How Can Organic Vegetable Growers Increase Soil Fertility Without Overloading the Soil with Nutrients?

Brian Caldwell, NOFA-NY Farm Education Coordinator

Part 1. The Problem

This is an issue that is just beginning to be recognized. It arises from a common practice among organic vegetable growers—that of applying compost or manure to vegetable fields nearly every year in order to fertilize crops and raise soil organic matter (OM) levels. While this is a beneficial practice in the short term, in the long run it can lead to over-fertilization and water pollution. The problem is similar to over-fertilization that occurs on livestock farms with insufficient land on which to properly spread their manure.

On most new land that is just being put into organic vegetable production, it is common and quite worthwhile to apply a big "shot" of nutrients and organic matter through heavy applications of compost and manure. After the first heavy application, amounts can be reduced in subsequent years. However, manure or compost is still usually applied at a rate that will supply at least the necessary nitrogen (N) needed for the next crop, which means that extra phosphorous (P) and potassium (K) beyond the crop requirements will be added to the soil. Over the years, soil P and K levels build to moderate, then high or excessive levels. The soil is out of balance. In fact, if manure or compost is added specifically to increase soil organic matter levels, which is a goal for many organic farmers, then usually all nutrients will be added beyond crop requirements.

Let's look at an example from my own farm. "Field 1" is a small field of about 1/5 acre which had been the farmstead garden for many years before I moved to Hemlock Grove Farm in 1977. It had higher nutrient levels than our other fields. I have soil test data (Table 1) from this field over a period of 21 years, starting in 1978. I also have records of the nutrient-carrying materials I added to this field for 16 years, which can be extrapolated for the 21 year period, as I used similar practices over the whole time. Though the field is small, all data have been standardized on a per-acre basis for comparison.

Year	Soil P	Soil K	Soil pH	Soil OM
1	25	400	6.1	3.2
2	37	40	6.0	3.4
12	43	515	6.7	3.3
21	82	685	7.0	3.7

Table 1. Soil Test Data, Field 1

This data shows the problem. Soil nutrient levels are all in the high range after 21 years, which seems good, but if I continue the same practices, they will get too high.

Phosphorus levels are already very high, and going up faster than anything else. (Cornell test values are on a scale that reads lower than typical values, so my current P level would probably be measured at over 500# by most labs). High soil P does not hurt crop plants, but can contribute to water pollution. Note that soil organic matter levels have increased only slightly, from 3.2% to 3.7%. Soil nitrogen levels are so variable because of weather conditions that they are not routinely measured, but OM level gives an indication of how much is stored in the soil.

Using guestimates as to the nutrient composition of the applied compost, hay mulch, manures, etc. (but not including N from cover crops) and of the amounts that typical mixed crop vegetable harvests may have removed over the period, I've made a rough nutrient budget for this field over the 21 years. The field did not seemingly get heavy applications of organic fertilizers, averaging only 6 tons per acre per year of beef or sheep manure, with occasional additional applications of hay mulches, commercial and homemade compost, and wood ashes. (In retrospect, the 500#/A of rock phosphate we put on one year looks like a mistake.) Adding all this up, though, gives an estimated total N-P-K addition of 3500-2200-3650 to this field over 21 years. I further estimate crop removal at 1500-200-2000 over that time (note how little P is actually removed by vegetable crops). So, net additions to this field were around 2000-2000-1650 pounds per acre of N-P-K. No wonder test values went up!

Where do excess nutrients go? Extra added P and K are mostly held in the soil in unavailable forms, but most nitrogen is not. Some of the nitrogen is held in the increased amount of soil organic matter after 21 years— a .5% increase holds about 400# of N. But most (over 1500# /A or about 70#/A/year in this case) of the excess nitrogen will not be held in the soil, but will leach into groundwater or volatilize into the air. In many situations, such as typical home gardens, this is not a problem, since only a relatively small amount of nitrogen is in question. But if this practice is done on a widespread basis or on large farms, there is potential for significant groundwater pollution. The same situation occurs when excessive chemical fertilizer is applied.

I believe that there is no good reason to continue to increase these soil nutrient levels. The field produces good yields and quality. It has clearly reached a "mature" state in which heavy applications of brought-in organic materials are unsound. A field like this needs an approach that produces crops and maintains soil OM levels without the "booster" type approach.

Part 2. How do we raise soil OM levels without causing this problem?

High levels of soil organic matter are desirable in many ways. Higher OM improves soil water holding capacity, aeration, infiltration, nutrient holding and release, and more. But how do we achieve high soil OM sustainability over the long term! And how high should it be!

Virgin soil had much higher organic matter levels than current cultivated soils. How did high soil organic matter levels arise naturally (presumably, without groundwater pollution)? The answer is: very slowly, and in the absence of tillage and crop removal. Intensive tillage is the primary culprit in "burning up" soil organic matter at a very high rate, requiring that we add outside sources of OM to the soil. Under natural untilled forest or prairie conditions, highly carbonaceous organic litter (leaves, etc.) is added to the soil surface each year, and roots die within the soil. No additional P or K is added to the soil system, except what weathers slowly from the rocks. Nitrogen is added in small amounts from precipitation and bacterial

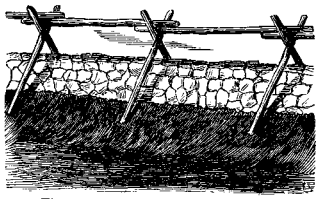
fixation, but held tightly in the vegetation and decomposing surface litter. Small amounts of nutrients are sequestered away each year in humus and "locked up" OM that is not available to decomposers or oxygen. Nutrients cycle around and around, with relatively slow breakdown of soil OM, and accumulation of high-carbon OM on the soil surface. In this way, soil organic matter can build up very gradually over thousands of years, to levels around 10% in many virgin mineral soils.

When this land is cleared and repeatedly tilled, OM levels drop rapidly down to less than 2% in the absence of manure or compost applications. A sick soil. But remember, our real goal for a farm field is to preserve or increase soil quality, not just its OM content. We tend to be in a frame of mind that says, "the more OM, the better." While there is some truth to this, under any given tillage and cropping regime there is an "equilibrium" level of soil OM. Generally, the less tillage, the higher this equilibrium level. OM levels can be maintained above equilibrium only by continuous heavy applications of compost or manure that carry far more nutrients than the crops can use. This is wasteful and leads to pollution. (The Biodynamic goal of the farm as a self-contained organism helps to avoid this problem, because it discourages importation of large amounts of nutrients.) Research at the Rodale Research Center has shown that soil biological activity, quality, and fertility can be very high, even at modest (2.5-3.0%) soil OM levels, if a large portion of the OM is in the "active" form, i.e. in the process of being broken down. So, the key soil quality strategy in farming is not merely accumulating a high soil OM level, but cycling it rapidly and effectively. It is counterproductive to shoot for virgin soil OM levels on tilled farm fields.

It is important to realize that the constant production of tilled crops, especially vegetables which return few residues to the soil, is the harshest way to treat your soil. Sod crops in rotation are the only tried and true way to increase long term soil OM levels without negative "side effects." Sod accomplishes this because the soil is not tilled, and extensive root systems are formed. Traditional field crops rotations often involved applying manure or compost to a field only once in every 4- or 5- year cycle. Organic matter levels and soil nitrogen were greatly enhanced by at least 2 years of a sod hay crop. Phosphorus and potassium did not build up in such systems, but were instead mostly cycled around the farm through feed and manure.

An ideal rotation for vegetable growers, from a soil and nutrient standpoint, would be to substitute vegetable crops for the heavy feeding (field corn) and light feeding (small grains) crops in this traditional rotation. Heavy feeding vegetable crops would include intensive greens, brassicas, sweet corn, leeks, cucurbits, etc., while light feeders would be root crops, beans and peas, etc. A sod crop of legumes and grasses will provide a maximum OM contribution, while supplying its own nitrogen. If hay is harvested, there may be a net removal of P and K. These nutrients can then either be sold off the farm, or fed or otherwise recycled within the farm.

An experimental method of increasing soil OM without heavy nutrient loading is to use high-lignin, relatively low nutrient OM sources such as wood chips. These interact in a limited way with the soil, because of their high lignin content and low surface to



volume ratio, but do provide an excellent OM source over the long term. Cornell did a 15-year study in the 1950s and 1960s in which 10 T/A/year of hardwood chips was added to experimental plots of Honeoye silt loam, a rich soil type. Soil OM and other soil quality levels were dramatically raised, with some positive (and some limited negative) effects on vegetable crop yields. Little soil nitrogen was "tied up," contrary to expectations.

Recently, Quebec research on positive results from the use of chipped hardwood branch wood ("remial") was reported in the *Maine Organic Farmer and Gardener* magazine (12/98-2/99 issue). The authors stressed the importance of fungus organisms in the soil. There is growing opinion from some soil scientists, notably Dr. Elaine Ingham of Oregon State University, that many of our agricultural soils are overbalanced toward bacteria, rather than fungal populations, because of the highly available nutrient sources we use. There may be other benefits to favoring soil fungi—perhaps establishing large and varied fungal populations in our soils could also help reduce fungal pathogen populations.

So, what are the take home lessons here?

1. Significantly increase the sod and light-feeding crops in your rotation on "mature" fields.

2. Reduce tillage and keep soil covered with cover crops and mulches.

3. Don't waste nutrients by excessive manure or compost applications. This is particularly important if your P levels are in the "high" range. Rely more heavily on getting nitrogen from legume cover crops and sod than from manure or compost.

4. If you want to increase soil OM levels further, try experimenting with spreading wood chips on your fields in moderate (1O T/A or less) amounts. They can be spread just before spring tillage, or even better, left as mulch on the surface until next spring.

This article originally appeared in *The Small Farmer's Journal*, Summer, 2001.

Reprinted from Organic Farms, Folks and Foods, the quarterly newsletter of the Northeast Organic Farming Association of New York, Inc., (©2002 by NOFA-NY), an organization dedicated to the creation of a sustainable regional food system which is ecologically sound and economically viable. For permission to reproduce more copies contact NOFA-NY at: 518-534-5495. Please include this message in any reprints.