Mineralization of Nitrogen from Compost

Tim Griffin
USDA-ARS
University of Maine
Orono ME 04469
tgriffin@maine.edu

Mark Hutchinson
University of Maine Cooperative Extension
377 Manktown Rd
Waldoboro ME 04572
mhutch@umext.maine.edu

Introduction:

Compost and other amendments play several roles in vegetable production systems. Most often, they are applied as "soil conditioners;" because they contain stabilized carbon (C), they can improve many physical properties of soils, including water-holding capacity, aeration, and aggregation. They also contain a broad range of nutrients, including macronutrients like nitrogen (N), phosphorus (P), and potassium (K). We have had a difficult time predicting the rate and extent (i.e. when, and how much) of N release from compost. These characteristics are affected by compost characteristics, maturity, soil type, and environmental conditions. We also need to be aware of the fact that N is released from current *and past* compost applications. In the following, we summarize some results of lab, greenhouse, and field research on the availability of N from composts.

Compost Effects on Soil Properties and N Release:

The Potato Ecosystem Experiment, developed and managed by the University of Maine at the Experiment Station Farm in Presque Isle, ME, offers a good chance to look at the impacts of long-term compost application. This experiment was started in 1990, and includes amended and non-amended plots in a 2-yr barley – potato rotation. Soil samples were taken in 1999, following eight consecutive years of compost + beef manure application. A number of soil properties were measured, and several are summarized in Table 1. Clearly, the application of these amendments greatly increased the amount of C in the soil. This is true for "total" C (a big pool of C), particulate organic matter C (which is easily degraded and releases N), or the amount of C tied up in soil microbes. This, in turn, improves the physical properties as discussed above.

Table 1: Changes in soil C as a result of eight years of compost + manure application. (Griffin and Porter, unpublished data).

	Total Carbon (%)	**Particulate Organic Matter C** (% of total C)	**Microbial C** (mg per kg of soil)
Amended	2.20	39.3	454
Unamended	1.58	24.3	252
% increase from amendment	39	62	80

These annual amendments have resulted in consistent potato yield increases, ranging from 0 to 25%, depending on climate in any particular year. The amendments have also almost completely eliminated fertilizer application in the 2-yr rotation (except from some N applied at potato planting).

Greenhouse Experiment on Compost N Release for Lettuce:

During the winter (2002-2003), we conducted a greenhouse experiment with lettuce, in an attempt to answer grower questions about the availability of N from composts, and from the raw stock materials used to make the compost. Specifically, the grower had access to by-products from a baked bean processor ("bean waste") and from a fish processor ("fish waste"). One option would be to use these materials raw, and presumably they would have a large amount of rapidly available N. Alternatively, each of these materials could be stabilized by composing with sawdust, horse manure, or some other C-rich material. The grower had also tried simply mixing the fish waste with sawdust, allowing the mixture to sit for 2-3 days, and then spreading it. The grower thought that the sawdust would tie up the N, and that this N would be released later. We included all of these options, along with an un-fertilized treatment, in the greenhouse experiment. Some initial assumptions had to be made regarding N availability, in order to calculate application rates. This information is summarized in Table 2.

Table 2. Characteristics of amendments used in greenhouse lettuce experiment.

Amendment	Dry Matter	Organic N	NH_4-N	Target Application
	--------------------	%	--------------------	
Bean waste	36	1.49	0	100 lb PAN, 80% avail.
Bean compost	100	1.36	0	100 lb PAN, 10% avail.
Fish waste	12	1.07	0.15	100 lb PAN, 80% avail.
Fish waste + sawdust	50	0.25	0	100 lb PAN, 80% avail.
Fish compost	100	0.79	0	100 lb PAN, 10% avail.

Amendments were stirred into 400 g of sandy soil, and packed into 4 inch square pots. Lettuce (3 leaf stage, variety 'Winter Density) was then transplanted into each pot, and all pots were well watered for duration of experiment. An additional set of pots, treated the same way except *without plants*, were used to monitor soil N level after amendment application. In these plots, soil samples were taken every 7-14 days, and soil NH_4 and NO_3 were measured. Lettuce was harvested after 45 days. Leaf material was weighed wet, then dried and re-weighed. It was then ground and analyzed for N concentration. Immediately after harvesting lettuce, perennial ryegrass was planted in each pot, and harvested after 28 and 56 days, to evaluate residual N availability.

Both composts clearly increased lettuce growth and leaf N concentration at harvest (see Table 3). This was not surprising when compared to an unfertilized pot, as this was a sandy soil with relatively low organic matter. What was surprising is that the raw bean and fish wastes did not *appear* to affect lettuce yield; at first glance, it looked like they did not supply any N to the lettuce. However, the fact that raw stocks increased N concentration in the leaves is the first indication that N was released. The other indication comes from the second set of pots without plants. As shown in Figure 1, raw fish waste with or without sawdust released N very quickly, before there was any significant plant demand, while the bean waste released very little N.

Table 3. Greenhouse lettuce yield and leaf N concentration from addition of fresh and composted bean and fish wastes.

Amendment	**Leaf Dry Weight**	**Root Dry Weight**	**Leaf N Conc.**
	----- grams / pot ------		%
Control	0.80	0.52	1.52
Bean waste	0.72	0.58	2.68
Fish waste	0.81	0.68	3.03
Fish waste + sawdust	0.87	0.63	3.01
Bean compost	2.32	1.44	3.24
Fish compost	2.40	1.15	4.64
LSD	0.51	0.28	0.39

The composts, in contrast, released N for the duration of growth. The high level of N in the soil also indicates that all application rates were probably too high. Both composts used here were not fully mature, as indicated by ammonia smell from both. This results in more rapid N release than with fully mature materials. This was confirmed by the growth of the two subsequent ryegrass crops, shown in Table 4. Fresh weight of the ryegrass was roughly three times greater in compost amended pots amended with fresh materials. This again points out the need to account for nutrient availability from the composts, which are certainly variable, rather than following the "more is better" line of thinking.

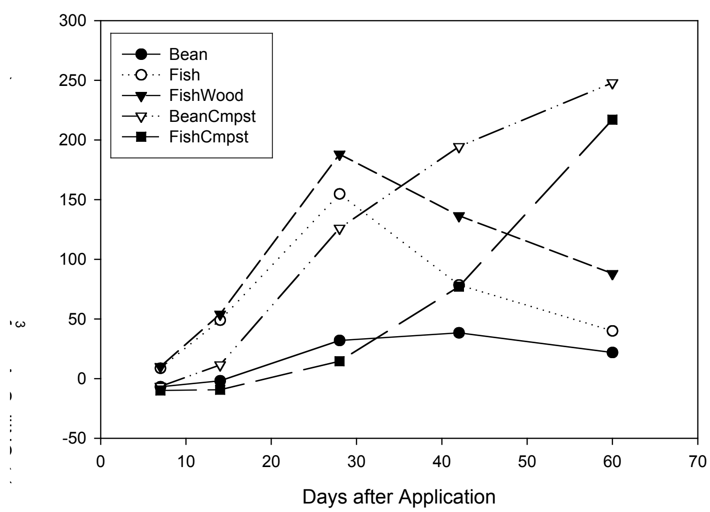

Figure 1. Changes in soil N level after application of fresh and composted bean and fish wastes.

Table 4. Growth of ryegrass in pots amended with fresh and composted bean and fish wastes, after removal of lettuce crop.

Amendment	**First Ryegrass Cutting**	**Second Ryegrass Cutting**	**Total Yield**
	-------------grams / pot	-------------	
Control	1.4	1.1	2.5
Bean waste	3.2	2.1	5.3
Fish waste	4.2	2.5	6.7
Fish waste + sawdust	6.8	3.4	10.2
Bean compost	11.5	7.8	19.3
Fish compost	14.1	9.8	23.9
LSD	2.1	1.1	

<u>Followup Field Evaluation of Compost N Availability:</u>

In Spring/Summer, 2003, we conducted a small plot field experiment to followup on some of the lessons learned in the greenhouse. This experiment had only four treatments: an unfertilized control, fish compost applied at rate the grower had previously used (40 lb total N acre) and twice grower rate, and a 10 day old mixture of fresh fish waste and sawdust. Plots were amended on May 16, and lettuce seedlings were transplanted at a 12 inch spacing on May 30. Lettuce was harvested on July 16. Soil samples were taken periodically from each plot to measure soil NO_3 level.

Lettuce yield was identical for the unfertilized control and both compost application rates, indicating that either the rates were too low (and no N contribution was realized) or N was not limiting in the control plots. The soil NO_3 levels again provide some clues on the response; soil N levels in roughly the last month of lettuce were slightly higher with compost (1x) and higher still with compost (2x). In general, however, soil NO_3 levels were in the range of 20-30 mg kg^{-1} soil (ppm) during this period. This means that some N was released from the compost applications, but there was also significant N available from soil organic matter. The field used for this experiment was consistently cover cropped with hairy vetch pus winter rye, and received small amounts of compost (as were used in this experiment), and provided more N than would be expected from a very sandy soil.

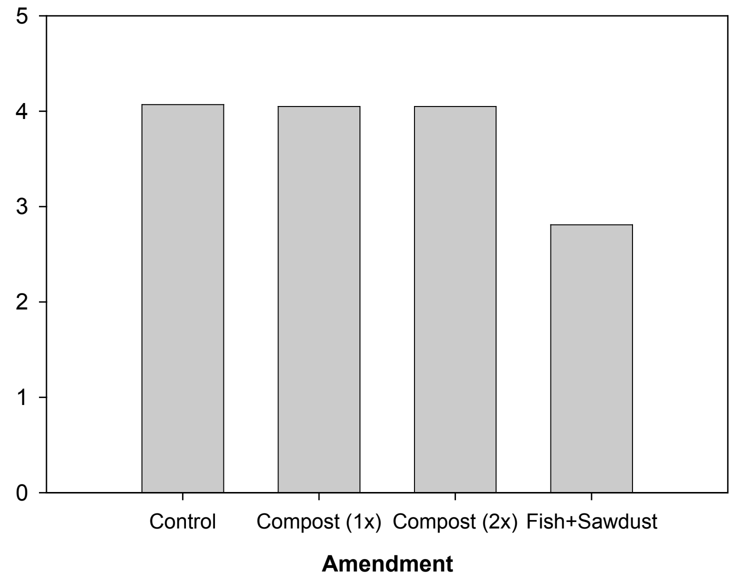

Figure 2. Lettuce yield following amendment with compost, from field experiment.

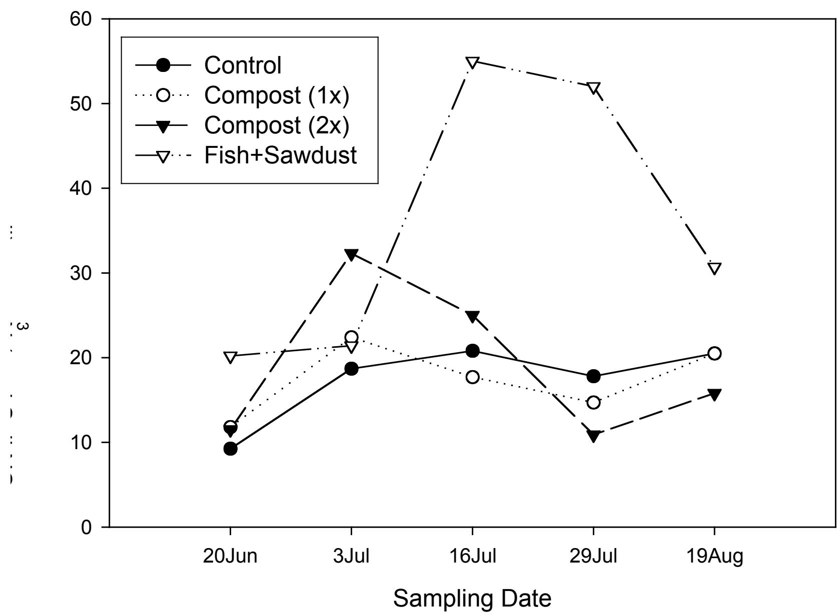

Figure 3. Changes in soil NO_3 in field experiment evaluating fish compost N release.

The effect of applying freshly mixed fish waste and sawdust is interesting. There was a yield reduction of about 40% from this treatment, which could have two causes. First, it could be that the sawdust caused a short-term immobilization of soil N. From June 20 onward, the level of soil NO3 was similar or higher than the other treatments, but may have been lower initially. Many crops are particularly sensitive to N shortage early in the season, and reductions in growth rate early can not be overcome later. By the time lettuce was harvested (July 16), soil NO_3 levels in this treatment were more than three times *higher* than other treatments, in the range or 50 mg kg^{-1} soil, and this N is almost certainly going to be lost if there is no plant demand. The other possibility, which is less likely, is that there is a phytotoxic effect from the fish and sawdust mixture. However, the mixture was made almost a month before lettuce transplanting, so water-soluble phytotoxic compounds would have been lost in the interim.

Lessons Learned:

The results of these simple experiments are reminiscent of Goldilock's; we started with too much available N (greenhouse), moved to too little available N (field). Can we define the "just right" available N scenario? Maybe not precisely, but in general. We learned that the availability of N from immature compost is higher/much higher than our initial assumption of 10%, and could be more like N availability from manures of 25-35%. The mature material used in the field experiment (produced in Fall, 2002 and applied in Spring, 2003) is more representative of soil conditioning composts, and it does appear that N available is fairly low. Even though we did not see a yield response in the field, we also did not see dramatic differences in soil NO_3 levels for several months after application. If availability of N from this material were at the 25-35% level discussed above, we would have observed elevated NO_3 levels, especially in the month after the lettuce crop was removed. We also confirmed, from the long-term potato experiment in Presque Isle, that consistent compost application adds significant amounts of C and N to the soil, and can displace synthetic fertilizer as a result.