Enhancement of Soil Characteristics With Compost To Maximize Parsley Yield In Sandy Soils

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A B S T R A C T

Growing Italian parsley (Petroselinum crispum [Mill.]) as a short-duration crop on sandy soil is becoming more and more popular among small producers in the warm and humid climate of north Florida. The low fertility sandy soils in Florida and the ensuing crop production can both benefit from the application of compost to agricultural land, which also offers a means of recycling biosolids and municipal solid waste (MSW). The effects of applying compost (75% MSW:25% biosolids) versus fertilizer, fertilizer + compost (50:50), and control treatments were assessed in a field study using a randomized complete block design with four replications. The variables included: (a) parsley fresh weight (FW); (b) soil and plant tissue nutrient concentrations; and (c) soil bulk density and moisture retention in the winter and spring. Parsley yield from a non-amended control plot was 15.02 mg ha^{-1}, but in soil amended with fertilizer or compost + fertilizer, it doubled to 30.75 and 32.67 mg ha^{-1} in soil amended with fertilizer + compost or fertilizer alone, respectively. The compost and fertilizer + compost treatments showed significantly higher total soil carbon (C) levels of 2.16% and 1.95% and nitrogen (N) levels of 0.19% and 0.16%, respectively. In plots that received only compost at the end of the winter growing season, the addition of compost greatly decreased soil bulk density to 1.03 Mg m^{-3} and increased soil moisture retention in simulated drier conditions at 1500 kPa to 0.12 m^3m^{-3}. Overall, the addition of compost improved the plants' chemical and physical characteristics and raised parsley yields.

Keywords: Compost, Municipal solid waste Waste management Plant nutrients, Soil nutrients, Soil physical properties

1. Introduction

Parsley (*Petroselinum crispum* [Mill.]) is cultivated both as an herb for consumption in the fresh and dried states and as a source of essential oils. Parsley is used as a fresh culinary herb and grouped with vegetables, and because herbs are a minor crop in most areas, data on acreage and sales of specific herb genera are not readily available from the National Agricultural Statistics Service (NASS). In the warm and wet north Florida climate, growing Italian parsley is gaining popularity with small producers as a short duration (69 days) niche crop, with a potential to fetch premium prices. Vegetables grown in the sandy soils of Florida require relatively high fertilizer inputs, especially those with a short duration growing season. Minimizing fertilizer leaching has become important due to potential negative environmental impacts.

In 1988, 15.8 million tons of municipal solid waste (MSW) were generated in the state of Florida, which increased to 36.85 million tons in 2005 (Bureau of Solid and Hazardous Waste, 2005), an estimation based on the state's 17.9 million population. Since the passage of the Solid Waste Management Act in Florida in 1988, there has been a dramatic growth in recycling with a substantial decline in landfilling.

Composting of urban waste and recycling through land application is a valuable alternative to landfills or incineration. The composted product offers both a source of organic matter and plant essential nutrient contents, which are beneficial to successful crop production (Stratton et al., 1995). Composts formulated from a wide range of feedstocks have long been used in agriculture. Several studies have shown that continuous application of MSW to agricultural fields resulted in increased soil organic carbon content (Crecchio et al., 2001; Hoffmann, 1983; Keonoh, 1978; Zinati et al., 2001a). Dalmat et al. (1982) showed that co-composted municipal waste (municipal solid waste plus biosolids) not only provided a fairly stable form of organic matter but also a source of plant nutrients that significantly increased fertility and productivity of Haitian soils. The effects of formulated composts from urban wastes on agricultural systems include physical changes in soil structure and water balance (Agassi et al., 1998; Movahedi Naeini and Cook, 2000), chemical properties (Tester, 1990; Zinati et al., 2001b), nutrient availability to crops (Hadas and Portnoy, 1997; Sanchez et al., 1997; Zinati et al., 2004), and crop yields (Cheung and Wong, 1983; Montemurro et al., 2005; Ozores-Hampton et al., 1994).

Although, the co-compost derived from MSW and biosolids was used for improving roadside soils, little information is available on the suitability of the co-compost as a stable source of nutrients for parsley plant production and as a soil amendment for improving physical and chemical properties.

The objective of this study was to evaluate the effects of applications of compost on the fresh weight and tissue nutrient content of parsley, and on properties of sandy soils.

2. Methods

2.1. *Site preparation*

A field experiment was conducted in Gainesville at the

Horticultural Research Area, University of Florida campus, located between the 82822'W longitude and 29839'N latitude, during the winter and spring seasons of 2002. Soil type at the experimental site was classified by Calhoun et al. (1974) as Millhopper fine sand (loamy, siliceous, hyperthermic, Grossarenic, Paleudult; Table 1). Plant beds of 1.20 m × 27 m in size were prepared before planting in both seasons. Soil was rototilled once, to a 6-cm depth to remove weeds and then was sprayed with glyphosate (Roundup1, Monsanto, Canada Inc.), a systemic herbicide, 1 wk before compost application.

2.2. *Compost source and properties*

Before initiation of this study, compost was obtained from a north Florida county facility. The compost was formulated by mixing 75% MSW with 25% biosolids, prepared using an in-vessel compost digester, and cured for 3 mo. Among the properties of the compost (Table 1), the C:N ratio of the compost was determined to be 23.6, which facilitates the growth of microbes and degradation of organic matter (Garcia et al., 1992) but may not immediately release nitrogen (CEPA, 2002). The other properties showed a pH of 7.83 and an electrical conductivity (EC) of 3.65, indicating the alkalinity and high salt content of the material.

2.3. *Treatments and experimental design*

Treatments included nitrogen sources: a fertilizer, a fertili- zer + compost (50:50), only compost, and a control. The experi- ment was a randomized complete block design with four replications. Inorganic nitrogen (N) fertilizer, ammonium nitrate (38-0-0), was applied at the recommended rate of 134 kg N ha^{-1} (Hochmuth et al., 2001) to the plots that received fertilizer only treatment. To the plots that received compost only, compost was incorporated into the soil within the surface 15 cm depth and at a rate of 19,007 kg ha^{-1} to supply an equivalent of 134 kg N ha^{-1}, assuming 50% N-mineralization during the first year of application.

For fertilizer + compost (50:50) treatments, a combination of ammonium nitrate at 197 kg ha^{-1} and compost at 9504 kg ha^{-1} was applied to deliver a total of the recommended 134 kg N ha^{-1}. Control plots did not receive any nitrogen from any source. These treatments were applied in December 2001 for the winter plant production and in April 2002 for the spring production season.

All the plots including control received both phosphorus and potassium based on soil test as per the University of Florida recommendations (Hochmuth et al., 2001).

2.4. *Plant sampling and determination of nutrient concentrations*

Italian parsley, a ‘Dark Green” variety was transplanted using 3- wk-old parsley seedlings into plots of 1.4 m^2 area with five rows spaced at 20 cm within and between the rows in each plot on January 9th and May 2nd, 2002, for winter and spring seasons, respectively. Thirty seedlings per plot were irrigated using drip irrigation, twice daily for 30 min per irrigation cycle except on rainy days.

Nine plants per treatment were harvested at maturity of 69 days after transplanting (DAT) in both seasons as described by Hochmuth et al. (2001). Fresh weight of above-ground plant biomass per treatment was recorded. Subsamples from the top biomass of each treatment were used for nutrient concentration analysis. The subsamples were cleaned by giving a rapid-rinse with de-ionized water, to ensure against any possible absorption of water. The subsamples were then oven-dried at 65 8C and ground with a stainless steel mill to pass a 0.5 mm sieve. The ground plant tissue samples from both seasons were then analyzed at the University of Florida, Analytical Research Laboratory, in Gaines-ville, FL (ARL) for N, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), and molybdenum (Mo) in parsley tissue (dry weight basis) using standard analytical procedures (Mylavarapu and D'Angelo, 2007).

2.5. *Soil sampling and determination of soil properties*

Soil samples were collected from the top 15-cm depth, at the end of each growing season from each plot. The soil samples were air-dried at room temperature, ground to pass a 2 mm sieve, and analyzed for pH, EC, and Mehlich-1 extractable P, K, Ca, Mg, Zn, Mn, and Cu at the ARL as per the standard procedures (Mylavarapu and D'Angelo, 2007). Total C and N (combustion procedure) were determined using standard procedures for the CN Analyzer (Model FP 528, LECO, St. Joseph, MI) at the Agricultural Services Laboratory, Clemson University, Clemson, SC.

For determination of water holding capacity, at the end of each growing season and from each sampling plot, intact undisturbed soil cores (5 cm dia × 3 cm length) were collected using a slide hammer (AMS core sampler[1], American Falls, Idaho) from the 0 to 12 cm soil depth. Soil samples were saturated with de-ionized water for 72 h. Each saturated sample was placed in the Tempe cells

(SMS Temp Cells[1], Tucson, Arizona) attached to adjustable water columns at the Soil Moisture Laboratory at University of Florida, in Gainesville, and was subjected to a series of pressures from 0 to 1500 kPa as per Klute (1986).

At each given pressure, extracted moisture content was determined as the weight difference of the soil sample between the previous and the current pressures. Soil moisture (u) at each specific pressure was obtained as a product of gravimetric water content and the corresponding bulk density.

At the end of the water extraction process, the undisturbed soil cores were removed from the Tempe Cells1 and were re-saturated for determination of

Table 1

Chemical properties of soil and compost before application

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Treatment	C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	pH	EC (dS m^{-1})
Soil	1.50	0.13	0.42	0.07	3.08	0.17	4.59	10.15	0.18	7.00	0.46
Compost	32.73	1.41	1.04	0.38	2.83	0.19	566.49	176.39	226.87	7.83	3.65

[a] Values of each element represent means of four replications.saturated hydraulic conductivity (*K*s) following procedure by Klute and Dirksen (1986). Subsequently, the soil cores were oven-dried at 105 8C for determination of bulk density.

2.6. Statistical analysis

All data were analyzed and interpreted using the SAS system (SAS Institute Inc., 2001). Effects of treatments on plant fresh weight, plant nutrient concentrations, and soil properties were evaluated by PROC ANOVA. Variances and separation of means was analyzed using Fisher's protected Least Significant Difference (LSD) for post hoc comparisons at alpha = 0.05. Values are reported as mean and standard deviation (SD).

3. Results and discussion

3.1. Fresh weight of above-ground plant biomass

In both seasons, parsley above-ground fresh weight (FW) was highest in fertilizer + compost and fertilizer treatments ($P < 0.01$) (Table 2). Parsley FW from the spring grown crop was three-fold

higher and significantly different from the winter grown crop (Table 2).

Since both plant growth and compost mineralization rate are primarily stimulated by the temperature and moisture, signifi- cantly higher temperatures during the spring season (Fig. 1) have resulted in higher shoot growth and higher rate of mineralization, indicating a continuous supply of N to the plants, probably at rates similar to that of inorganic soluble fertilizer. Cool temperatures in the winter season possibly affected parsley biomass production significantly suggesting that while ambient and consequent soil temperatures played a role, reduced sunlight had an overriding effect on the production even at optimum recommended fertilizer rates supplied through soluble N sources.

Our data further showed that a 50:50 combination of inorganic fertilizer and compost had adequately supported optimum parsley above-ground fresh weight. Inorganic fertilizer N provided the initial boost even as the N from compost mineralized likely ensuring a consistent N supply during the initial growing season and meet subsequent demand. Interaction between the seasons and the treatments were however not observed indicating that sunlight was a limiting factor for a leafy plant like parsley.

Table 2

Fresh weight of parsley and nutrient concentration in parsley's tissue in winter and spring growing seasons.

Treatment	Fresh weight (Mg ha^{-1})	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mo (mg kg^{-1})
Control	15.02b[a]	2.11c	0.56b	3.76c	1.93	0.39c	32.31c	24.33c	3.55c	71.72	2.41d
Fertilizer	32.67a	2.50b	0.61ab	4.66b	2.03	0.46b	39.76b	27.08c	4.92b	68.89	3.92c
Fertilizer/compost	30.75a	2.83a	0.60ab	5.43a	1.81	0.52ab	48.15a	31.36	5.64b	67.90	4.87b
Compost	18.00b	2.89a	0.64a	5.40a	1.83	0.52a	53.25a	36.76a	6.73a	67.72	6.03a
Treatment	***	***	*	***	NS	***	***	***	***	NS	***
Season	***[b]	NS[c]	NS	*	**	NS	*	*	NS	*	NS
Season											
Winter	10.80b	2.71	0.60	5.22a	2.06a	0.44	37.54b	34.01a	5.19	81.24a	4.68
Spring	37.40a	2.45	0.60	4.44b	1.74b	0.50	49.19a	25.76b	5.22	56.87b	3.94

[a] Within columns, the same letter indicates means were not different using Fisher's protected (P, 0.05) LSD test.
[b] Significant F test at *P < 0.05, **P < 0.01, and ***P < 0.001, respectively.
[c] NS, nonsignificant F test at P < 0.05.

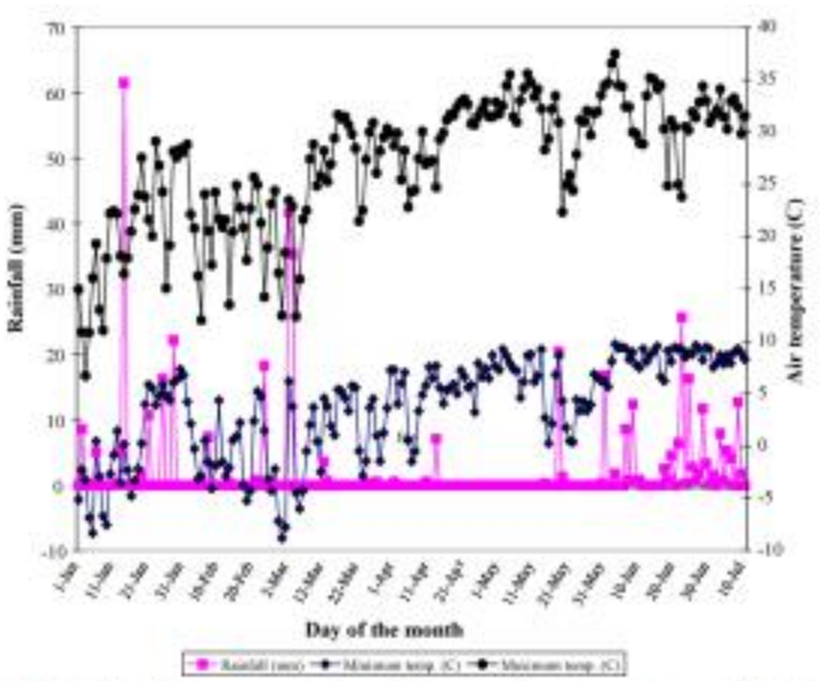

Fig. 1. Rainfall and air temperature during parsley's winter and spring growing seasons in 2002.

3.2. *Plant tissue nutrient concentrations*

There was no significant season × treatment interaction effect on tissue N, P, K, Ca, Mg, Zn, Cu, and Fe concentrations (Table 2). Nitrogen and K concentrations were highest in fertilizer + compost and compost only treatments compared to either control or fertilizer treatments, indicating that adequate mineralized N was available from compost applications during the latter part of both growing seasons. However, N from fertilizer source was probably not available beyond the earlier part of the active growing season, due to its ready solubility and mobility. The application of fertilizer + compost combination is essentially a combination of quick and slow release sources, which could have supplied N through the crop growth period.

Lower concentrations of K in plant tissue in spring season could be attributed to the higher seasonal rainfall (Fig. 1). Phosphorus concentration in tissue was highest in plants grown in compost treated plots and significantly different at $P < 0.05$ from the control plots possibly due to the mineralization of organic P fractions in compost. There was no significant difference in Ca and Fe concentrations among treatments. Plants grown with compost or fertilizer + compost recorded the highest Mg concentrations.

Concentrations of Zn, Cu, Mn, and Mo were determined to be the highest in plant tissue from the compost treatment reflecting their high concentrations in the compost material (Table 1). Plant tissue Cu and Zn concentrations were found to be well below the maximum values (25 and 500 ppm, respectively) considered toxic to plants (Chaney, 1983).

3.3. *Soil properties*

3.3.1. *Chemical properties*

There was no significant effect of season or season × treatment on soil pH, total C, total N, Melich-1 extractable P, K, Ca, Mg, Zn, Mn, Cu, and Fe concentrations (Table 3) except for EC, which was significantly lower in the spring season. The decrease in EC from winter to spring season can be attributed to uptake of nutrients by plants and leaching of salts due to continuous rainfall (111 mm) between June 17th and July 9th during the spring season in comparison to intermittent rain spells between January 13 and 14 (67 mm) and between March 3 and 4 (70 mm) during the winter season. Build up of soil EC is one of the main concerns arising from long-term compost applications affecting the crop productivity. High intensity rainfall events can obviously help minimize salt build up in sandy soils.

In both seasons, amending soil with compost only or in combination with inorganic fertilizer N, significantly increased soil C and N soil concentrations ($P < 0.001$), obviously due to applied organic nutrient source. Soil P and Ca concentrations were lowest in control plots and highest in compost treated soils, reflecting the corresponding higher concentrations in the applied compost composition. However, there was no significant treatment effect on soil K and Mg concentrations.

Significantly ($P < 0.001$) higher levels of Zn, Mn, and Cu were observed in soils amended with compost, signifying the impact of higher initial concentrations of micronutrients in the compost composition and their potential for accumulation and extractability.

3.3.2. *Physical properties*

There was no significant interaction between treatment and season on soil bulk density with a single application of compost. There was no significant difference ($P < 0.001$) in soil bulk density

between control (1.16 Mg m^{-3}) and fertilizer treatments (1.19 Mg m^{-3}). However, addition of compost significantly reduced the soil bulk density to 1.03 Mg m^{-3} in plots that received only compost and to 1.18 Mg m^{-3} in treatments that received fertilizer + compost. The decrease in bulk density has been attributed to the mixing of soil with less dense organic material (Khaleel et al., 1981; Tester, 1990).

There was no significant difference in *K*s values among treatments (Tables 4 and 5) within each season. Mean soil water retention (volumetric water content, uv) at different extraction pressures for the 0–12 cm soil depth as a beneficial result of compost applications was demonstrated and detailed in Tables 4 and 5. During the winter season, the saturated water content in

Table 3
Nutrient concentration in soil amended with different treatments.

Treatment	pH	EC (dS m^{-1})	C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})
Control	7.21	0.27	1.50b	0.13b	0.45b	0.05	3.04d	0.17	5.54c	10.23b	0.21c	16.13
Fertilizer	7.31	0.27	1.55b	0.14b	0.46ab	0.05	3.27c	0.17	4.63c	10.32b	0.17c	17.72
Fertilizer/compost	7.36	0.30	1.95a	0.16a	0.49ab	0.10	3.55b	0.17	12.76b	11.25b	0.44b	19.18
Compost	7.36	0.40	2.16a	0.19a	0.51a	0.19	3.80a	0.19	23.05a	13.51a	0.67a	19.38
Treatment	NS	NS	***	***	**	***	***	NS	***	***	***	NS
Season	NS[a]	***[b]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Season												
Winter[a]	7.24	0.46a[c]	1.80	0.16	0.45	0.09	3.52	0.17	12.64	12.01	0.41	17.81
Spring	7.38	0.16b	1.78	0.16	0.51	0.07	3.31	0.18	10.35	10.65	0.34	18.40

[a] NS, non-significant *F* test at $P < 0.05$.
[b] Significant *F* test at $^{**}P < 0.01$ and $^{***}P < 0.001$.
[c] Within columns, the same letter indicates means were not different using Fisher's protected (*P*, 0.05) LSD test.

Table 4
Saturated hydraulic conductivity (*Ks*) and soil water content (θ) at different pressures (kPa) at end of winter plant growing season.

Treatment	*Ks* (cm h^{-1})	Soil water content (θ, m^3 m^{-3}) at different pressures								
		0 kPa	0.3 kPa	4.4 kPa	10 kPa	15 kPa	34 kPa	100 kPa	500 kPa	1500 kPa
Control	2.79	6.56 ± 0.02a[a]	5.17 ± 0.46a	3.43 ± 0.19a	2.31 ± 0.19a	2.06 ± 0.18a	1.65 ± 0.08b	0.89 ± 0.09b	0.40 ± 0.11b	0.10 ± 0.06b
Fertilizer (F)	2.86	6.58 ± 0.02a	5.90 ± 0.33a	3.49 ± 0.28a	2.35 ± 0.18a	2.18 ± 0.17a	1.74 ± 0.14ab	0.93 ± 0.19ab	0.42 ± 0.19ab	0.10 ± 0.06b
Fertilizer/compost	3.32	6.55 ± 0.02a	5.73 ± 0.28a	3.58 ± 0.07a	2.34 ± 0.07a	2.23 ± 0.07a	1.75 ± 0.07ab	0.99 ± 0.13a	0.50 ± 0.09a	0.11 ± 0.05ab
Compost (C)	3.13	6.61 ± 0.21b	5.98 ± 0.30a	3.64 ± 0.18a	2.45 ± 0.14a	2.36 ± 0.13a	1.90 ± 0.09a	1.04 ± 0.14a	0.52 ± 0.11a	0.12 ± 0.08a

[a] Mean ± standard deviation, within columns, the same letter indicates means were not different using Fisher's protected (*P*, 0.05) LSD test.

Table 5
Saturated hydraulic conductivity (*Ks*) and volumetric water content (θ) at different pressures (kPa) at end of spring plant growing season.

Treatment	*Ks* (cm h^{-1})	Soil water content (θ, m^3 m^{-3}) at different pressures								
		0 kPa	0.3 kPa	4.4 kPa	10 kPa	15 kPa	34 kPa	100 kPa	500 kPa	1500 kPa
Control	3.07	6.50 ± 0.04a[a]	3.15 ± 0.62b	2.56 ± 0.19b	2.11 ± 0.12b	1.94 ± 0.10b	1.69 ± 0.14b	1.04 ± 0.14b	0.55 ± 0.12a	0.14 ± 0.03b
Fertilizer (F)	3.00	6.50 ± 0.08a	4.39 ± 0.30a	3.11 ± 0.28a	2.59 ± 0.23a	2.26 ± 0.25a	1.85 ± 0.19ab	1.10 ± 0.11ab	0.4.8 ± 0.10b	0.12 ± 0.08b
Fertilizer/compost	4.26	6.23 ± 0.11b	4.43 ± 0.31a	3.06 ± 0.20a	2.49 ± 0.14a	2.33 ± 0.14a	1.78 ± 0.18ab	1.19 ± 0.17a	0.64 ± 0.06a	0.18 ± 0.04a
Compost (C)	3.27	6.62 ± 0.04a	4.58 ± 0.11a	3.15 ± 0.25a	2.51 ± 0.27a	2.28 ± 0.26a	1.92 ± 0.19a	1.19 ± 0.14a	0.69 ± 0.13a	0.19 ± 0.02a

[a] Mean ± standard deviation, within columns, the same letter indicates means were not different using Fisher's protected (*P*, 0.05) LSD test.

compost amended soil was highest compared to the other treatments at all pressures. The soil samples were subjected to pressures between 0 and 1500 kPa, to determine the moisture retention capacities from the point of saturation, at field capacity (10 kPa for sandy textures) to permanent wilting point (1500 kPa). As the plots were irrigated regularly, influence of compost amendments on soil moisture retention capacities was particularly noticeable at these pressures. Soils in all treatments showed smooth transition in moisture contents between succes- sive pressures without any sudden drop in moisture contents. At 10 kPa and 1500 kPa, the soil water content was highest in compost amended soils and lowest in control soil. Compost application at the highest rate has obviously resulted in improved moisture retention, which is a critical soil physical factor particularly in sandy soils during dry weather for sustaining plant growth. A similar trend was observed in the soil moisture retention characteristics in the spring season in compost amended treatments.

4. Conclusions

The results of our study showed that sequential applications of compost with and without fertilizer increased the fresh weight of parsley, nutrient uptake and soil nutrient concentrations, soil water retention, and reduced soil bulk density. Our results confirm the benefits of compost application for potential use as a source of nutrients, particularly providing sufficient N, for optimum production of fresh leafy vegetables such as parsley. Obviously compost applications have significant amounts of total carbon and nitrogen, potentially improving the physical and chemical proper- ties of the soils for sustaining optimum crop production. Addition of compost to sandy soil induced a relatively important increase in soil total carbon content, and a slight increase of C/N ratio noticed without affecting soil pH, and increased soil water retention fertilizer + compost and compost treatments. Organic amend- ments certainly beneficially influence both water and nutrient retention properties of sandy textured soils. However, fertilizer phosphorus application rates should be appropriately adjusted for the amounts applied through compost along with N to minimize environmental losses.

References

Agassi, A., Hadas, A., Benyamini, Y., Levy, G.J., Kautsky, L., Avrahamov, L., Zhevelev, H., 1998. Mulching effects of composted MSW on water percolation and com- post degradation rate. Compost Sci. Util. 6, 34–41.

Bureau of Solid & Hazardous Waste, 2005. Final Disposition of MSW in Florida, Introduction Appendix A Table 5A, In Solid Waste Annual Report Data, http:// appprod.dep.state.fl.us/www_rcra/reports/WR/Recycling/2005AnnualReport/ AppendixA/5A.pdf.

Calhoun, F.G., Carlisle, V.C., Caldwell, R.E., Zelazny, L.W., Hammond, L.C., Breland, H.L., 1974. Characterization Data for Selected Florida Soils. Soil Sci. Dep. Res. Rep. SLS 74-1. Univ. of Florida, Gainesville.

California Environmental Protection Agency (CEPA), Integrated Waste Management Board, 2002. Compost: Matching Performance Needs with Product Character- istics. CIWMB Publication #443-00-005. http://www.ciwmb.ca.gov/Publica- tions/Organics/44300005.pdf.

Chaney, R.L., 1983. Potential effects of waste constituents on the food chain. In: Parr, J.F., Marsh, P.B., Kla, J.M. (Eds.), Land Treatment of Hazardous Wastes. Noyes Data Corp., pp. 152–240.

Cheung, Y.H., Wong, M.H., 1983. Utilization of animal manures and sewage sludges for growing vegetables. Agric. Wastes 5, 63–81.

Crecchio, C., Curci, M., Mininni, R., Ricciuti, P., Ruggiero, P., 2001. Short-term effects of municipal solid waste compost amendments on soil carbon and nitrogen content, some enzyme activities and genetic diversity. Biol. Fertil. Soils 34, 311–318.

Dalmat, D.J., Parr, J.F., Von Lignau, A., LaGuerre, P.A., 1982. Co-composting's poten- tial for developing nations. Biocycle 22, 43–47.

Garcia, C., Costa, H.F., Ayuso, M., 1992. Evaluation of the maturity of municipal waste compost using simple chemical parameters. Comm. Soil Sci. Plant Anal. 23, 1501–1512.

Hadas, A., Portnoy, R., 1997. Rates of decomposition in soil and release of available nitrogen from cattle manure and municipal waste composts. Compost Sci. Util. 3, 48–54.

Hochmuth, G.J., Maynard, D.N., Vavrina, C.S., Stall, W.M., Raid, R.N., Webb, S.E., 2001. Parsley production in Florida. In: Hochmuth, G.J. (Ed.), Vegetable Production Handbookfor Florida. Univ. of Florida Cooperative Extension Service, pp. 283–289. Hoffmann, G., 1983. Recycling of municipal waste compost in vineyard soils. In: Novak, B. (Ed.), Studies About Humus. Transactions of the VIII International

Symposium. Vol. I. (Abstracts), Prague, p. 69.

Keonoh, W., 1978. Effects of organic materials on soil chemical properties. J. Lorean Soc. Soil Sci. Fert. 2, 161–174.

Khaleel, R., Reddy, K.R., Overcash, M.R., 1981. Changes in soil physical properties due to organic waster applications: a review. J. Environ. Qual. 10, 133–141.

Klute, A., 1986. Water retention: laboratory methods. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. Second Edition. American Society of Agronomy, Madison, Wisconsin, USA, pp. 635–662.

Klute, A., Dirksen, C., 1986. Hydraulic conductivity and diffusivity: laboratory methods. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. American Society of Agronomy, Madison, Wisconsin, USA, pp. 687–732.

Montemurro, F., Convertini, G., Ferri, D., Maiorana, M., 2005. MSW compost appli- cation on tomato crops in Mediterranean conditions: effects on agronomic performance and nitrogen utilization. Compost Sci. Util. 13, 234–242.

Movahedi Naeini, S.A.R., Cook, H.F., 2000. Influence of municipal waste compost amendment on soil water and evaporation. Commun. Soil Sci. Plant Anal. 31, 3147–3161.

Mylavarapu, R.S., D'Angelo, W., 2007. Analytical Procedures and Training Manual for the UF/IFAS Analytical Research Laboratories. Technical Publication, Uni- versity of Florida, IFAS, Gainesville, FL 32611, 24 pp.