Evaluation of Farm Plot Conditions and Effects of Fish Scrap Compost on Yield and Mineral Composition of Field Grown Maize

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The increasing availability of composted soil amendments derived from residues not normally encountered in farming has prompted this study of fish scrap compost. An on-farm field trial with maize (*Zea mays*) was established to test the effects of composted fish scrap (CFS) in comparison to uncomposted farmyard manure (FYM) and inorganic nutrients (NPK). Fish scraps were previously composted with sawdust. Farm manure resulted from bedding dairy animals with a sawdust/straw mixture. Both CFS and FYM had C:N ratios of approximately 31. Yields and nutrient content were evaluated following application of 0.50, 23 and 106 Mg/ha of NPK, FYM and CFS, respectively which were applied based on estimated N-release. Ear-node leaves sampled at tasseling and analyzed for major and minor nutrients indicated that phosphorus was very significantly lower in compost compared to manure and NPK. Statistical analysis revealed that were was no significant differences in yields which decreased in the order FYM > NPK > CFS > Control. Simple regression analysis indicated that no single tissue trait explained yields but multiple regression showed that P and Cu levels in tissue explained 55% of yield variation (p=0.026). Apparently, the relatively high C:N of aged CFS and FYM had little or no effect on growth while slightly but not significantly decreasing plant total-N in CFS plots. The study underscores the fact that previous soil conditions on the farm must be accounted for before traits like C:N or other mineral characteristics of amendments are used to predict yield potential.

Land application and composting of agricultural manures have been documented since at least the early part of the century (Wheeler, USDA, Pfeiffer, Howard, Balfour, Howard[2]). Modern farmers who use animal manures and particulary organic farmers who often depend entirely on composted manures as a primary fertility source are familiar with application and crop response patterns (Koepf, Wistinghausen). Almost as much information is available for municipal sewage sludges and composts made from them (deHaan, USEPA, USEPA1). More recently, however, composting has been widely undertaken for materials which are not farming by-products including mixed and separated municipal solid waste (MSW) (Stilwell, Miller, Bewick), food scraps (Fricke) and fish wastes (Brinton, Frederick, Genes). There is very little information available regarding crop response for these products, and consequently growers may be reluctant to use them. Therefore, research and practice to determine suitable agricultural usages is warranted.

We previously demonstrated composting methods for fishery by-products in the coastal region of Maine by blending mixed fish scraps with wood products (Brinton) and in coastal Florida utilizing crab shell and scallop by-products with cypress bark and wood pulp (Cato). We are not aware of any previous work to document soil and crop effects from fish scrap composted with sawdust. Therefore, a study was undertaken to measure yield and nutrient effects of a matured fish compost applied to silage maize (*Zea mays*).

Experimental

A field plot study was laid out on Spear Farms near Waldoboro, Maine, (69W05 longitude, 44N02 latitude). Compost from a previous fish scrap project (Brinton) was applied alongside farmyard manure (FYM) and conventional, inorganic fertilizer (NPK). Each treatment was replicated three times in random block design.

Manure and Compost Materials

Samples of manure and compost were collected on the research site and analyzed for major nutrients immediately prior to establishing the experiment. Analytical procedures were in accordance with recommended practice for manures and soils (agron, manual). Fourteen grab samples of matured fish compost were taken the previous fall and again late spring and homogenized for analysis. Fourteen grab samples each of barn manure and lagoon manure were taken and also homogenized for analysis. Overwintering compost in outdoor windrows markedly diminished NH_4-N, K and Ca but had no significant effect on organic content and C:N ratio. Bedded free stall manure was significantly different in composition from lagooned manure on the same farm. The test results are shown in Table 1.

The analyses reveal that bedded dairy manure had a C:N comparable to the composted fish scrap, and was chosen over lagoon manure for the comparison trials. The relatively high C:N in these materials can be readily explained. In the case of composted fish scraps, we employed mixed hardwood-softwood sawdusts as an absorbent and bulking material for the high nitrogen fish scraps, since these carbonaceous materials are readily available in the region (Seekins). The quanitity required is dictated by the moisture content of the fish scraps and considerations of looseness and odor control in processing (Brinton), resulting in initial C:N ratios of over 40 in the active composts. Additional nitrogen in the form of fish scrap could have been added later to this compost, but shortness of season prevented this. There was very little soluble nitrogen remaining after the composting process. In the case of the dairy manure, it was heavily bedded with a combination of straw and sawdust for reasons of hygeine and moisture absorption, resulting in a similarly high C:N.

Site Selection Procedure

Researchers are familiar with the problem in selecting on-farm test sites which are not likley to confound the outcome of an amendment trial (Little). Our objective was to find a soil in a medium-nutrient condition, as we wished to avoid the condition where a high level of nutrient sufficiency would most likely obviate the potential yield differences between various treatments. Field trials comparing amendments on dairy farms are often

TABLE 1. Manure compost analyses*

Moisture	pH	% Organic, Matter	% Total Nitrogen	% Ammonia	%P	%K	%Ca	%Mg	C:N
Finished Fish Compost at Day 60									
50.5	7.05	71.4	1.29	0.046	0.37	0.50	1.30	0.07	32.7
Fish Compost over-wintered on Research Farm (Day 300)									
64.6	6.10	66.0	1.15	0.009	0.80	0.12	0.56	0.07	33.2
Manure Slurry from Dairy Barn on Research Farm									
82.6	8.20	76.6	5.49	0.461	1.63	3.62	1.62	0.41	8.1
Dairy Manure with Bedding Used for Field Trial									
65.3	9.50	70.2	1.29	0.061	1.21	0.76	0.84	0.22	31.6

*Values for moisture and pH are "as is." All others are dry basis %.

constrained by high nutrient soil conditions resulting from years of use of all on-farm manures and residues (Holyoke).

Three preliminary field sites were selected on a dairy farm in Waldoboro (Spear) and soil samples taken to ascertain nutrient status and subsequenlty to verify homogeniety of the parcels. The data indicated moderately high nutrient availability in at least two of the sites led to their rejection for our study. This field-site we chose lay on the intersection of Peru fine sandy loam (coarse-loamy, mixed, frigid), and Boothbay silt loam (fine, mixed, mesic). Soil test data for all the evaluated fields are shown in Table 2.

Data in Table 2 revealed that two of the fields (Upper Grass, Upper Corn) were considerably richer in nutrients than the other (Lower Meadow). Under such circumstances of nutrient sufficiency little or no yield effects from any added fertilizer treatments would normally be expected. We selected the low lying, somewhat poorly drained hayfield owing to its medium nutrient status. This soil shows no apparent nutrient deficiencies, and available nitrogen (nitrate as NO_3-N) status was moderately high (Orono). Some soil nitrogen testing procedures developed in the northeast USA suggest that no supplemental nitrogen is required for medium to high yields of silage corn if soil nitrate levels in late June exceed 42—52 ppm in the top 6 inches of soil (UVM, Orono2).

Soil Homogeneity Evaluation

After the site was chosen, it was subdivided into the 12 randomized test parcels. Subsequently, each parcel was individually sub-sampled to a depth of 15cm and soil samples were laboratory analyzed. The results of the soil testing are shown in Table 3, grouped in order of the selected treatment type.

The variability of soil parcel test results appears to be random with no statistically significant differences between the parcels. Slightly higher potassium fertility was observed in the control plots ($p=0.073$) receiving no treatment. The Bray P1 phosphorus fluctuated considerably between the parcels with a coefficient of variation (CV%) of 48%.

Amendment Applications

The manure and compost materials were soil-applied with a tractor and manure spreader to the previously plowed 21 x 9m plots (70 x 30 ft) and inorganic fertilizers were surface broadcast with a tractor-mounted spin spreader. After spreading, the field was disced and planted two days later. Rates were initially calculated to be approximately the same between the treatments based on estimated N-release of amendments for the growing season. The actual amendment application rates were confirmed by measuring deposition to a 2 x 2m plastic film spread within each plot and are given in Table 4.

TABLE 2. Site selection soil analyses

Soil pH in water	Org-Matter percent	CEC cmol⁺/kg	NO_3-N mg/kg	Bray-P1 mg/kg	Potassium mg/kg
Upper Corn Field					
6.1	7.2	16.9	45	116	470
Upper Grass Strip					
6.6	8.4	14.4	37	60	310
Lower Meadow Hay-Land*					
6.4	6.0	13.0	50	42	105

*Tested 2 weeks later than the upper sites

Results

Leaf Tissue Analysis

At tasseling stage, 25-30 ear-node leaves were harvested randomly from within each parcel, dried for 36 hrs at 80°C and ground in a Wiley mill. Dried tissue was analyzed either by Kjeldahl digestion for total-N, water extraction and by ion-chromatography for NO_3-N, or ashed and subsequently analyzed by flame photometry for major and minor nutrients as shown in Table 5.

The data show that inorganic NPK increased plant total-nitrogen, phosphorus and copper, manure increased phosphorus, chloride and potash, while compost increased chloride, potash and trace elements iron, zinc and manganese. All minerals appear to be in a normal sufficiency range. Although yields increased over the control with compost, the compost treated tissue gave less total-N than all others even the control, similar to what we have observed with compost and maize elsewhere (Brinton2).

TABLE 3. Soil parcel homogeneity analyses*

Parcel I.D.	Soil pH in water	Org-Matter percent	CEC $cmol^+/kg$	NO_3-N mg/kg	Bray-P1 mg/kg	Potassium mg/kg
			Control Parcels			
00A	6.5	6.3	10.4	47	61	80
03A	6.2	6.1	13.5	60	35	90
20A	5.9	6.5	12.6	35	22	80
MEAN	6.2±.3	6.3±0.2	12.2±1	47±13	39±20	83±6
			Compost Parcels			
02B	6.8	4.8	6.0	30	59	65
11B	6.3	7.2	16.8	35	19	65
22B	5.8	6.8	16.8	54	21	70
MEAN	6.3±.5	6.3±1.3	13.2±6	40±13	33±23	67±3
			Manure Parcels			
10C	6.5	6.8	18.0	35	33	70
12C	6.2	6.0	14.6	29	19	60
21C	5.9	8.3	18.8	37	16	65
MEAN	6.2±.3	7.0±1.2	17.1±2.2	34±4	23±9	65±5
			N-P-K Parcels			
01D	6.5	7.6	15.9	31	22	65
13D	6.2	5.7	15.6	48	37	85
23D	5.9	6.7	11.6	33	24	90
MEAN	6.2±.3	6.6±1.0	14.4±2.4	37±9	28±8	80±13

*Tested just prior to planting

TABLE 4. Soil amendment applications

Parcel Treatment	Dry Matter Mg/ha	Dry Matter (t/a)	Total-N kg/ha	Avail-N* kg/ha	Phosphate kg/ha	Potash kg/ha
Compost	104	(47)	1211	225	832	133
Manure	26	(12)	342	171	320	201
N-P-K	0.50	(.23)	180	180	78	118

*estimated @15% for compost, 50% for manure

The slight increase in potassium from compost and manure resulted in a slight decrease in tissue magnesium which is anyway on the low side. K^+ ion competes with Mg^{++} ion in plant uptake. Of the noted differences, the phosphorus effects were highly significant ($p < 0.001$) as measured by analysis of variance (ANOVA) and Duncan's Multiple Range test. No other mineral effects achieved this level of significance. In the statistical analysis we partitioned separate degrees of freedom for block (soil) effects. The least significant differences (LSD) are shown for the $p = 0.10$ level.

Yields Analysis

At the end of the season the maize was harvested by cutting two meter sections of row at three randomly selected locations within each parcel. Whole plants and ears were weighed, and stalks and ears were counted. Data was converted to yield/area values by multiplying by an appropriate factor determined by row-spacing. The data for these yields is seen in Table 6.

The yield effect is seen as FYM ≈ NPK > CFS > Control. This gradient of effects is similar to what we previously reported in another maize compost and manure trial (Brinton2). Manure was superior to the control (no treatment) by 20%, followed by 19% with NPK and 8% with compost. The yield effect of fertilizers is transmitted primarily as the increase of stalks relative to ears. The manure and NPK treatments increased population counts, but only the NPK increased ear count. Increased population count relates to improved germination and early growth. The noted stalk yield differences for manure and NPK over control were marginally statistically significant at $p = 0.10$. The lack of significant differences between treatments is not surprising considering the initial soil conditions. The yield of control parcels was approximately 20 tons/acre, which is considered excellent in Maine.

In our case, the C:N ratio of the compost was sufficiently high to predict a large net immobilization of soil available nitrogen. This could explain the lower total-nitrogen in the leaf tissue at the time of sampling, however, the yields did not decrease relative to the control. Similar-

TABLE 5. Maize tissue analysis

Treatment	N	P	Cl-	K+	Ca++	Mg++	NO_3-N	Cu++	Zn++	Mn++	Fe+++
	dry weight						mg/kg (ppm) dry weight				
Control	3.32	0.322	0.84	0.90	0.78	0.14	88.7	11.8	55	92	135
Compost	3.16	0.316	1.04	1.06	0.70	0.13	72.7	10.6	68	133	161
Manure	3.31	0.357	0.97	1.23	0.65	0.13	76.7	12.4	51	123	134
NPK	3.48	0.357	0.84	0.90	0.89	0.16	61.0	13.0	62	142	140
LSD	0.50	0.015	0.34	0.39	0.21	0.04	57.0	2.1	42	65	48

TABLE 6. Maize crop yields

Treatment Plots	Fresh Yields (Mg/ha fr weight)			Population (# x 10^3/ha)	
	Stalks	Ears	Biomass	Plants	Ears
Control	27.78	17.85	45.63	62.1	54.3
Compost (CFS)	31.29	18.05	49.34	61.1	53.7
Manure (FYM)	35.62	19.02	54.63	69.3	55.0
Inorganic (NPK)	34.42	19.86	54.28	69.1	69.0
LSD @0.10	7.06	5.60	12.45	15.2	18.4

ly, the manure as a result of bedding material had a high C:N while nitrogen in maize tissue did not change, and yields were increased over the control. Either C:N ratio is a poor indicator of nitrogen response or yield effects are due to other factors, or both. For example, regression analysis revealed that no single mineral characteristic explained the yield variability by more than 28%. However, a multiple regression of total yields on phosphorus and copper concentration of leaf tissue explained 55 of the yield variability (p = 0.026, r^2 = 0.55). Similarly, 70% of the yield variation (p = 0.055) was explained by additionally accounting for iron and calcium in the multiple regressions. Also, it was noted that soil texture had improved markedly under compost. Therefore, tilth effects must not be excluded in concluding that treatments may have improved yield potential for our heavy, low lying soils.

Finally, potential yield differences between varying soil treatments may be masked under circumstances of nutrient rich conditions resulting from previous continued manure applications typical in modern farming. High rates of carbonaceous composts or manures thus may not influence N-release to the point of being deleterious to crops as is normally predicted but are likely to improve soil tilth and other yield factors.

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