DECOMPOSITION OF ORGANIC MATTER IN SOIL

The rapidity with which a given organic amendment is decomposed depends on temperature, the supply of oxygen, moisture, and available minerals, the C/N ratio of the added material, the microbial population, the age and lignin content of the added residue, and the degree of disintegration. Arshad and Frankenberger (1990) found that organic amendments contributed to the production of ethylene in the soil. Ethylene is produced by a diverse group of microorganisms and is important to many phases of plant development.

REQUIREMENTS

Oxygen. Oxygen supply is essential to aerobic micro-organisms, the primary agents in decomposition. Thus, reduction in air supply will.. result in reduced decomposition rates.

Water. Respiration of soil microflora is generally greatest at 60-80 percent of the waterholding capacity of soil. Too much water results in less oxygen supply and may hinder processes. At low moisture levels, supplemental moisture will result in a large increase in decay, whereas similar additions at moisture levels nearer optimum will effect little change.

pH. Microbial populations are highest in soils with a neutral pH. Neutral soils, therefore, are more conducive to decomposition than acidic or alkaline soils. Since many soils in the coniferous nurseries are commonly acidic, the addition of lime could manipulate soil pH and supply calcium, accelerating initial decomposition. Lime additions, however, need to be monitored carefully to prevent an increase in pH and subsequent infection by damping-off fungi.

Temperature. Temperature is one of the most important environmental factors determining how quickly natural materials are metabolized and subsequently mineralized. There is no single optimum temperature because the composition of and optimum temperatures for microbial species vary. In the temperature range of 41°-86°F, decomposition of plant residue is usually accelerated with rising temperature. Maximum decomposition rates are reached within a range of 86°-104°F. Above 104°F, decomposition rates generally decline (Alexander 1961).

Nitrogen. Nitrogen is essential for microbial growth and therefore the breakdown of organic matter. As described earlier, if the added material is low in nitrogen, microbes will compete with higher plants for nitrogen. This may result in a nitrogen deficiency. If supplemental nitrogen is added, decomposition is stimulated. Nitrogen-rich materials, such as legumes or blood meal, are metabolized quickly and need no supplemental nitrogen. When organic amendments having a C/N ratio of greater than 20 or 30 are added to soil, supplemental nitrogen is needed. Some materials such as sawdust, however, need only to have their C/N ratio brought down below 50 to eliminate nitrogen tie-up. The decomposers of such materials will recycle nitrogen fast enough to keep up with carbon metabolism (Refer to Tables 3 and 4 for C/N ratios).

Nitrogen is required for the initial application of mulch, for a moderately thick mulch of at least 1 inch, and again after some of the more slowly decomposable constituents become available. Bollen (1969) recommends 5-10 pounds of nitrogen for each ton, dry basis, of mulch at the time of application, and 2.5-5 pounds of nitrogen per ton should be added the second year. No further additions of nitrogen should be required because it will be released from microbial bodies after their death. Irrigation must be adequate after heavy application of nitrogen to prevent salt injury to plants. Theoretical amounts of supplemental nitrogen required with application of some wood mulches are outlined in Table 7. Actual amounts can be figured using the calculations shown in Appendix A.

Adding sawdust and bark in quantity to the soil has frequently inhibited growth, but studies show that such effects are usually the result of nitrogen deficiency (Allison 1973). To calculate the amount of nitrogen required to decompose organic material, it is necessary to know the amount of nitrogen immobilized by the micro-organisms in breaking down various products. Table 8 shows the percent of nitrogen immobilized for the sawdust of various tree species and wheat straw. For instance, if 1 ton of lodgepole pine sawdust is added to an acre, the percent of nitrogen immobilized after 160 days is 0.80. Therefore, at least 16 pounds of nitrogen per acre (0.008 x 2,000 lb) would be required. Examples of calculations are in appendix A. To account for a slightly increased amount immobilized beyond 160 days, it would probably be better to add 20 pounds of nitrogen per acre. A supplement of 20-25 pounds of nitrogen per ton of incorporated dry sawdust is adequate for most woods (Allison 1965). Red alder decomposes more quickly because it contains more N than other species and may require as much as 25-30 pounds of additional nitrogen per acre. It must be emphasized that this supplemental nitrogen is designed only to meet microbial demands necessary to decompose the added material and in no way is intended to provide for the nitrogen needs of the crops that will follow.

Table 7 — Characteristics of wood mulch and theoretical amounts of supplemental nitrogen required for application of commercially prepared wood mulch [1]

Characteristic of mulch and supplemental N required	Unit	Ground bark		Sawdust (Douglas–fir;
		Douglas–fir	Hemlock	
Thickness	in/acre	1	1	1
Moisture content[2]	percent	67	80	74
Weight:				
Wet	lb/ft3	18	21	17
	tons/acre	66	100	70
Ovendry (105-)	lb/ft3	11	11	11
	tons/acre	20	20	18
Volume[2]	ft3/acre	134	134	134
Supplemental N required with mulch:[3]				
Nitrogen —				
Initial application	lb/acre	100– 200	100– 200	100– 200
2d year	lb/acre	50– 100	50– 100	50– 100
Ammonium sulfate —				
Initial application	lb/acre	500-1,000	500-1,000	500-1,000
2d year	lb/acre	250– 500	250– 500	250– 500

[1] Values given have been rounded.

[2] Values are highly variable; the ones shown have been assumed.

[3] Nitrogen requirement was calculated assuming that 5-10 pounds N per ton, dry basis. was needed with initial application of wood mulch and 2.5-5 pounds N per ton was needed the 2d year (Bollen 1969).

Source: Bollen (1969).

RATE

Decomposition begins as soon as succulent green plant tissue is incorporated in a warm, moist soil. Associated with this decomposition is the release of ammonia and other macronutrients and micronutrients. This release is rapid in the first few months and continues at an ever-deereasing rate. The crop that follows is thus assured'a steady release of nutrients (Allison 1973).

The quantity of lignin and cellulose in plant residue is also important in predicting rates of decomposition. Slow rates of decomposition are commonly observed with residues that are high in lignin and cellulose (Alexander 1961) . Paustian et al. (1992) modeled the long-term (30-year) effects of the quantity and quality of organic amendments on soil organic matter and nutrient dynamics in a Swedish field. In those treatments not receiving organic matter the soil organic matter levels showed net losses. They also stated that lignin content showed a strong positive effect on organic matter accumulation. Adding fertilizer nitrogen increased organic matter carbon levels in all cases.

Size of particles also affects decomposition. Generally, a decrease in size will increase the decomposition rate, increase the amount of amendment that is water soluble, and hence increase the demand for nitrogen. Distribution of particles will affect the degree to which mulch will pack. For instance, if material has mostly fines with few larger pieces, it may have a tendency to seal the surface and impede infiltration.

Table 8 - Amount of nitrogen immobilized by micro-organisms decomposing sawdust and wheat straw incorporated into the soil

Type of sawdust	Nitrogen Immobilized after -				
	10 days	20 days	40 days	80 days	160 days
	Percent, dry weight				
Softwoods:					
California Incense-cedar	0.17	0.25	0.52	0.69	0.72
Redcedar	.17	.22	.17	.28	.41
Cypress	.13	.08	.17	.25	.37
Redwood	.13	.22	.21	.31	.34
Western larch	.20	.21	.44	.64	.79
Eastern hemlock	.08	.08	.20	.35	.42
Red fir	.22	.14	.36	.54	.83
White fir	.04	.00	.25	.35	.54
Douglas-fir	.07	.21	.07	.14	.30
Engelmann spruce	.15	.06	.48	.69	.74
White pine	.08	.05	.29	.48	.41
Shortleaf pine	.78	1.00	1.27	1.30	1.13
Loblolly pine	.01	.15	.31	.63	.60
Slash pine	.04	.02	.17	.46	.64
Longleaf pine	.01	.00	.15	.30	.49
Ponderosa pine	.05	.07	.19	.44	.42
Western white pine	.11	.08	.35	.61	.89
Lodgepole pine	.07	.01	.29	.61	.80
Sugar pine	.13	.15	.33	.43	.54
Average	.14	.16	.33	.50	.59
Hardwoods:					
Black oak	.86	1.17	1.21	1.20	**1.05**
White oak	.62	.96	1.19	1.15	1.09
Red oak	.93	1.20	1.40	1.23	1.16
Post oak	.77	1.07	1.27	1.25	1.20
Hickory	.78	1.00	1.12	1.17	1.07
Red gum	.90	1.28	1.24	1.18	1.04
Yellow-poplar	.98	1.19	1.13	1.15	1.05
Chestnut	.38	.88	1.14	1.07	1.13
Black walnut	.80	1.18	1.20	1.15	1.07
Average	.78	1.10	1.21	1.17	1.10
Average, all woods	.35	.46	.61	.72	.75
Wheat straw	**1.25**	**1.68**	**1.35**	**1.14**	—

= No data.
Source: Allison (1965).

TIMING

Application of organic elements is best made in the spring, thus allowing decomposition during warm summer months. Supplemental fertilization is made in the spring and grass or another cover crop can be planted. Soils should be kept moist but not saturated to encourage decomposition.

MICROBIAL ACTIVITY

For centuries compost (artificial manure) has been used in China, India, and other Asiatic countries, and to a lesser extent in western countries. There are an infinite number of composting methods, but no one method is superior (Allison 1973). The basic purpose of composting is to bring about a rapid and thorough partial decomposition of organic materials with little loss of nutrients in order to produce an end product that has desirable physical and chemical properties.

Processes commonly used in composting involve piles of alternate layers of organic wastes and other materials including topsoil, peat, wood products, or other absorbing substances. Addition of animal manures speeds up decomposition and improves physical characteristics of the compost product.

Supplemental fertilizer nitrogen may be needed if organic wastes have wide or high carbon-to-nitrogen ratios. Often, animal manures can provide all or a portion of this requirement for extra nitrogen. Limestone is often mixed into the compost pile to alter the pH and to encourage microbial decomposition.

Good aeration is needed in the compost pile, especially if succulent vegetable wastes are mixed with materials having slower decomposition rates. Aerobic digestion is accomplished by mixing the pile occasionally to prevent packing into soggy anaerobic mixtures. Natural rainfall or irrigation can provide moisture that is required by microorganisms breaking down the mixture, though prolonged exposure can leach nutrients. The decay process may take 3-4 months in temperate climates but varies with materials used and climatic conditions.