Using Composted Wastes on Florida Vegetable Crops

Monica Ozores-Hampton,[1] Thomas A. Obreza,[1] and George Hochmuth[2]

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Summary. Large volumes of compost produced from waste materials like yard trimmings, household trash (municipal solid waste), or biosolids (wastewater sludge) will likely become available for use by the Florida vegetable industry in the future. Using compost to produce vegetables has the potential to increase water and fertilizer conservation and reduce leaching from inorganic fertilizers in Florida's sandy soils. Compost quality for vegetable production systems should be based on soluble salts, phytotoxic compounds, C:N ratio, plant nutrients, trace metals, weed seeds, odor, moisture, pH, water-holding capacity, bulk density, cation exchange capacity, and particle size. In Florida, immature compost contained phytotoxic compounds that were harmful to crop germination and growth. Amending soil with mature composted waste materials has been reported to increase the growth and yields of vegetable crops grown in Florida. However, a beneficial response does not always occur, and the magnitude of the response is often not predictable.

Composting is a biological decomposition process during which microorganisms convert raw organic materials into relatively stable humus-like material. During decomposition, microorganisms assimilate complex organic substances and release inorganic nutrients (Metting, 1993). An adequate composting process kills pathogens and stabilizes compost organic C before the material is applied to land (Chaney, 1991). In 1997, 27.2 million tons (24.7 million t) of solid waste were produced in Florida [≈10 lb (4.3 kg) per person per day], which was twice the national average (Goldstein, 1997; Smith, 1994b). Waste disposal has become a concern due to the increasing population and increased cost of conventional disposal methods such as landfilling. Regulation requires that new Florida landfills be lined because of shallow groundwater levels; this has contributed to the rise of solid waste tipping fees to an average of $46/ton in 1993 (Smith, 1995b). In Florida, municipal solid waste (MSW), yard trimmings (YTs), and biosolids are high-volume wastes that could be composted instead of landfilled or incinerated (Smith, 1994c). The largest portion of solid waste is MSW. Nationally, composting may be an attractive waste management tool, since 30% to 60% of the waste materials can be composted into an environmentally safe matter (Smith, 1994a). In Florida, there are 44 operating composting facilities, of which 29 are YT composting facilities (Smith, 1995b).

[1]Southwest Florida Research and Education Center, 2686 State Road 29 North, Immokalee, FL 34142-9515. To whom reprint requests should be addressed.

[2]Horticultural Sciences Department, University of Florida, Gainesville, FL 32611.

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In Florida, 12 million tons (10.9 million t) of MSW, 3 million tons (2.7 million t) of YTs, and 0.5 million tons (0.45 million t) of animal manure could be composted annually (Smith, 1994c), but most wastes are currently landfilled or burned (Goldstein, 1997) (Fig. 1). Since a significant (50% to 65%) reduction in waste volume occurs during biological decomposition, 8 million tons (7.3 million t) of compost would be produced annually if all biodegradable material in Florida was composted (Smith, 1995b).

The largest potential compost user is the agricultural industry (Parr and Hornick, 1992). Using compost in agriculture reduces the need to expand landfills or build incinerators. Additionally, amending Florida's sandy soils with compost may reduce the frequency and rate of irrigation and inorganic fertilizer applications (Ozores-Hampton, 1993). New technology and the development of processed solid waste materials have made high-quality products available to the agricultural community (Bryan and Lance, 1991).

Florida is a major vegetable-producing state, with 418,000 acres (170,000 ha) under cultivation each year (Florida Agricultural Statistics Services, 1997). Sandy soils used to grow Florida vegetables have low native fertility (Dade County Soil Survey, 1995) and so require relatively high fertilizer inputs. Minimizing fertilizer leaching or runoff has become important due to potential negative environmental impacts. Grower input costs could be reduced through water and fertilizer conservation, which would also decrease negative environmental effects (Hanlon et al., 1996). MSW compost can also significant help develop and maintain soil organic matter (Parr and Hornick, 1992).

From the urban viewpoint, compost production represents a safe disposal method for thousands of tons of waste materials produced every year, but there are few official recommendations for compost use in Florida agriculture. The development of sustainable alternative production systems in vegetable crop production is a goal to be achieved in the near future, and compost made from waste materials can play a significant role. The purpose of this publication is to present information of composted waste materials as a soil amendments in vegetable crop production systems in Florida.

Physical and chemical characteristics of composted wastes

Composts produced from a wide range of waste materials have become available in Florida on a large scale (Smith, 1995a). While environmental regulators are mainly interested in compost trace metal concentrations, growers have different interests once compost has passed regulatory health and safety standards. From a commercial grower's point of view, compost quality is judged on moisture concentration, nutrient concentration, pH, soluble salts, organic matter concentration, C:N ratio, water-holding capacity, bulk density, cation exchange capacity, particle size, presence of weed seeds, and odor. Most benefits of soil-applied compost have been attributed to improved physical properties due to increased organic matter concentration rather than nutrient value (Gallardo-Lara and Nogales, 1987; Hernando et al., 1989; McConnell et al., 1993). Optimum chemical and physical parameters for composts that might be used in vegetable crop production are listed in Table 1 [Florida Department of Agricultural and Consumer Services (FDACS), 1995].

Moisture concentration and bulk density. Composts with 35% to 55% moisture by weight are optimum for handling, transporting, and applying. High moisture concentration increases transportation cost due to weight transported, and aggregates become too massive for spreading in the field. Material with low moisture content is too dusty and can be hydrophobic. The compost bulk density value is used to convert between volume and weight for determining application rates.

Compost pH. A compost pH of 5.0 to 8.0 is acceptable for use on vegetable crops. Compost with a pH at the extremes of the range would be useful when adjusting acidic or basic soils.

Soluble salts. Compost should have an electrical conductivity (EC) of ≤6.0 $dS\cdot m^{-1}$ (mmhos/cm), based on a saturated extract. The salt content of the amended soil must be compatible with crop requirements so that no crop damage occurs as a result of compost

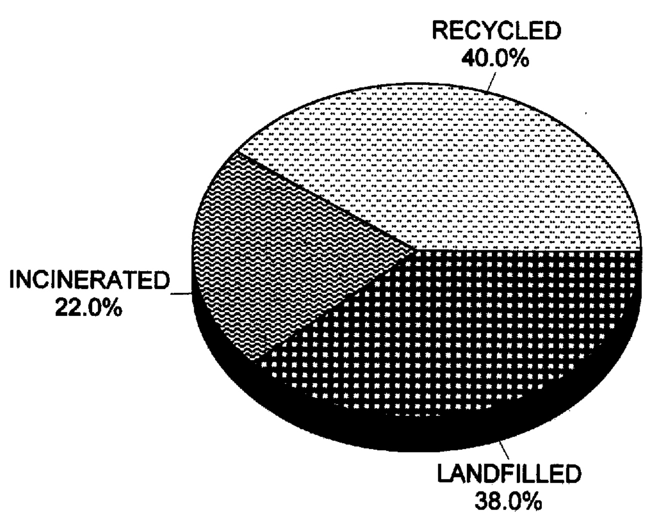

Fig. 1. Distribution of municipal solid waste in Florida. (Source: Goldstein, 1997.)

application. Salinity effects are negligible between 0 to 2 dS·m^{-1}, while yield of very sensitive crops may be restricted between 2 and 4 dS·m^{-1}. Yields of many crops are restricted with an EC of 4 to 8 dS·m^{-1}, and, at >8 dS·m^{-1}, only salt-tolerant crops will grow satisfactorily (Lorenz and Maynard, 1988). If EC exceeds 6.0 dS·m^{-1}, leaching of the amended soil with ≥1 inch of water should occur before planting seeds

Particle size. Compost passing through a 1-inch (2.5-cm) screen or smaller is preferred to minimize large objects that can cause damage to spreading equipment and field machinery. Larger particles can be used depending on soil characteristics, application method, or spreading equipment.

Nutrient concentration. Compost is not considered fertilizer; however, significant quantities of nutrients (particularly N, P, and micronutrients) become available with time as compost decomposes in the soil. Amending soil with compost provides a slow-release source of nutrients, whereas mineral fertilizer is usually water soluble and is immediately available to plants (Ozores-Hampton, 1993). Compost usually contains large quantities of plant-available micronutrients. The nutrient and trace metal concentrations of different compost types are presented in Table 2.

Aesthetics and inerts. Compost used in vegetable crop production should be free of weed seeds and should contain <2% foreign matter such as metals, glass, plastic, rubber, bones, and leather.

Available compost types

Composts made from the following organic waste materials are available to use in Florida vegetable crop production:

MSW includes paper, cardboard, food waste, yard waste, rubber, leather, textiles, wood, and small amounts of glass, metals, and plastics. Most of the inert (uncompostable) materials are screened out before the compost is released for use. The largest compostable portion of Florida MSW is paper (Smith, 1994b).

YTs include leaves from trees and shrubs, pine needles, grass clippings, tree bark, woody branches, roots, and shredded prunings. After January 1992, Florida YT waste could no longer be accepted in a Class I landfill, so composting YTs became an attractive option (Smith, 1995a).

Biosolids are the solid portion of waste from municipal wastewater treatment plants. Composting biosolids creates heat that can be used to reduce pathogens before it can be land-applied. Biosolids are often mixed with MSW or YTs to create a co-compost, because the N added by the biosolids accelerates the raw material composting process.

State regulation

The effects of biosolids on crop growth have been investigated extensively during the last 20 years. Presently, biosolids and biosolids mixed with either MSW or YTs are regulated at the federal level under Clean Water Act Section 503. In 1992, the Environmental Protection Agency (EPA) reported increasing evidence that most biosolids (70%) used in agriculture as fertilizers or soil conditioners are clean and safe (Kidder and O'Connor, 1993). The effect of trace metals in biosolids following land application on humans and domestic animals depends on the particular materials, soil, plant, and animal characteristics (Chaney, 1990). MSW compost is somewhat similar to composts prepared from biosolids, but normally contains lower trace metal and organic toxin concentrations than biosolids (Chaney, 1991). Therefore, trace metal concentrations in MSW compost should be of minimal concern to the user and general public. Research in Florida on tomatoes (*Lycopersicon esculentum* Mill.) and squash (*Cucurbita maxima* Duch. Ex Lam.) grown on calcareous soil to which biosolids, MSW, and co-composted biosolids–MSW were

Table 1. Physical properties of compost used in vegetable production.[z]

Physical properties	Optimal range	Effect
Moisture (%)	35–55	Higher moisture, increased handling and transportation costs
Organic matter (%)	50 or more	Higher organic matter lowers application rate
pH	5–8.0	In acid soil, alkaline compost will raise pH
Water holding capacity (WHC) (%)	20–60	Higher WHC leads to lower irrigation frequency
Soluble salts (dS·m^{-1})	<6.0	Higher than 6.0 means potential toxicity
Bulk density (lb/cu yd fresh)	500–1000	Higher moisture content means a greater bulk density
Particle size	Passes 1-inch screen	Increase soil porosity
C:N ratio	15–25:1	Higher C:N ratio causes N immobilization
Maturity (GI[y])	>60	GI <60 indicates phytotoxicity
Compost stability	Stable	Instability can cause N immobilization
Weed seeds	None	uncomposted materials disseminated weeds

[z]FDACS, 1995.
[y]GI = (% seed germination × root length growth in % of control)/100 (Zucconi et al., 1981a).

Table 2. Chemical and physical analysis of different composted organic waste materials.

Element	MSW[z]	YT[y]	Co-MSW/BS	Co-YT/BS[x]
Concn (% dry weight)				
C	20.3	70.7	---	28.1
N	1.2	0.76	1.18	1.70
P	0.3	0.10	0.98	0.81
K	0.4	0.24	0.64	0.35
Ca	3.1	1.28	1.55	4.05
Mg	0.3	0.14	0.32	0.24
Fe	2.0	---	2.71	1.02
Na	0.35	---	---	0.19
Concn (ppm dry weight)				
Cd	2.9	---	3.7	4.5
Cu	281	---	350	193
Ni	34	---	12	18
Pb	231	---	21.7	71.3
Zn	655	---	510	303
Additional properties				
C:N	16.9	93	---	16.7
Cation exchange capacity (meq/100g)	65.8	---	---	121
pH	7.6	5.7	---	7.1
Electrical conductivity ($dS \cdot m^{-1}$)	5.0	4.1	---	4.7

[z]MSW = municipal solid waste (He et al., 1995).
[y]YT = yard trimming (Nordstedt and Smith, 1994).
[x]BS = biosolids (Graetz, 1995).

applied reported no trace metal accumulation in the edible plant parts (Ozores-Hampton et al., 1994, 1997).

Florida MSW composts are regulated under Rule 17-709, "Criteria for the production and use of compost made from MSW" [Department of Environmental Protection (DEP), 1989], which provides general guidelines for the compost user and producer. Rule 17-709 is in a review process for modification; therefore, we do not discuss state regulation in detail. In general, the Florida classifies composts by type according to the waste processed, product maturity, amount of foreign matter, particle size, organic matter concentration, and trace metal concentrations.

Florida currently regulates allowable concentrations of five trace metals in MSW compost. According to EPA classification, the maximum permissible Cd, Cu, Pb, Ni, and Zn concentration for code 1 MSW compost are 15, 450, 500, 50, and 900 ppm ($mg \cdot kg^{-1}$) dry weight (DEP, 1989). The state also limits the total cumulative amount of Cd, Cu, Pb, Ni, and Zn applied in MSW compost to the soil (Table 3). For situations in which repeated compost applications can be expected, such as agriculture, the annual trace metals loading rate must be less than or equal to one-tenth of the total listed in Table 3. For applications for which repeated compost use is not expected, such as land reclamation or as a soil amendment on highway medians, the metals loading rates listed in Table 3 may be applied within a 1-year period (DEP, 1989).

Compost maturity and stability

Using compost made from waste materials has been frequently associated with damage to crops by phytotoxic compounds in the compost (Chanyasak et al., 1983; Hadar et al., 1985). Crop injury has been linked to use of poor-quality compost, such as that from early stages of the composting process (Zucconi et al., 1981a). The type and degree of plant injury is directly related to compost maturity or stability. Maturity is the degree to which it is free of phytotoxic substances that can cause delayed seed germination or seedling and plant death. Stability is the degree to which compost consumes N and O_2 in significant quantities to support biological activity and generates heat, carbon dioxide (CO_2), and water vapor that can cause plant stunting and yellowing of leaves (FDACS, 1995). Plant stunting has often been attributed to high C:N ratio of the organic material before humification and plant injury from exposure to phytotoxic compounds such as volatile fatty acids and ammonia (Zucconi et al., 1981b). Presence of phytotoxic compounds in a compost is temporary and is associated with the initial composting stages. Phytotoxins rapidly decrease after this stage, but the compounds do not totally disappear after 8

Table 3. Total amount of trace metal applied to Florida soils.[z]

Trace metal	lb/acre
Cadmium	<4.45
Nickel	<111
Copper	<111
Zinc	<222
Lead	<445

[z]Source: DEP, 1989.

weeks (Zucconi et al., 1981b). Toxicity has been related to composting method, where phytotoxins disappeared faster in static piles than with the windrow method (Zucconi et al., 1981b).

Phytotoxin identification in compost extracts from fresh and 5-month-old material showed that fresh compost contained acetic, propionic, isobutyric, butyric, and isovaleric acids in the largest concentrations (DeVleeschauwer et al., 1981). Acetic acid at 300 ppm ($mg \cdot kg^{-1}$) inhibited growth of cress (*Lepidium sativum* L.) seed (DeVleeschauwer et al., 1981). Similar responses were reported by Keeling et al. (1994), who showed decreased germination rates of seven vegetable crops in immature MSW compost alone compared to combinations of immature compost with peat or N (from KNO_3). When water extracts from immature compost were analyzed, the major compound identified was acetic acid at 6000 to 28,000 ppm ($mg \cdot kg^{-1}$). Germination rate was not improved when N was combined with immature MSW compost, implying that compost C:N ratio had no effect on seed germination. Low seed germination and seedling growth inhibition were attributed to phytotoxicity (Keeling et al., 1994).

In Florida, unstable compost consistently caused N immobilization, in which available forms of inorganic N are converted to unavailable organic N (Smith, 1993a, 1993b, 1994a), and inhibited growth of vegetable crops such as beans (*Phaseolus vulgaris* L.) (Kostewicz, 1993), corn (*Zea mays* L.) (Gallaher and McSorley, 1994a, 1994b), peppers (*Capsicum annuum* L.), tomatoes, and squash (Bryan et al., 1995). When immature compost is applied and a crop is planted immediately, growth inhibition and stunting may be visible for 40 to 60 d. When using compost with C:N ratios >25 or 30, N fertilizer should be applied or planting delayed for 6 to 10 weeks to allow the compost to stabilize in situ (Obreza and Reeder, 1994).

Compost maturity as defined by the Florida Dept. of Environmental Protection

a) Mature compost is a highly stabilized compost material that has been exposed to prolonged periods of decomposition. It will not reheat upon standing to >68 °F (20 °C) above ambient temperature. It can be beneficially used and can be applied in direct contact with roots. The material should be brown to black in color. This maturity level is indicated by an organic matter reduction of >60% by weight compared to the original feedstock.

b) Semi-mature compost is compost material that is at the mesophyllic stage. It will reheat upon standing to >68 °F (20 °C) above ambient temperature. It can be beneficially used, although direct contact with the roots should be avoided. The material should be a light to dark brown in color. This maturity level is indicated by an organic matter reduction of >40%, but ≤60% by weight.

c) Fresh compost is compost material that has been through the thermophilic stage and has undergone partial decomposition. The material will reheat upon standing to >68 °F (20 °C) above ambient temperature. It can be beneficially used, but proper care is needed, as further decomposition and stabilization will occur. The material should be similar in texture and color to the feedstock in the composting process. This maturity level is indicated by an organic matter reduction >20% but ≤40% by weight.

Crop yield response to compost application

Overview. Compost application has produced positive results in a wide variety of crops. Contradictory crop response results were found when compost was compared to a traditional fertilizer program. Compost application to soil can improve physical and chemical properties such as water-holding capacity, cation exchange capacity, bulk density, and percentage organic matter and can increase the microbial population (Gallardo-Lara and Nogales, 1987). However, compost can be associated with negative effects on germination and crop yield when applied to soil in an immature state. Combining compost and inorganic fertilizer has generally been more effective in producing a positive plant response than separate application of either material alone. As fertilization regulations become stricter, organic materials will play a more important role in fertilizer efficiency by increasing the nutrient holding capacity of the soil and decreasing nutrient leaching.

Amending soil with composted materials such as biosolids, MSW, and YTs has been investigated extensively and has been reported to increase crop yields of bean, black-eyed pea (*Dolichos sphaerospermus*), okra (*Abelmoschus esculentus* L.) (Bryan and Lance, 1991), tomato, squash, eggplant (*Solanum melongena* L.), bean (Ozores-Hampton and Bryan, 1993a, 1993b, 1994; Ozores-Hampton et al., 1994), watermelon (*Citrullus vulgaris* Schrad.), (Obreza and Reeder, 1994), corn (Gallaher and McSorley, 1994a, 1994b), and pepper (Roe et al., 1993; Stoffella, 1995).

Annual production of compost made from Florida's solid waste could be easily assimilated by the Florida vegetable crop industry. If only 20 ton/acre (45 t·ha^{-1}) fresh weight compost were applied to each of the 418,000 acre (170,000 ha) of vegetables annually grown in Florida, 8.4 million tons (7.6 million t) of compost could be recycled each year (Smith, 1994c). However, N mineralization rates of organic wastes is the most important factor in determining optimum compost application rates and frequencies (Sims, 1995).

Biosolids. Biosolids are sources of all plant nutrients and organic C. In Florida, applying biosolid composts to soils increased yields of several vegetable crops including tomatoes, squash, and beans (Tables 4 and 5). In calcareous soil, application rates as low as 3 to 6 ton/acre (6.7 to 13.5 t·ha^{-1}) resulted in crop yield increases for tomatoes, squash, and beans (Bryan and Lance, 1991; Ozores-Hampton et al., 1994).

MSW and YT compost. The effects of MSW and YT compost on crop growth are only starting to be investigated due to recent availability of these materials in large quantities (Smith, 1990, 1995a). Soil incorporation of MSW compost was reported to increase yields of several vegetable crops (Tables 4 and 5). In Florida, MSW compost application rates of 40 ton/acre (90 t·ha^{-1}) resulted in crop yield increases for bean (Ozores-Hampton and Bryan, 1993b) and watermelon (Obreza and Reeder, 1994).

Potential problems associated with using compost to produce vegetables

- Using immature compost can cause detrimental effects on plant growth. We recommend assaying compost for the presence of phytotoxic compounds using a cress seed germination test (Zucconi et al., 1981a). If germination index (GI = (% cress seed germination × root length growth in % of the control)/100 is <60, allow ≈90 d between the time of compost application and planting of the crop. An alternative measure is to continue composting the material to maturity before it is applied.
- Most vegetable crops are sensitive to high soluble salts, especially when they are direct-seeded. We recommend measuring the soluble salts concentration of a saturation extract. If the EC is <6.0 dS·m^{-1}, no salt toxicity should occur. If the EC is >6.0 dS·m^{-1}, the amended soil should be leached with water before planting seeds (only a few crops can tolerate this salt level).
- High C:N compost can result in N immobilization. Have the compost analyzed for C:N ratio. If it is >25:1 to 30:1, some N fertilizer applied to the crop may be immobilized due to N immobilization, possibly causing plant N deficiency.
- Lack of equipment to spread compost in vegetable fields is a concern. We encourage compost facilities to play an active role in developing spreading equipment.

Conclusions

Using compost to improve crop yield and soil physical properties has been reported in Florida, although the response is not always predictable. Future research in compost use should be directed to a) improving methods to measure compost maturity and stability, b) determining appropriate compost rates with and without inorganic fertilizer (based in soil type and crop), c) developing spreading equipment, d) using compost as alternative method to control weeds, nematodes, and diseases, and e) informing people of the benefits of composting as an alternative method of waste disposal.

Table 4. Effects of yard trimming compost on vegetable crops in Florida.

Crop	Compost type[z]	Rate (ton/acre[y])	Soil type	Crop response	Citation
Corn	YT	0, 60, 120 (1 year)	Sandy	No response, N immobilization	Gallaher and McSorley, 1994a
Corn	YT	240, 300, 360 (3 years)	Sandy	Increased yields	Gallaher and McSorley, 1994a
Pepper	YT/BS	0, 60	Sandy	Increased yields	Stoffella, 1995
Cucumber	YT/BS	0, 60	Sandy	Increased yields in residual compost	Stoffella, 1995
Pole beans	YT	0, 25, 50, 100 (1 year)	Sandy	100 ton/acre appears to be optimum rate with adequate fertilizer	Kostewicz, 1993
Pole beans	YT	0, 25, 50, 100 (2 year)	Sandy	Immature compost caused N immobilization and reduced yield. Strong residual effects.	Kostewicz, 1993
Okra	YT	0, 10, 20	Sandy	No response	Kostewicz and Roe, 1991
Cream peas	YT	0, 10, 20	Sandy	No response	Kostewics and Roe, 1991
Tomatoes, peppers, cucumbers	YT/BS	0, 60	Sandy	Increased yield	Stoffella, 1995

[z]YT = yard trimming; BS = biosolids.
[y]To convert ton/acre into t·ha^{-1} multiply by 2.24.

Table 5. Effects of municipal solid waste compost on vegetable crops in Florida.

Crop	Compost type[z]	Rate (ton/acre[y])	Soil type	Crop response	Citation
Tomato	MSW-BS	0, 6, 12 (year 1)	Sandy	Increased yield with mature compost	Obreza and Reeder, 1994
Tomato	MSW-BS	0, 12, 24 (year 2)	Sandy	Decreased yield with immature compost	Obreza, 1995
Tomato	MSW	0, 33, 50 (year 1)	Sandy	Decreased yield with immature compost	Obreza and Reeder, 1994
Tomato	MSW	0, 66, 100 (year 2)	Sandy	No response to mature compost	Obreza, 1995
Watermelon	MSW-BS	0, 6, 12 (year 1)	Sandy	No response to mature compost	Obreza and Reeder, 1994
Watermelon	MSW-BS	0, 12, 24 (year 2)	Sandy	No response to mature compost	Obreza, 1995
Watermelon	MSW	0, 33, 50 (year 1)	Sandy	Increase yield 59%	Obreza and Reeder, 1994
Watermelon	MSW	0, 33, 50 (year 2)	Sandy	No response to mature compost	Obreza, 1995
Tomato	MSW-BS	0, 11	Calcareous	No response to mature compost	Ozores-Hampton et al., 1994
Tomato	MSW	0, 21	Calcareous	No response to mature compost	Ozores-Hampton et al., 1994
Squash	MSW-BS	0, 11	Calcareous	No response to mature compost	Ozores-Hampton et al., 1994
Squash	MSW	0, 21	Calcareous	No response to mature compost	Ozores-Hampton et al., 1994
Tomato	MSW-BS	0, 15, 30 (year 1)	Calcareous	Decreased yield 'immature compost'	Bryan et al., 1995
Tomato	MSW-BS	0, 30, 60 (year 2)	Calcareous	Decreased yield immature compost from previous year, but, yield increase with mature compost	Bryan et al., 1995
Tomato	MSW	0, 60, 120 (year 1)	Calcareous	Increased yield with mature compost	Bryan et al., 1995
Squash	MSW-BS	0, 15, 30 (year 1)	Calcareous	Immature compost from previous season did not reduce yield	Bryan et al., 1995
Squash	MSW	0, 30, 60 (year 1)	Calcareous	Increase yield with mature compost	Bryan et al., 1995
Squash	MSW/M	0, 100, 150	Sandy	Yield was higher in compost mulch than plastic, due to disease problems in plastic	Roe et al., 1993
Eggplant	MSW	0, 40, 60	Sandy	Increased yield with mature compost	Ozores and Bryan, 1993a
Broccoli	MSW	0, 3, 6, 12	Sandy	No response to mature compost	Roe et al., 1990
Black-eyed peas	MSW	0, 3, 9	Sandy	At low and high N rate compost increased yield	Bryan and Lance, 1991
Bush beans	MSW	0, 36, 72	Calcareous	Increased marketable yield by 25%	Ozores and Bryan, 1994
Snap beans	MSW	0, 40, 60	Calcareous	No yield response with fertilizer, however yield was increased with lower fertilizer rate	Ozores and Bryan, 1993b
Southern peas	MSW	0, 36, 72	Calcareous	Increase marketable yield by 100%	Ozores and Bryan, 1994
Peppers	MSW/M	0, 50, 100	Sandy	Unmulched plot had lowest yield, composts were next, and plastic mulch was highest. There were N differences between compost mulch rate.	Roe et al., 1992
Peppers	MSW	0, 40, 60	Sandy	Increased yield with mature compost	Ozores and Bryan, 1993a
Peppers	MSW/M	6, 18, 54	Sandy	Decreased yield with compost mulch compare with plastic mulch	Roe et al., 1993

[z]MSW = municipal solid waste, BS = biosolids, M = mulch.
[y]To convert ton/acre into $t \cdot ha^{-1}$ multiply by 2.24.

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