matter tilled under was 33:1 or more, a withdrawal of nitrogen occurred. Between 17-33 to one nitrogen, nothing was added or withdrawn; in other words, nitrification ceased. But if the ratio was under 17 to one, the nitrogen store of the soil was increased. This shows the value of adding compost to the soil, because its carbon-nitrogen ratio is usually quite low.

When tilling under organic matter with a high carbon-nitrogen ratio, the best practice is to apply with it a high-nitrogen fertilizer. The eco-organic grower can use for such purposes blood meal, bone meal, composted poultry manure, cottonseed meal, fish meal, feather meal and soybean meal, as well as a number of other organic materials having a high-nitrogen content. Such nitrogen-rich materials will speed decomposition and prevent the temporary nitrogen drain.

We found that earthworms feeding on oat straw composted with fish meal yielded a carbon-nitrogen ratio from 23 to 11 during a period of two years, while the soil microorganisms alone reduced it to about 18 during the same period. This means that the earthworm is an even more efficient user of nitrogen than microorganisms.

We've seen that the carbon-nitrogen ratio of tilled under organic matter is important to the conservation of the soil's store of nitrogen. It is also important to the general operation of soils. Mainly, it is a matter of having enough nitrogen available. There is a difference in the way a low carbon-nitrogen ratio works, depending on whether it is raw organic matter or humus.

We've discussed the dynamic action of organic matter and showed that organic matter applied to the soil represents nitrogen on the move. In a finished compost, it is in a more static condition. Less is given off. In terms of the carbon-nitrogen ratio, we can express it in the following manner. In the application of raw organic matter, the extent of nitrogen movement depends on its carbon-nitrogen ratio. If it is high, as in sawdust, there will be no movement. But if it is a material like young sweet clover (12:1), there will be a very satisfactory rate of nitrification.

In humus, however, although the carbon-nitrogen ratio is low, let us say 10:1, there is a resistance to rapid decomposition. The movement is slower and will take place over a longer period of time. This is of some value as it means the nitrogen is stored for future use. In the case of fresh organic matter with a low carbon-nitrogen ratio, not only is there a fast movement, but much carbon is given off in the form of carbon dioxide. Many entomologists believe this may kill off some of the larvae of destructive insects.

As rainfall goes down, the carbon-nitrogen ratio also declines. The higher the rainfall, the lower the nitrogen. The carbon-nitrogen ratio of arid soils is always lower than those in regions of higher precipitation. In a soil which had a rainfall of 15 inches per annum, the carbon-nitrogen ratio was 13:1. Where it was 10 inches or less of rain, the carbon-nitrogen ratio was about 11:1. It has also been found that the higher the temperature, the lower the carbon-nitrogen ratio. So in general, higher rainfall means a higher carbon-nitrogen ratio; higher temperature tends to lower the carbon-nitrogen ratios; and higher acidity raises the carbon-nitrogen ratio.

The carbon-nitrogen ratio of the soil humus remains almost unaffected by the addition of chemical nitrogen fertilizer. The application of organic matter that is high in nitrogen is necessary for the continuous accumulation of humus. Comparative studies of the carbon-nitrogen ratios of organic versus chemically managed soils is scant, though there is room here for future research.

Crow Miller and his wife and partner, Elizabeth, consult and speak widely and are authors of Let's Get Gardening *and other books. The Millers can be contacted at Agri-Balance Organic Consultants, P.O. Box 3083, Sag Harbor, New York 11963, phone (516) 725-5725, fax (516) 725-2110.*