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Multiple soil health & economic benefits applying municipal collected un-composted leaves to farmland

Case Study of Bob and Leda Muth Family Farm, Williamstown, NJ

By Jack Rabin, October 2005, updated September 22, 2011

Problems Targeted - Problems Overcome

Two decades ago Bob Muth recognized his gravelly sandy loam Coastal Plain soils warmed early, drained quickly, and produced profitable vegetable crops. But, the soils are naturally low in soil Organic Matter (OM), readily oxidize existing OM, and are low in native fertility. Coastal Plain soils also tend to leach fertility, naturally acidify toward a lower than ideal soil pH range, and compact easily when worked under typical spring conditions. Bob was experiencing increasing incidence of destructive soil-borne Phytophthora blight on his highest value crops.

High marketable yields required costly inputs and intense practices, yet results remained unreliable. The management path was not sustainable. Bob began a multi-year search for alternatives, sensing there was a path using practical soil husbandry solutions farmers recognized for generations. Bob worked with local communities and their Municipal Works Departments, utilizing field applications of un-composted municipal collected deciduous leaves, which communities would otherwise pay to handle. Leaves became statutorily banned from NJ landfills since 1987. Colleagues and professionals raised three concerns with Bob about applying un-composted leaves to farmland:

1. **Biological.** Soils experts and literature reported that un-composted leaves immobilize soil Nitrogen due to high Carbon:Nitrogen ratio and may lower soil pH. The result would be crop nutrient deficiency imbalances and reduced yields.
2. **Practical and Social.** Foreign matter in curbside leaf collections, from diapers to beer cans, fouls farming activity. Leaves blowing from fields to neighbors' yards are a potential source of nuisance complaints.
3. **Regulatory.** The state Department of Environmental Protection and local inspectors treated leaves as regulated waste disposal instead of–well–leaves, natural organic matter. This changed in NJDEP waste recycling 7:26A-1.4 (a) 12.

Based on Rutgers research, Bob experimented, trying different approaches on his farm, and evolving a successful approach with remarkable benefits. After years of working together, Municipal Public Works Departments cooperate with Bob on everything from specifying machinery they use to collect (or vacuum) leaves, timing of delivery, and educating residents to keep foreign material from their curbside leaf piles.

5-Year Cycle of Rotation–Timing and Practices

On frozen ground in late winter, an initial 6″ deep layer of leaves–about 20 dry tons per acre–is applied into standing cover crop (planted the previous Fall) with manure spreaders. Applying into standing cover crop reduces windblown leaf nuisance to neighbors, and frozen ground avoids equipment compacting soils. The deep leaf layer significantly delays Spring soil warming and drying. Primary tillage leaf incorporation with a chisel plow or and/or offset disk is delayed until May or June, later than typical locally. So begins a five-year rotation cycle on Bob's farm (Table 1). Less deep 2″ maintenance leaf applications occur in subsequent rotation cycles. Rotations on Bob's organically farmed fields receiving maintenance leaf applications are reduced from five to three years.

Since nitrogen immobilization is severe the first year, Bob plants forages like Timothy or orchard grass. Typically orchard grass is used because of its ruggedness and aggressive roots. Forages can be mowed and cash cropped to supply nearby equine owners, or grown as fallow cover. This is normally left in for two years. In the fourth year, Bob plows and plants rye vetch cover crop to prepare for his high value crop.

Table 1. Typical 5-year Bob Muth rotation incorporating un-composted leaves. There are variations, with fewer years between vegetables after establishment.

Year	Season	Activity	Equipment
1	Late Summer-Early Fall	Plant cover crop	Disk or Field cultivator, Drill
	Winter	Apply leaves into standing cover	Front end loader, large Manure spreader
	Spring (Late)	Primary tillage incorporation	Chisel Plow, Offset disk
	Late Summer-Fall	Plant pasture grass	Drill or Brillion;
2	Annual	Grow grass	Optional mow and hay making
3	Annual	Grow grass	Optional mow and hay making
	Late Spring-Early Summer	Primary tillage incorporate grass	Chisel or Moldboard plow
4	Late Summer-Early Fall	Plant rye vetch cover crop	Disk and Drill
	Early Spring	Tillage incorporate rye vetch	
	Spring	Secondary tillage	Disk
	Spring-Summer-Fall	Shape beds, lay plastic & drip, transplant	Bed shaper, Plastic mulch layer, Water wheel transplanter
5	Repeat rotation cycle. Adjust maintenance leaf application to soil test needs. Crops may finish too late in Fall for good cover crop establishment.		

Timing the Fall cover crop seeding is critical for ideal late winter height. There is about a 3-week window for seeding, but usually only 3-5 ideal seeding days. Since September is a busy harvest and sales month, management and labor needs to be readily available for seeding cover crop on short notice, without detracting from other farm activities.

Depending on weather conditions, and with a couple of employees with two spreaders running, about 500 cubic yards of leaves can be spread daily. The Muth Farm can accept up to 8,000 cubic yards per year at three designated all-weather sites on the farm. The site needs to be as all weather as possible for heavy trucks, which may deliver during wet winter slow periods. Staging should be adjacent to fields, avoiding undue inefficiencies. The notification process regarding on-farm staging sites receiving leaves has been simplified. Farmers simply notify the Department, host municipality, and county as per N.J.A.C 7:26A 1.4(b)5.

Some municipalities perform tub grinding on collected leaves, which reduces their volume about 3-4 to 1 compared to raw leaves. A grower only need apply about a 2" layer of tub ground leaves. As expected, first year cover crops after incorporation appear "rough," with visible temporary nutrient deficiencies. By the second year, crops grown on these fields begin appearing normal.

Strategic Management of the Whole Farm

Skeptics miss something fundamental in Bob's pursuit of sustainable farming practices, soil health, and profit. According to Bob, he simply, "Practices the good soil husbandry farmers have recognized for generations." Instead of beneficially reusing un-composted municipal-collected leaves as a fertilizer substitute within existing practices, Bob has redesigned the farm, integrating the cropping cycles around the leaves in a modified management system. Bob uses ***Whole Farm Planning***. Bob's practices are no longer a 'tactical' measure (like IPM scouting); they are a 'strategic,' long-term approach.

Growers and ag professionals express concerns about immense effort and hassles Bob devotes to leaf applications. These include: community coordination, management time, providing all-weather staging sites for truck deliveries, interaction with permits and inspectors, equipment, and complex fallow rotations. Some growers don't explore winter leaf application because they feel exhausted from management burdens and physical labor by seasons' end; when they take a needed well-earned break repairing equipment, deer hunting, or vacation. Some may be on rented land with annual leases. Other growers drop their jaw fearing risks of foregoing crop sales by not planting high value crops on every tillable acre, every year, or alternate years. They express disbelief Bob maintains thriving financial viability when he describes his rotations; limiting his best vegetable crop production to about 20% of his acreage annually.

Eschewing Debt and Diversifying Markets

Bob and Leda also eschew indebtedness–the greatest risk to farming sustainably–and transitioning to these practices. Bob reduced cash crop production acreage, reduced costly workforce requirements, and dramatically reduced costs from inputs like commercial fertilizers. Healthier soils reduced risk of calamitous losses from rain, soil-borne diseases, and drought, while maintaining farm income. A thriving 450 member CSA further secures market alternatives.

Whether on the 48 homestead acres Bob's father accumulated from around 1945 as small purchases while a part-time farmer and factory worker (this homestead land is in a Family Trust with siblings), to the additional 70 acres Bob purchased with farm profits, the 90 tillable acres on his 118-acre farm have soil test results with 3.5-5.5% Organic Matter (OM) and 9-10.5 Cation Exchange Capacity (CEC). These are remarkable compared with 0.9-1.2% OM typical on area fields.

Six Benefits of Leaf Incorporation at Muth Family Farm

1. **Beneficial re-use of community waste no longer allowed in landfills.** Deciduous leaves formerly were a high carbon organic community waste stream material. While previously transported to landfills with costly tipping fees, leaves cannot be disposed of as waste in NJ. On Bob's farm leaves are beneficially re-used, in a productive agricultural system where soils are naturally deficient in soil organic matter (OM) and low native fertility. Bob made a choice not to charge communities a tipping fee, or keep them low, for receiving their material, which maintains positive valuable municipal relationships.

2. **Nitrogen fertility for free.** Nitrogen, in the nitrate NO_3-N form plants require, is the most yield limiting, costly, and petro-chemical manufacturing dependent crop nutrient. Perform a demonstration calculation: The purchase price of typical 16-8-8 or Calcium Nitrate (15.5% $CaN0_3$) fertilizer in summer of 2009 exceeds $500 per ton. As a 15.5% material, one ton of $CaN0_3$ provides 310 lbs per ton (0.155 x 2,000 lbs) actual N. 400 lbs/acre of N are mineralized over a subsequent four-year period from a 6" leaf application, so Bob is saving about $650 per acre from not applying 1.3 tons of fertilizer. Since N releases more slowly from mineralizing organic material than fertilizer, there is potentially **less N leaching loss**.

3. **Soil Organic Matter (OM) increase.** Un-amended, Muth's gravelly sandy loam soils (10-12% +/- clay) have low OM, typically 0.9-1.2%. After years of his leaf incorporation practice, Muth's soils routinely test in the 3.5-5.5+% OM range, and as high as 8% for periods, unheard of in the region. Atlantic *Coastal Plain soils naturally oxidize OM*. In return, these coarse droughty soils offer farmers quick drainage to reenter fields after rain and early warming for profitable crop maturities. Even without intense cropping and tillage contributing to OM reduction, the natural state of this money-making, productive soil is *low fertility*, *low Cation Exchange Capacity (CEC)*, ease of compaction, ease of nutrient leaching, drought tendency from poor *water holding capacity*, and poor root zone *tilth*. Increasing OM changes these dynamics. OM increases are difficult for farmers to attain with green manure cover crops or crop rotations alone.

Demonstration calculation of soil OM: A 6 to 7-inch plow furrow slice of soil weighs about 2 million lbs per acre. 20,000 lbs of dry OM (20,000 lbs ÷ 2,000,000 lbs) will change soil OM by 1%. Since green manure plant materials are mostly water, incorporating 20,000 lbs of Sudex (vigorous *Sorghum-Sudan grass hybrid a summer soil building cover crop*) likely adds 3,000 lbs +/- OM to soil. Even with intense cover crop rotations, with OM continually oxidizing, it could take a decade to improve soil OM by 1%. In one 6-inch layer of leaf mulch, 40,000 lbs of OM is applied per acre. This changes OM 1% in one crop rotation cycle instead of 10-20+ years.

4. **Increased root zone soil moisture retention *and* faster infiltration.** Bob's healthy soils reduce two economic production risks at the same time, which at first glance appear opposite. Bob's healthy soils retain more soil moisture, and more uniform soil moisture, in the root zone. At the same time his soils facilitate rapid infiltration of surface water after irrigation or hard rainfall. More uniform root zone soil moisture decreases incidence of crop physiological defects, which become culls and raises marketable yield. These include, Blossom End Rot of tomato and pepper or cucumber 'nobs' from lack of even moisture or drought stress during pollination and development. Uniform moisture retention reduces yield loss risks during periods of intermittent precipitation, or when growers simply get behind irrigating. These soil quality factors infiltrate free surface water more quickly, reducing erosion down the rows, and reduce soil-borne diseases incidence, described next.

5. **Decline in Phytophthora blight crop destruction.** *Phytophthora capsicii* blight is the most destructive and economically devastating soil-borne *fungal pathogen* of intensively produced *Solanaceous* and *Cucurbit* crops in the region. Control with fungicides, while an essential part of integrated crop management, is costly. Control is frequently marginal, *resistant pathogen races* emerge, and devastated farmers lose income. *Free soil moisture* for only two hours around the *crop root zone* is a sufficient condition for Phytophthora infection, thus fast removal of standing water after precipitation or irrigation is an essential ecological approach to managing this pathogen. Modifying soil OM and improving tilth changed the soil-root-water environment on Muth's farm. Combined with the longer rotations associated with leaf application, a dramatic decline in Phytophthora blight incidence was observed.

6. **Soil test results show beneficial release of Ca from mineralization of deciduous leaves.** Pre-practice adoption, a commonly held view advised Muth that leaves would acidify his soil, lowering its pH, and raise his purchased *lime requirement* to balance soil pH. Rutgers research and Muth's soil test results in years after leaf incorporation showed slight beneficial rises in Ca levels and pH. Calcium is an essential plant nutrient, usually requiring liming amendments to soils. The added Cation Exchange Capacity of the higher OM soils buffers nutrients on soil particles, such as Ca, against leaching.

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Fertilizer value chemical composition per acre of 6" layer of leaves

Crop Nutrient	Leaf Composition Fert. Analysis % (n = 100 municipal samples)	6" 20-ton layer contains approx. lbs
N	1.0	400
P	0.1	40
K	0.4	160
Ca	1.64	656
Mg	0.24	96
S	0.11	44
Mn	0.055	22
B	0.0038	1.5
C	47.3	18,908
C:N ratio mean = 50 range is 27-72		

Creatively Avoiding Soil C:N Ratio Imbalance Problems

From *Knott's Handbook for Vegetable Growers* (4th Ed. 1997. Maynard, D.N. and G. J. Hochmuth. John Wiley & Sons. ISBN: 0-471-13151-2) we learn about Decomposition of Soil-Improving Crops: "The ***normal Carbon:Nitrogen (C:N) ratio in soils is [between] 10:1 [and 12:1]***. Turning under organic matter alters this ratio because most organic matter is richer in carbon than in nitrogen. Unless the residue contains at least 1.5% nitrogen, the decomposing organisms will utilize [native] soil nitrogen as the energy source for the decomposition process.

Soil organisms can tie up as much as 25 lb of nitrogen per acre from the soil in the process of decomposition of carbon-rich fresh organic matter. A soil-improving crop should be fertilized adequately with nitrogen. This fertilization will increase the nitrogen content somewhat and improve layer decomposition. Nitrogen may have to be added as the soil-improving crop is incorporated into the soil. This speeds the decomposition and prevents a temporary shortage of nitrogen for the succeeding vegetable crop. As a general rule, about 20 lb of nitrogen should be added for each ton of dry matter for a nonlegume green-manure crop."

Deciduous shade tree leaves Bob obtains have a **Carbon:Nitrogen ratio averaging 50:1, with a range varying from 27:1 to 70:1.** This is far above the ideal 12:1 ratio found in soils or even the 30:1 suggested for compost piles. He uses **fallow crop rotation**–time–instead of supplemental nitrogen fertilizer to achieve his results without adding more fertilizer N inputs to avoid immobilization deficiencies.

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Learn more about Using Leaves and Cover Crop Amendments

Components of Bob's approach are not detailed when reading profiles of Bob and Leda Muth in places like *The New American Farmer, Profiles of Agricultural Innovation*, 2nd Edition, 2005 published by USDA SARE, http://www.sare.org/publications/naf.htm, or during Bob's excellent presentations. Our Rutgers NJ experiences applying leaves to farmland soils, field plot results, yields, and soil changes are available here:
http://njsustainingfarms.rutgers.edu/soilcompost.html
For cover crops information and other resources, visit the Northeast Sustainable Agriculture Research and Education website at: http://nesare.org/

Three practical, easy to learn from, DVD/videos highlighting diverse practices similar to Bob Muth are available: ***Farmers and their Innovative Cover Crop Techniques***, ***Vegetable Farmers and Their Sustainable Tillage Practices***, and ***Vegetable Farmers and Their Weed-Control Machines***. These NE SARE sponsored videos were produced by Vern Grubinger at the University of Vermont. The practices of Bob Muth and other farmers are demonstrated. Specify VHS or DVD format and send $15 to: UVM Center for Sustainable Agriculture, 106 High Point Center, Suite 300, Colchester VT 05446. (802) 656-5459 or visit:
http://www.uvm.edu/~susagctr/?Page=videos.html=

USDA SARE published two valuable books, which can be purchased, or accessed for free by online: ***Managing Cover Crops Profitably*** is a 2007 3rd Edition of a 244 page, easy to read and use book, exploring how and why cover crops work. It provides the information needed to build cover crops into any farming operation. This is the most comprehensive practical book published on the use of cover crops to sustain cropping systems and build soils. It is available at http://www.sare.org/publications/covercrops.htm.

Building Soils for Better Crops, 2000 2nd Edition, by Fred Magdoff, is also a handy guide on managing healthy profitable soils with minimal inputs, interpreting soil test results, and other practices. It is available at: http://www.sare.org/publications/soils.htm.