VABF's Sustainable Technologies

Mulches and Soil Fertility: *nutrients, organic matter, tilth and soil life*

Mulches improve vegetable yields primarily by saving soil moisture and suppressing weeds, but they also influence soil fertility. Mulching simulates nature's way of replenishing soil organic matter and plant nutrients. Each year, leaves, other plant residues and animal dung fall to the ground. Soil organisms then "eat" the residues from below, and gradually convert them into humus. The decay process releases nutrients and helps keep the soil loose and crumbly. Humus is essential for holding nutrients and moisture, and for maintaining healthy soil. Because the humus itself decomposes gradually, it must be replenished regularly. In well-aerated and well balanced soils, ten tons (dry weight) of fresh organic residues will regenerate about one to two tons of humus.

Organic mulches can help maintain soil organic matter, tilth and nutrient reserves in gardens and cropland. Regeneration of humus depends on the quantity and quality of the materials applied, and on conditions favorable to aerobic decomposition. A mulch that interferes with aeration or upsets soil nutrient balance may hinder humus formation and crop growth. However, mulching practices tailored to existing soil conditions can help maintain or improve soil and crop health.

Mulch Effects on Soil Nutrients

Will organic mulches "rob" nitrogen (N) from the crop? In most cases, not much. Legume hay and other materials with more than 1.7 percent N actually release some crop-available N. When soil organisms consume residues with less than 1.5 percent N, they "borrow" soluble N from the soil, and tie it up in organic matter. When low-N materials like sawdust, straw or grass hay are mixed *into* the soil, they cause a microbial feeding frenzy that leaves little N available to the next crop. However, when organic materials are spread *on top of* the soil as a mulch, the microbes nibble rather than bingeing. They tie up a little N at first, then give it back later. In several studies, mulching annually with grain straw actually *improved* soil N availability after five to ten years. Crop-available phosphorus (P) and sulfur (S) levels also increased.

Finely divided, N-poor materials like sawdust, and residues with lots of soluble carbohydrate, like corn stalks, can tie up enough N to increase fertilizer needs. Also, organic mulches can indirectly cause N deficiency by keeping the soil too cold, wet and poorly aerated. These conditions inhibit soil microorganisms that release N from organic matter. This problem occurs mainly under a very heavy or matted mulch, or one that is applied too early in the spring before the soil has warmed up.

Organic mulches also add the cation (positively charged) nutrients potassium (K), calcium (Ca) and magnesium (Mg) to the soil. A proper balance of K, Ca and Mg is essential to soil and crop health. The "base saturation ratio" (shown on soil test reports) should be about 70-75 percent Ca, 10-12 percent Mg and 2-5 percent K. Adequate Ca helps maintain good tilth and stimulates beneficial soil life and humus formation, which in turn stabilizes Ca and other nutrients against leaching.

Hay, straw and crop residues contain all three elements, and are particularly rich in K (Table 1). As the mulch breaks down, rain carries these minerals into the soil. A five tons per acre mulch may deliver 100 to 200 pounds K per acre, enough for many vegetable crops. However, grass hay and straw have low Ca:K ratios, which can cause problems on some soils. Annual applications of three to six tons per acre can push soil K levels up 50 to 100 percent in five to ten years, while slightly lowering Ca levels. If the soil's Ca:K ratio is already too low – a common imbalance in Virginia and neighboring states – repeated use of straw or grass hay mulches may cause the soil to become sticky and poorly aerated, and crops to become more pest and disease prone. On soils low in K, these same mulches might improve soil mineral balance and crop nutrition.

Legume hay, buckwheat straw, and tree-derived mulches have higher Ca levels (Table 1). Autumn leaves, pine straw and bark have very high Ca:K ratios, and may help correct a soil Ca deficiency. However, fresh leaves and bark of some species, notably black walnut, yellow poplar and red cedar, can be toxic to crops. Composting, or aging outdoors for six to 12 months eliminates toxicity from leaves. Some nutrients may leach out during this time, but the Ca:K ratio remains high.

Table 1. Typical nutrient concentrations in several organic mulching materials

	Percent of dry weight				
	N	P	K	Ca	Mg
Legume hay	2.50	0.32	1.45	1.30	0.15
Grass hay	1.40	0.30	2.15	0.37	0.24
Grain straw	0.65	0.10	1.59	0.38	0.19
Corn stover	0.95	0.13	1.16	0.40	0.10
Buckwheat straw	1.25	0.07	0.95	2.00	0.30
Lawn clippings	3.40	0.35	2.25	0.50	0.32
Hardwood tree leaves, green	2.36	0.24	1.18	1.71	0.47
Hardwood tree leaves, autumn	0.74	0.16	0.53	2.45	0.46
Pine straw	0.75	0.06	0.26	0.68	0.18
Sawdust, wood chips	0.14	0.01	0.04	0.19	0.01
Bark, hardwood	0.24	0.06	0.21	2.60	0.12

Mulch Effects on Soil pH

Soil pH, a measure of acidity or alkalinity, should be between 6.0 and 7.0 (slightly acid to neutral) for most vegetable crops. Will mulching make the soil too acid (pH below 6)? Not necessarily. Even highly acid materials like sawdust, pine straw and leaves tend to shift toward neutral as they decompose into humus. Depending on soil conditions, management practices and thickness of the mulch, soil pH may drop slowly, remain unchanged, or even rise slightly under organic mulches. Acidification is most likely when a thick or matted mulch interferes with aeration and humus formation, or when soluble ammonia-nitrogen fertilizers are used in conjunction with organic mulches.

Mulch Effects on Soil Organic Matter

In natural forests, trees drop one to two tons of leaves each autumn, which is usually sufficient to replenish humus and nutrients. On the farm, tillage and cultivation accelerate the breakdown of soil humus, which releases more nutrients for crop production, but requires larger annual organic inputs to maintain soil organic matter. As a rule of thumb for humid temperate climates, about five to ten tons (dry weight) of organic inputs annually will adequately replace organic matter consumed in crop production.

Residues replenish the soil only if they decompose properly, which requires adequate soil aeration, favorable temperature and moisture, and a diversity of beneficial organisms. Conditions that can interfere with this process include:

- inadequate aeration (heavy, tight soil; matted or excessively thick mulch)
- soil nutrient imbalance, especially Ca deficiency or extreme pH (below 5.0 or above 8.0)
- too wet or too dry soil conditions
- an extremely low N content in the organic residues
- cold or extremely hot soil conditions
- lack of earthworms or beneficial bacteria and fungi
- natural toxins in some residues that delay decomposition

Organic inputs containing 1.5 to 2 percent N form the most humus. However, mulches with considerably less N, such as grain straw, can gradually enhance soil organic matter and N reserves. Maintaining adequate soil aeration, and using a diversity of inputs – mulches of different kinds, cover crops, compost, crop residues – will promote healthy decomposition and humus formation. Because soil organic matter levels change very slowly in response to management practices, it may take five to twenty years to determine whether inputs are sufficient to maintain good organic matter levels. Other indicators of soil health may respond more quickly, including tilth and earthworm populations.

Mulching, Soil Tilth and Soil Life

Organic mulching has the most immediate and dramatic effect on the condition of the soil surface. Pull back a layer of hay, straw or sawdust, and you will likely see a soft, open, moist surface made up of crumbs 1/20 to 1/2 inch across. Earthworms, ground beetles, spiders and other desirable critters will be crawling around, and you may see nightcrawler burrows opening at the surface. Even a light mulch of two or three tons hay or straw per acre (one 35-lb square bale per 250 to 375 square feet) will protect surface tilth by absorbing the impact of heavy rains and preventing surface crusting. As microbes "eat" the mulch, they release gummy substances that hold soil together in crumbs, and they also create humus. Mulch supports earthworms, which mix the humus throughout the topsoil and help the soil "breathe" and absorb rainfall. In bare soil, earthworms have less to eat, and many die during the first hard freezes of autumn. Organic mulch provides food and also slows the rate of soil freezing, which gives the worms time to adapt.

In some cases, organic mulch worsens tilth. If the mulch interferes with aeration or putrefies, it can kill or inhibit those organisms that keep the soil loose and crumbly. Also, a mulch with a high K:Ca ratio could aggravate an existing soil Ca deficiency, thereby making the soil more sticky.

What About Plastic Mulch?

Plastic protects the surface from rain impact, and can reduce the loss of soil nutrients by leaching. However, plastic mulch adds no organic matter and creates an unnatural "skin" over the soil, and some growers avoid plastic because of possible adverse effects on the soil.. The recent VABF mulching study detected no compaction or loss in tilth after a single season's use, but fewer earthworms were found under plastic at the end of the season than under hay or paper mulches. Insufficient food and/or hot dry conditions under the plastic probably caused the worms to migrate elsewhere. Repeated use of plastic could adversely affect the soil by restricting earthworm activity.

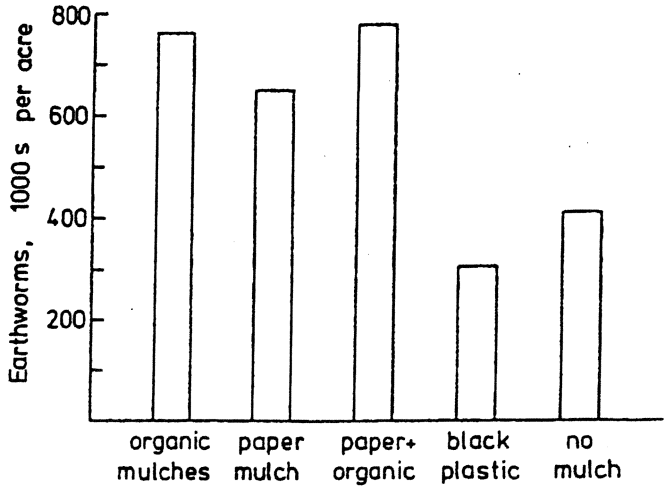

Figure 1. *Earthworms preferred organic or paper mulches over plastic in the VABF mulching study.*

On larger, more mechanized farms, black plastic may be the most economical choice for certain heat-loving crops such as melons. To maintain soil organic matter while using plastic mulches:

- Apply compost in planting rows before mulching.
- Spread organic mulch or sow cover crops in alleys between plastic-mulched beds.
- Rotate plastic-mulched crops with organic-mulched crops and/or green manures.

How to Optimize Mulch Effects on Soil Fertility

- Use a diversity of mulches, cover crops, composts and residues to maintain soil organic matter. Annual organic inputs of five to ten tons per acre (dry weight) will approximately maintain soil humus; more can help increase humus levels. Winter cover crops typically add two to four tons per acre; buckwheat adds one or two tons. Use mulches with a moderate N content (1 to 2 percent) for maximum humus formation. If you use a low-N mulch, the crop may need some supplemental N.

- Keep the soil surface covered with mulch or vegetation most of the time. Choose coarse, loose mulching materials that will let the soil "breathe." Avoid very heavy or matted mulches that may cut off aeration and stop humus formation.

- Mulching may not be the best use for well ripened compost. Maximize the benefits of compost by mixing it into the topsoil at 10 to 20 tons per acre (one 100-lb wheelbarrow load per 100 to 200 square feet) or adding it to planting holes or seed furrows.

- Get a good soil test initially and every few years to monitor soil pH and nutrients. Add minerals as needed, e.g.. calcitic limestone if only pH and Ca are low; dolomitic if Mg is also low. Most "agricultural lime" is partly or wholly dolomitic. Cattle feed lime, which is widely available and affordable, is essentially all calcitic. Use gypsum if you need to add Ca without raising soil pH.

- Choose mulching materials that match the soil's needs, with particular attention to Ca, Mg and K. If soil K is low and Ca is adequate, mulch with five to ten tons grain straw or grass hay per acre. If soil Ca is low, use mulches high in Ca such as aged hardwood leaves. *Note:* use municipal leaves, yard waste or sawmill byproducts when possible, as removing large amounts of leaf litter from the woods can seriously damage forest ecosystems.

- Carefully observe soil conditions under the mulch from time to time. An open, moist, crumbly, dark brown surface with worms or worm burrows visible is a good sign. If the soil is dry, irrigation will aid humus formation as well as helping the crop. If the soil surface is soggy or sealed-over, or the bottom of the mulch layer smells putrid, remove the mulch, cultivate the soil several inches deep, let the surface dry slightly, and apply a light, loose, dry mulch. If the soil is hard, compacted or sticky, loosen hardpan with a spading fork or chisel plow. Check the Ca-K-Mg balance and add mineral supplements as needed.

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Mark Schonbeck

VA Assoc. for Biological Farming
P.O. Box 1003
Lexington, VA 24450