Compost Utilization for Vegetable and Fruit Crops

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The movement towards agricultural sustainability and farming systems has revived interest in using composts on crops. Rising prices and decreased availability of fertilizer have also caused some growers to look toward renewable and organic sources of nutrients. The beneficial effects of many municipal composts, including increased cation exchange capacity and water-holding capacity, and lower bulk density, appear to be derived from adding organic matter.

In their 1987 review of municipal compost effects on the soil-plant system, Gallardo-Lara and Nogales noted that, although soil characteristics are generally improved, effects on crop yield often are "contradictory" when compared with those of other organic or mineral fertilizers. In many of the studies cited below, researchers have used several composts and/or run trials several times or for several years. Some use fertilizer, and some do not. Not surprisingly, this often results in varied outcomes.

COMPOST AFFECTS VEGETABLE AND FRUIT CROP GROWTH

Nutrient uptake. Addition of composts as soil amendments changes soil chemical and physical characteristics, generally improving the soil environment for crop growth. Obreza and Reeder (1994) reported that organic matter and extractable P, Ca, and Mg content in a sandy soil increased for at least a year, with increasing rates of application of municipal solid waste (MSW) composts. The pH increased with addition of one compost at 75 and 112 t·ha⁻¹, but did not with another at 13 and 27 t·ha⁻¹. Another MSW compost increased pH, K, Ca, Mn, Zn, and organic matter soil contents in the top 20 cm 6 months after incorporation into the soil at 50 and 100 t·ha⁻¹ (Parsons and Wheaton, 1994).

However, soil nutrient increases do not always result in increased plant nutritional concentrations. Although total N content of municipal composts ranges from 0.5% to 1.9% (Bevacqua and Mellano, 1993; Hornick, 1988; Hortenstine and Rothwell, 1968; Roe, 1993), almost all the N is in organic forms and availability is variable since mineralization is influenced by environmental conditions (Table 1). Hornick (1988) reported that annual applications of biosolids (sewage sludge/wood chips = BS/WC) compost increased N, P, and K concentrations in the soil, but not in sweet corn

(*Zea mays* L.) grain. However, compost application did increase N in leaves of orange (*Citrus sinensis* L.) (Parsons and Wheaton, 1994) and pear (*Pyrus communis* L.) (Korcak, 1986). Pear leaf Ca content was also higher in trees that had received biosolids compost 3 years earlier than in those that had not (Korcak, 1986). Concentration of N and K in broccoli (*Brassica oleraceae* Italica L.) and cabbage (*Brassica oleraceae* Capitata L.) grown in market packs of equal parts of BS/WC compost, sphagnum peat, and perlite (by volume) continued to increase for 8 weeks (Falahi-Ardakani et al., 1987). Blossom end rot in peppers, often related to Ca content, was lower in plots with 135 t·ha⁻¹ compost (47% moisture) than in those without compost (N. Roe, unpublished data).

Shoot and root growth. Growth of vegetable and fruit plants in compost has been studied by growing plants in pots and flats as well as in field tests (Table 2).

One property that can affect response is compost maturity. Water extracts from fresh, 6-week-old, or 1-year-old MSW composts were applied to seeds of Chinese white cabbage (*Brassica chinensis* L.), carrot (*Daucus*

carota L.), and tomato (*Lycopersicon esculentum* Mill.) (Wong and Chu, 1985). The fresh extract at 8% (m/v) or more suppressed growth of cabbage and carrot and at 4% suppressed tomato growth. Chanyasak et al. (1983) reported that growth of komatsuna (*Brassica rapa* var. *pervidis* Bailey) was inhibited by additions of 3-d-old MSW "composts," but not by more mature composts (Table 2).

Effects of compost on growth can vary with soil type and plant species. Parsons and Wheaton (1994) reported that early growth of orange tree trunks increased in one location but not in another in response to MSW compost applications (Table 2). In another experiment, adding an MSW compost at 1.2% to 25% to pots containing one of three tropical soils increased corn biomass during the first growing season; however, only the highest rate was effective when a second and third crop were grown in the same media (Paino et al., 1996). Compost increased shoot dry mass of broccoli grown in field soils in pots (Table 2), but rates >34 t·ha⁻¹ decreased lettuce dry mass in loamy sand, perhaps because of high salt levels (Shiralipour et al., 1996). In the loam and clay loam, dry mass of lettuce

Table 1. Effects of composts on concentrations of nutrients in plants.

Crop	Plant part	Compost ^a	Rates (t·ha ⁻¹ or %)	Nutrient	Effect	Reference
Cabbage, broccoli	leaves	BS/WC	33%	N, K	+	Falahi-Ardakani et al., 1987
Orange	leaf		50, 100	N, Ca	+	Parsons and Wheaton, 1994
Pear	leaf	BS	33	N	+	Korcak, 1986
Sweet corn	grain	BS/WC	40, 80, 160	N, P, K	0	Hornick, 1988

^aBS = biosolids; WC = wood chips; YT = yard trimmings.

Table 2. Vegetable and fruit shoot and root growth response to applications of municipal waste composts.

Crop	Compost ^a	Rate (t·ha ⁻¹ or %)	Shoot	Root ^b	Notes	Citation
Komatsuna	MSW	10–20 equivalent	+	NA		Chanyasak et al., 1983
Tomato, cabbage, muskmelon	BS/WC	50%	0, –, –	NA	pots	Sterrett et al., 1983
Okra	MSW	10% to 30%	NA	+	pots	Bryan and Lance, 1991
Okra	MSW	0 to 100%	+	+	pots	Roe, 1993
Orange	MSW	49	–	NA		Parsons and Wheaton, 1994
		0, 50, 100	+	+		Ozores-Hampton et al., 1994
Tomato	MSW	24, 48	+	NA		Vavrina, 1994
Tomato (2 years)	MSW	25%, 50%, 75%, 100%	–, 0, +, 0	–, 0, +, 0	2 composts	
Tomato	MSW	37, 74, 148	+ or –	NA	2 composts	Bryan et al., 1995
Snap bean	Leaf	2.5 cm mulch	+	NA		Gray and Tawhid, 1995
Corn	MSW	1.2% to 25%	+	NA	tropical soils	Paino et al., 1996
Broccoli, lettuce	BS/YT	34, 67, and 135	+	NA		Shiralipour et al., 1996

^aBS = biosolids; MSW = mixed municipal waste; WC = wood chips; YT = yard trimmings.

^bNA = not available.

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shoots was greatest in the pots amended with 67 t·ha⁻¹ of compost.

Variability among composts also affects plant response (Table 2). In a medium of 1 perlite : 1 BS/WC compost (by volume), use of a compost higher in heavy metals reduced dry mass of tomato and cabbage transplants (Sterrett et al., 1983). Application of MSW composts to soils either increased or had no effect on tomato plant height (Bryan et al., 1995; Ozores-Hampton et al., 1994).

Optimum nutrient concentrations and moisture levels for plant growth generally result in the highest shoot : root ratios (Boote, 1977). Therefore, large shoot : root ratios indicate a favorable environment for shoot growth. However, few studies have reported effects of composts on root growth (Table 2). Shoot and root mass of okra (*Hibiscus esculenta* L.) plants in pots generally increased and shoot : root ratios decreased as compost rates increased from 0 to 8%, but shoot : root ratio was higher in 100% compost than in sandy soil or other compost : soil mixes (Roe, 1993). Okra plants grown in pots with 10% to 30% MSW had more lateral roots, while those in gravelly loam soils had larger taproots (Bryan and Lance, 1991). Taproots of pepper seedlings in 100% MSW compost were shorter, and lateral root number decreased with increasing compost rates (Roe, 1993). Vavrina (1994) reported no differences between shoot : root ratios of tomato transplants grown in varying percentages of MSW composts and those grown in a commercial growing mix. Total root length of young orange trees was reduced by adding MSW compost (Parsons and Wheaton, 1994).

COMPOSTS AS TRANSPLANT MEDIA

Lack of uniformity in composts often precludes their use as commercial transplant media (Vavrina, 1995). Growing transplants in a 1 MSW : 1 perlite mix (by volume) vs. 1 compost : 1 peat : 1 perlite (by volume) did not affect cabbage, tomato fruit, or muskmelon fruit yield after transplants were set in the field (Sterrett et al., 1983) (Table 2). Tomato germination percentages were either not affected or were reduced when increasing percentages of MSW composts from three different compost producers were added to a standard peat : lite growing mix (Vavrina, 1994). Shoot dry mass increased linearly with increasing percentages of two of the composts and quadratically with a third. Root dry mass also increased linearly with increasing percentages of the first two composts but was not affected by the third. Fruit production was delayed in tomato plants produced from seedlings grown in three different batches of MSW compost, but, except for seedlings grown in one particular bulk batch of compost, total yields were similar to those of plants started in a standard commercial growing mix (Vavrina, 1995). Transplants grown in three separately handled lots of one brand of compost differed in height 5 weeks after seeding.

Falahi-Ardakani et al. (1987) reported that lettuce (*Lactuca sativa* L.), tomato, pepper

(*Capsicum annuum* L.), and eggplant (*Solanum melongena* L.) seedlings grown in market packs containing equal parts of biosolids/wood chips (BS/WC) compost, sphagnum peat, and perlite (by volume) appeared to have sufficient N only for 5 weeks of growth.

COMPOST AS MULCHES

Mulches may be synthetic products, such as polyethylene, or natural organic materials, such as paper, hay, or straw. Using composts as mulches may increase soil organic matter, add nutrients, and increase both water-holding capacity and cation exchange capacity.

Roe et al. (1994) transplanted pepper plants into *Phytophthora capsici*-infested plots using polyethylene mulch or organic mulches of MSW or BS/WC compost. Fourteen weeks after transplanting, survival was greater in the organic mulches, but fruit yield (6.99 t·ha⁻¹) of plants mulched with polyethylene was greater than that of those mulched with MSW compost (2.95 t·ha⁻¹) or BS/WC compost (4.03 t·ha⁻¹). This was attributed to much higher production per plant in polyethylene mulch. Seedlings from a subsequent squash crop emerged faster under compost mulches than under polyethylene, but final plant stands and yields were similar.

Compost mulch may help reduce plant stresses attributed to soil crusting and drought stress. Gray and Tawhid (1995) reported that snap bean (*Phaseolus vulgaris* L.) seedling emergence and plant survival were increased by the addition of 2.5 cm of leaf compost over rows after seeding. Pod yields of snap beans were increased by the mulch in a dry season but not in a wetter one.

COMPOST EFFECTS ON YIELDS

Although compost often increases yields of vegetable crops, the response varies with compost feedstocks and maturity, rates and method of application, crop species and variety, fertilizer rates, and interval between application and planting (Table 3). Yield response is generally greater in soils with low fertility, but response varies with species (Gallardo-Lara and Nogales, 1987).

There are few reports of response of root and leaf crops to composts (Table 3). Low rates of MSW compost did not increase yields of radish (*Raphanus sativus* L.) grown in pots of sandy soil; however, root yields at the high rate were 4–6× those from plants receiving lower rates of compost or fertilizer equivalent to 200, 166, and 88 kg·ha⁻¹ of N, P, and K, respectively (Hortenstine and Rothwell, 1968). Incorporating compost below root level may limit response. Biosolids compost at 12 and 25 t·ha⁻¹ (dry mass) increased onion (*Allium cepa* L.) and spinach (*Spinacia oleracea* L.) yields when incorporated to a depth of 10 cm, but not 30 cm (Mellano and Bevacqua, 1992). When onion and lettuce (*Lactuca sativa* L.) plants were grown in plots of sandy loam soil, compost applied over a 2-year period at cumulative totals of 37 and 74 t·ha⁻¹ increased yields (Bevacqua and Mellano, 1993).

In coarse, infertile soils, compost usually increases yields. Early okra yields from plants grown in pots with compost were higher than those from plants grown in nonamended gravelly soil, whether the compost was mixed with soil or used as a mulch (Bryan and Lance, 1991) (Table 3). However, inorganic nutrient sources may give similar increases. Sweet corn grain yields from plots amended with three rates of biosolids compost for the first 2 of 3 years were similar to those from plots fertilized annually with N, P, and K at 179, 122, and 112 kg·ha⁻¹, respectively (Hornick, 1988).

Response of legumes to composts may differ from that of other crops, due to their ability to fix N. When N was supplied at 84 kg·ha⁻¹, addition of 13 and 20, but not of 7 t·ha⁻¹ of MSW compost increased cowpea (*Vigna unguiculata* L.) pod yield; with 168 kg·ha⁻¹ of N, yields increased at all compost rates (Bryan and Lance, 1991). Incorporation of an MSW compost at 90 and 135 t·ha⁻¹ into a calcareous limestone soil did not affect the first crop yield of snap beans, but yield increased quadratically with increasing compost rates in the subsequent crop (Ozores-Hampton and Bryan, 1993a).

Whether in sandy tropical soils with low organic matter, or loamy temperate soils, solanaceous crops tend to respond positively to composts, if the composts are mature. Ozores-Hampton and Bryan (1993b) reported that application of MSW compost at 90 and 134 t·ha⁻¹ increased yields of marketable and large eggplant fruit and large bell peppers. When N was applied at 240 kg·ha⁻¹ on a tomato crop and 120 kg·ha⁻¹ on the subsequent squash (*Cucurbita pepo* L.) crop, amendment with an MSW compost at 48 t·ha⁻¹ or another at 24 t·ha⁻¹ did not increase fruit yield in either crop (Ozores-Hampton et al., 1994). Use of MSW on drip-irrigated plots, with N at 215, 309, or 403 kg·ha⁻¹; P at 44 kg·ha⁻¹; and K at 248, 356, or 464 kg·ha⁻¹, reduced yields in the initial crop of bell peppers, but increased the yield of extra-large and total marketable tomato fruit in the second crop (Clark et al., 1994). The compost may have been immature, since total yields in early and final harvests and the yield of extra-large fruit in a subsequent pepper crop were increased. Fertilizer application to the second crop increased yields only in the absence of compost. Obreza and Reeder (1994), however, reported that immature MSW composts either did not affect or decreased yields of tomatoes for 2 years, when compared with normally fertilized plants. In 1 year, the high rate of compost significantly increased the yield of a subsequent watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nak.] crop, indicating that the compost had matured during the 1st year. Bryan et al. (1994) applied two MSW composts at 0, 33, or 67 t·ha⁻¹ and another at 0, 67, and 135 t·ha⁻¹. The cropping rotation was tomatoes, squash, an additional compost application (identical rates), then tomatoes. In both tomato crops, growth and yields were reduced by one of the composts. In squash, total yields and fruit size were increased by all rates of two of the composts, but

Table 3. Relative yield responses of vegetables and fruits to additions of municipal waste composts.

Crop	Compost ^a	Rate (t·ha ⁻¹ or %)	Site/timing	Response	Citation
Broccoli	MSW	7, 13, 20	Sandy field soil	+, 0	Roe et al., 1990
Bell pepper, eggplant	MSW	90, 135	Calcareous field soil	+, +	Ozores-Hampton and Bryan, 1993b
Cowpea	MSW	7, 13, 20	Calcareous soil in field	0, 0, +	Bryan and Lance, 1991
Okra	MSW	10% to 30%	Calcareous soil in pots	+	Bryan and Lance, 1991
Onion, lettuce	BS/YT	37, 74	Sandy loam in pots	+	Bevacqua and Mellano, 1993
Onion, lettuce	BS/YT	12, 25	Incorporated to 10 cm	+	Mellano and Bevacqua, 1992
Pear	BS	33	Acidic sandy loam	0	Korcak, 1986
Peppers	leaf	112	Undecomposed	0	Maynard, 1996
Peppers/tomatoes	MSW	67, 135	3 crop seasons	-, +, +	Clark et al., 1994
Radish	MSW	2–512 equivalent	Sandy soil in pots	0, +	Hortenstine and Rothwell, 1968
Snap beans	MSW	90, 135	Calcareous soil	0, +	Ozores-Hampton and Bryan, 1993a
Sweet corn	BS/WC	40, 80, 160	Old gravel mine	0	Hornick et al., 1988
Tomato/squash	MSW	48, 24	2 composts	0	Ozores-Hampton et al., 1994
Tomatoes/watermelon	MSW	13, 27, 75, 112	Immature composts	0, 0, -, +	Obreza and Reeder, 1994
Tomatoes	MSW	33, 67	2 composts	-, +, +	Bryan et al., 1994
		67, 135		+, +	
Tomatoes, peppers	BS/YT	135	Sandy field soil	0	Roe and Stoffella, 1994a, b
Tomatoes	MSW	56, 112	3 yrs	+	Maynard, 1995
Tomatoes/tomatoes	MSW	37, 74	2 composts, 4 crops	+, +	Bryan et al., 1995
		74, 148		+, +	

^aBS = biosolids; MSW = mixed municipal waste; WC = wood chips; YT = yard trimmings.

not affected by the other. However, transplanting tomato and pepper plants into a field containing a newly incorporated, noncured BS/YT compost at 135 t·ha⁻¹, either immediately or up to 4 weeks after compost application, did not affect yield of pepper or tomato fruit (Roe and Stoffella, 1994a, b). Marketable yield of tomatoes was increased by addition of two MSW composts, one at 37 and 74 and the other at 74 and 148 t·ha⁻¹ (Bryan et al., 1995). Rates were selected to provide 370 or 740 kg·ha⁻¹ of N. Application of compost increased fruit size in the 1st year, but not in the 2nd. When compost was applied in a factorial arrangement with 0, 50%, and 100% of a grower's standard fertilizer (71, 39, and 44 kg·ha⁻¹ of N, P, and K, respectively, broadcast and 283 and 278 kg·ha⁻¹ of N and K, respectively, banded in bed centers), fruit yields were highest in the plots with compost and 50% fertilizer (Roe et al., 1997). An MSW compost with fertilizer at 146, 64, and 121 kg·ha⁻¹ of N, P, and K, respectively, just before planting each spring increased tomato fruit yield in all 3 years (Maynard, 1995). Maynard (1996) tilled a 15-cm layer of nondecomposed leaves into plots in spring or fall, or leaf compost in spring for 3 years and applied fertilizer at 146, 64, and 121 kg·ha⁻¹ of N, P, and K, respectively. Yields of bell pepper were not affected by compost, but nondecomposed leaves reduced yields. Both compost and spring application of leaves increased yields the 2nd year, but yields were similar in all treatments the 3rd year.

Minimal research has been done on effects of compost on fruit tree yields, probably because of the length of time required for results. In pear trees, yields and average fruit mass were not increased by application of a lime-stabilized biosolids compost to the soil surface (Korcak, 1986).

GROWER USE OF COMPOST

Gallardo-Lara and Nogales (1987), in their review of municipal compost usage, noted that combining mineral fertilizers with composts generally results in higher yields than are ob-

tained with separate applications of either. Most subsequent investigations support this conclusion.

In the 1992–93 and 1993–94 seasons, trials using MSW compost were established in several bell pepper fields in Palm Beach County, Fla. In one trial, compost applications of 90 and 135 t·ha⁻¹ increased yields of large pepper fruit to 112% and 135% of the control, respectively, in the 1st year and 123% and 148% of the control, respectively, in the 2nd (Ozores-Hampton, unpublished data). In addition to the replicated trials, several hectares of compost trials were established in a commercial field. Growers were impressed with the yield increases, and the beneficial effects lasted through two cropping seasons. However, the compost company went out of business the next year, so whether or not growers would have continued to use the compost is not known.

Various municipal composts have been used on many farms in south Florida. However, they are not widely used, although one grower is using a dried biosolids product from out-of-state, and a compost demonstration is continuing on his farm.

In other areas, extension workers report composts being utilized by small, usually certified organic, farmers (A. Maynard, personal communication). Composts from animal manures are more commonly used than those from municipal sources, probably because they are available and inexpensive in agricultural areas, and there are fewer perceived potential problems from pathogens or heavy metals, such as Cd, Pb, Zn, Ni, or Cu.

Why is compost not being used more on a commercial scale in horticultural enterprises? One reason is the high turnover in the compost industry; growers may find that the compost company they dealt with last season is no longer in business. Each compost is different, and many companies do not stay in business long enough to produce a consistent product.

Although the sandy soils of south Florida are very low in organic matter, building up organic matter with composts is very difficult, because of natural decomposition in the tropi-

cal climate. Most growers know the value of organic matter in their soil, but growing cover crops is easier and less expensive than adding composts.

Hauling and application methods are also challenges for the industry. Compost may be free or inexpensive but handling adds to the cost. For most growers, improvements in yields are insufficient to justify these costs. Other factors, such as annual financial arrangements and non-ownership of land, do not encourage long-term soil improvements.

CONCLUSIONS

The addition of municipal waste composts often results in increases in plant growth and/or very slight, often nonsignificant, effects on yields. However, composts from municipal sources vary in nutrient and heavy metal content, maturity, and C:N ratio, and are used at varying rates and with varying rates of fertilizers. Thus, their effects on crops are difficult to summarize. Generally, if compost is mature, it changes soil characteristics, favoring crop growth.

In most nutritional research, nutrient sources can be replicated with a good degree of consistency. Compost maturity, composition, and uniformity currently are important research topics, and are improving in response to market demands. However, compost is a dynamic medium, and techniques such as sterilization, which would be necessary to stop microbiological activity, would also destroy some of its potential benefits. Duxbury et al. (1989) stated that applied studies are necessary for research on organic matter because *in vitro* studies "have little relevance to the behavior of soil organic matter as a source or sink of nutrients in soils." Many applied studies have been performed since that statement was made. However, in order to fully utilize this biological recycling method to benefit our horticultural industries, continued research is needed in all aspects of compost production, application methods, and biological control properties in crop production systems.

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