RESIDUAL EFFECT OF MUNICIPAL SOLID WASTE AND BIOSOLID COMPOST ON SNAP BEANS PRODUCTION

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ABSTRACT

The residual effects of compost (mixture of municipal solid waste and biosolid) on snap bean 'Opus' (*Phaseolus vulgaris* L.) production and soil nutrients concentration was evaluated from compost applied in the autumn of 1995 and winter 1996. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (0 vs. 100 kg·ha^{-1} of N). Main plots for 1996 consisted of 3.8 (49 t·ha^{-1}), 7.5 (99 t·ha^{-1}), 11.3 (148 t·ha^{-1}), and 15 cm (198 t·ha^{-1}) thickness of 4-week-old immature MSW compost applied as a mulch, and an untreated control. The second experiment consisted in 3.8, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. Main plots for 1997 consisted of 2 (26 t·ha^{-1}), 3.8, 7.5, and 11.3 thickness of 4-week-old immature MSW compost, and an untreated control. The second experiment consisted in 2, 3.8, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. In 1996, plant stand, marketable bean, and yield per plant were not different among 4 or 8-week-old compost and fertilizer treatments for 4-week-old compost. However, marketable yield and yield per plant was higher on the fertilized plots than unfertilized plots for 8-week-old compost. There were not differences on soil pH, OM, and nutrient concentration among 4 or 8-week-old compost treatments. In 1997, marketable yield and yield per plant increased linearly with increasing 4 or 8-week-old compost rate. Plant stand increased linearly as 4-week-old compost increased, however, there were no differences for 8-week-old compost. Plant stand, marketable yield, and yield per plant was higher in the fertilizer plots than unfertilized plots in both compost ages. Soil pH, OM, P, Ca, Zn, and Mn increased linearly as 4 or 8-week-old compost rate increased. There were no differences on K, Mg, and Fe between compost treatments and the control for 4 or 8-week-old compost. Positive residual effect of compost on snap bean production can be expected under normal irrigation practice.

INTRODUCTION

Solid waste disposal in has become a concern, since population is increasing, strong environmental regulation that require landfills lining to protect ground water, and expensive tipping fee (Smith, 1995b). In 1993, 21.4 million metric tons of solid waste were produced in the united States approx. 4.3 kg per person per day (Smith, 1994b and 1995). Waste materials such as municipal solid waste (MSW), yard trimmings (YT), and biosolid (B) are high-volume wastes that could be composted instead of landfilled or incinerated (Smith, 1994c). Nationally, composting may be an attractive waste management tool, since 30-60% of the waste materials can be composted in an environmentally safe matter (Smith, 1994a). Potential compostable organic material represent 65% of the MSW stream (Smith, 1990; Smith and Cisar, 1993). The largest potential compost user is the agricultural industry (Parr and Hornick, 1992). Florida is a major vegetable-producing state, with 149,850 ha under cultivation each year (FASS, 1997). Sandy soils used for agriculture in Florida have low native fertility (Brady, 1974). Proper fertilization is necessary to maximize yield and fruit quality (Hochmuth and Albregts, 1994), therefore to obtain high crop production, fertilizer inputs are high. Minimizing fertilizer leaching or runoff has become important due to potential negative environmental impacts. Soil-application of compost provides an alternative to current methods of waste disposal, and at the same time may decrease the amount of water and fertilizer applied to crops (Ozores et al., 1994b). Municipal solid waste compost can also play a significant role in the development and maintenance of soil organic matter content (Parr and Hornick, 1992). Amending soil with mature and stable composted materials such as biosolids, MSW, and YT has been investigated extensively, and has been reported to increase vegetable crop yields on beans, blackeye peas (*Pisum sativum* L.), okra (*Abelmoschus esculentus* L.) (Bryan and Lance, 1991) tomato (*Lycopersicon esculentum* Mill.), squash (*Cucurbita maxima* Duch. Ex Lam.), eggplant (*Solanum melongena*) and beans (Ozores-Hampton and Bryan, 1993a and b; Ozores-Hampton and Bryan, 1994; Ozores-Hampton et al., 1994a and b), watermelon (*Citrullus vulgaris* Schrad.) and tomato (Obreza and Reeder, 1994; Obreza et al., 1994), corn (*Zea mays* L.) (Gallaher and McSorley, 1994a and b), and pepper (*Capsicum annuum* L.) (Roe et al., 1993; Stoffella, 1995). Most benefits of soil-applied compost have been attributed to improved physical properties due to increased organic matter concentration, rather than nutrient value (Gallardo-Lora and Nogales, 1987; Hernando et al., 1989; McConnell et al., 1993).

The objectives of this investigation were to evaluate the residual effect of MSW and biosolids compost incorporated the previous year with a combination of inorganic fertilizer on snap beans production.

MATERIALS AND METHODS

Two field experiments were conducted during 1996 and 1997 at Southwest Florida Research and Education Center in Immokalee, Fla. Soil type is a Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods). Snap beans 'Opus' were planted on the same site as the previous (fall, 1995 and winter 1996) biological weeds control plots to determine if there were residual effects of MSW and BS on a second crop. The fields (1996 and 1997) experiments were a randomized complete block split-plots experimental design with four replications. The compost utilized for the experiments were provided by Bedminister Bioconversion of Tennessee, Inc., Sevierville, TN. The MSW and BS are co-processed through a three-compartment Eweson digester in an aerobic environment for 3 days and then cured for 8 weeks using the windrow composting methods. Compost chemical and physical properties were analyzed by the Soil and Water Science Department, University of Florida, Gainesville. The chemical and physical properties of the compost are presented in Table 1.

1996 experiments: Two field experiments were conducted simultaneously utilizing compost treatments applied on the fall of 1995. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (with and out fertilizer). Main plots consisted of 3.75 (49 $t \cdot ha^{-1}$), 7.5 (99 $t \cdot ha^{-1}$), 11.3 (148 $t \cdot ha^{-1}$), and 15 cm (198 $t \cdot ha^{-1}$) thickness of 4-week-old immature MSW compost applied as a mulch, and an untreated control. The second experiment consisted in 3.75, 7.5, and 11.25 cm thickness of 8-week-old MSW immature compost and an untreated control. In both experiments immature compost was place in both side of the beds 90 cm wide and 4.8 m long. Sub-plots consisted of 100-0-113 (N-P-K $kg \cdot ha^{-1}$) and no fertilizer application. Granular fertilizer applications were divided in 3 equal single application at planting, 2 and 4 week after planting. Sub-plots size area consisted of 3 single 2.4 m long center row and 2 border row. After removing polyethylene beds 240 days after treatment (DAT), compost was incorporated about 15 cm deep with a rototiller, and snap beans seeded. Beans were direct seed in a single row on beds 0.3 m wide and 15 high. Beans were planted at 5 cm between seeds and 90 cm between beds or equivalent to 222,000 $plants \cdot ha^{-1}$. Beans were planted on 27 Sept, 1996 and harvested 25 Nov, 1996. Harvested beans area consisted of 4 m long center rows. The plants were irrigated by maintaining a water table about 0.6 m below the soil surface, and were monitored for insects and diseases according to Univ. of Florida guidelines.

1997 experiments: Two field experiments were conducted simultaneously utilizing compost treatments applied on the winter of 1996. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (with and out fertilizer). Main plots consisted of 2 (26 $t \cdot ha^{-1}$), 3.8, 7.5, and 11.3 thickness of 4-week-old immature MSW compost, and an untreated control. The second experiment consisted in 2, 3.75, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. In both experiments, immature compost was place in both side of the bed 6.6 m long and 90 cm wide average. Sub-plots consisted of 100-0-113 (N-P-K $kg \cdot ha^{-1}$) and no fertilizer application. Granular fertilizer applications were divided in 3 equal single application at planting, 2 and 4 week after planting. Sub-plots size area consisted of 2 single 3.3 m long center row and 2 border row. After removing polyethylene beds 240 days after treatment (DAT), compost was incorporated about 15 cm deep with a rototiller, and snap beans seeded. Beans were direct seed at 5 cm between seeds and 53 cm between rows or equivalent to 374,000 plants·ha^{-1}. Beans were planted on 20 Feb, 1997 and harvested 14 April, 1997. Harvested beans area consisted of 4 m long center rows. The plants were irrigated by drip irrigation to mantain uniform soil moisture level to the crop. Insects and diseases were monitored according to Univ. of Florida guidelines.

Plant stands and marketable yield was measured at the time of harvest. Plots were manually harvested by removing the beans from the plants. Soil samples (500 g) were collected before planting in the composted non-fertilized areas and analyzed at Soil laboratory at Southwest Florida REC, Immokalee. Samples were oven dried at 28^{o}C and extracted with Mehlich-1 solution for Ca, Mg, P, and K (Hanlon and DeVore, 1989). Soil pH was determined by 1:2 soil:water saturated extract and organic matter by ignition (Dellavalle, 1992). Cooper, Mn, Fe, and Zn were determined by inductively coupled-argon plasma spectroscopy.

Concentration of volatile fatty acids such as acetic, propionic, butyric, isobutyric, valeric and isovaleric acids were performed by Wood End Research Laboratory, Inc Vermon, Maine 04352. The compost extract were prepared with 20 g compost dry weight and 50 ml of distilled water. At the laboratory the samples were diluted 1:10-1:1000 with distilled water and run through and HPLC anion column, eluted with 0.15mM H_2SO_4.

Data were subjected analysis of variance to determine treatment effects and interactions. Orthogonal contrast was utilized to describe the response of plant stand, marketable yield and soil nutrients to increasing rate of compost.

RESULTS AND DISCUSSION

Compost maturity tests. The biological cress germination methods was utilized to determine compost maturity 240 DAT. The cress test resulted in a germination index of 100 indicating the absence of phytotoxic compounds associated with immature compost (Zucconi et al., 1981b). Physical examination of the compost indicated a dark brown to black color and absence of unpleasant odor associated to immature and unstable compost that can cause seed or plant dead and/or N-immobilization. Thus, after 240 DAT composts was mature and stable. Both the 4 and 8-week-old composts complied the U.S. Environmental Protection Agency's criteria for "exceptional quality," indicating no restrictions on use or application rate (Kidder and O'Connor, 1993).

Soil analysis: There were no effects of compost on pH, OM, and nutrients concentration for 1996. In 1997, soil pH, OM, P, Ca, Zn, and Mn were higher in the compost treatments than the control for 4-or 8-week-old compost (Table 2). There were no differences on K, Mg, and Fe between compost treatments and the control for 4 or 8-week-old compost. Soil pH, OM, P, Cu, Zn, and MN increased linearly as 4 or 8-week-old compost increases. No differences were obtained in soil Cu concentration between 8-week-old compost treatments and the control, but Cu concentration increased linearly as compost rate increased. Soil Cu concentrations differ between 8-week-old compost treatments and the control, and Cu concentration increased as compost rate increased. Soil Ca concentration increased linearly as 4-week-old compost rate increased, but did not increased for 8-week-old compost.

1996 bean production: There were not interactions between compost and fertilizer, and no effects of 4 or 8-week-old compost or fertilizer effects for 4-week-old compost for any of the variables measured (Table 3). For the 8-week-old compost, higher marketable yield and yield per plant were reported from fertilized plots than unfertilized plots. Similar plant stand were reported from the fertilized plots and unfertilized plots for 8-week-old compost. Roe et al (1990) reported higher broccoli yield with 168 than 84 $kg \cdot ha^{-1}$ of N and not effects of compost. The addition of MSW and biosolids compost to the soil provides N almost completely in organic forms, therefore availability occurs only over extended period of time. However, incorporation of inorganic fertilizer which is mainly water-soluble and is almost immediately available to the crops. Results from our experiments indicated no residual effect of 4 or 8-week-old compost and no fertilizer effect of 4-week-old compost on plant stand, marketable yield or yield per plant. This may have been due to suboptimal soil moisture by a poor water tables management during the crop production, especially on the 4-week-old compost. Marketable yield was lower than southwest Florida commercial average on 4 or 8-week-old compost, indication the effects of poor irrigation. Lack of adequate irrigation system can diminish the residual effects of compost and fertilizer on snap bean production.

1997 bean production: There were not interactions between compost and fertilizer on 4 and 8-week-old compost for any of the variables measured (Table 4). There were effects of compost and fertilizer on 4 and 8-week-old compost experiments. Marketable yield, and yield per plant increased linearly as 4 or 8-week-old compost rate increases. Plant stand increased linearly as 4-week-old compost rate increases. Plant stand was similar on 8-week-old compost. Higher plant stand, marketable yield and yield per plant was obtained from fertilized plots than unfertilized plots for 4 or 8-week-old compost experiments. Residual effects of composted materials such as biosolids, MSW, and YT had produced positive results in a wide variety of crops. Municipal solid waste compost rates of 90 $t \cdot ha^{-1}$ applied early in the year resulted in crop yield increases for bean (Ozores-Hampton and Bryan, 1993b). Residual effects of compost of MSW, BS, and MSW and BS combination applied a year early resulted in squash yield increases of 23% over the control (Ozores-Hampton et al., 1994). Application of 112 $t \cdot ha^{-1}$ MSW 90 days before planting increased watermelon production by 30% as compared to southwest Florida commercial average (Obreza and Reeder, 1994). Compost may increase yield by improve long term physical and chemical properties such as water-holding capacity, cation exchange capacity, bulk density, and percentage organic matter, and can increase the microbial population rather than the value as a fertilizer (Gallardo-Lara and Nogales, 1987).

The lack of differences among compost treatments in soil nutrients and suboptimal soil moisture resulted in no significant yield responses to compost for 1996 experiments (Table 3). Higher soil pH, OM, and nutrient concentration due to compost treatments resulted in higher marketable bean yield for

1997 experiments (Table 2 and 4). Benefits from compost utilization to improve crop yield and soil chemical and physical properties have been reported, although the response is not always predictable.

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Table 1. Elemental concentration and chemical analysis of immature compost.

Characteristic	4-weeks		8-weeks	
	1995	1996	1995	1996
	----------(% dry weight)[x]---------			
C	40.4	38.1	38.0	38.0
N	1.24	1.22	1.31	1.18
P	0.37	0.21	0.37	0.26
K	0.32	0.31	0.34	0.30
Ca	2.21	2.04	2.21	2.27
Mg	0.24	0.18	0.24	0.23
Fe	0.86	0.88	0.97	0.96
	----------($mg \cdot kg^{-1}$ dry weight)[x]------			
Cd	2.0	3.0	2.0	3.0
Cu	197	303	550	207
Mn	219	303	226	207
Pb	182	238	192	268
Ni	39	33	38.5	40
Zn	567	487	550	459
Moisture (%)	39.7	37.5	42.0	64.0
C:N	35.5	31.3	29.0	31.8
pH	6.6	8.0	6.7	7.9
E.C. (dS/m)	10.1	8.4	9.5	10.5
G.I[z]	0	0	0	0

[x] Soil and Water Science Department, University of Florida, Gainesville.

[z] Germination Index (Zucconi et al., 1981a and 1981b).

Table 2. Residual effect of 4 and 8-week-old compost on soil pH, organic matter and soil nutrient concentration for 1997.

Treatments		pH	OM (%)	P	K	Ca	Mg	Cu	Zn	Mn	Fe
				----------mg·kg^-1----------							
			----------4-week-old compost----------								
Control		6.0	1.8	16	14	671	10	4.4	3.0	1.7	20.8
Compost, 1.9 cm		6.3	2.0	23	13	789	21	3.8	4.5	2.1	17.3
Compost, 3.8 cm		6.6	2.1	25	11	933	16	5.0	6.6	2.8	19.8
Compost, 7.5 cm		7.3	2.6	35	17	1,399	18	6.5	15.2	4.5	34.1
Compost, 11.3 cm		7.5	2.5	43	13	1,621	19	5.2	18.7	5.9	32.1
Compost		**	**	*	NS	**	NS	**	**	*	NS
Contrast:											
Control vs. compost		**	**	**	NS	**	NS	NS	**	**	NS
Compost:	Linear	**	**	*	NS	**	NS	*	**	**	NS
	Quadratic	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
			----------8-week-old compost----------								
Control		6.3	1.7	20	7	740	13	2.2	2.6	1.7	46.2
Compost, 1.9 cm		6.6	1.8	22	8	730	15	3.0	3.9	2.0	43.4
Compost, 3.8 cm		6.9	1.9	27	10	1,147	19	2.9	6.0	2.6	50.1
Compost, 7.5 cm		7.1	2.0	31	13	1,015	14	2.9	8.6	2.8	53.7
Compost, 11.3 cm		7.5	2.2	39	10	1,194	16	4.0	12.2	4.1	60.3
Compost		**	**	**	NS	*	NS	*	**	**	NS
Contrast:											
Control vs. compost		**	**	**	NS	*	NS	**	**	**	NS
Compost:	Linear	**	**	**	NS	NS	NS	*	**	**	NS
	Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**, *, ns: Significant at P = 0.01, P = 0.05, or not significant, respectively.
OM = organic matter

Table 3. Residual effects of compost and fertilizer rate on plant stand, total yield and yield per plant for 1996.

Treatments		Plant stand (No./4 m rows)	Bean yield ($t \cdot ha^{-1}$)	Yield/plant (g/plant)
		------------------------4-week-old compost------------------------		
Control		38	3.9	37.4
Compost, 3.8 cm		40	3.3	30.0
Compost, 7.5 cm		40	3.4	30.0
Compost, 11.3 cm		42	3.5	31.0
Compost		NS	NS	NS
Contrast:				
Control vs. compost		NS	NS	*
Compost:	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		40	3.1	32.0
90		41	4.0	31.8
		NS	**	NS
Interactions				
Compost X fertilizer		NS	NS	NS
		------------------------8-week-old compost------------------------		
control		44	7.0	57.4
Compost, 3.8 cm		43	5.7	48.5
Compost, 7.5 cm		42	5.7	50.0
Compost, 11.3 cm		43	6.4	52.7
Compost		NS	NS	NS
Contrast:				
Control vs. compost		NS	NS	NS
Compost:	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		43	5.0	42.2
90		43	7.3	62.1
		NS	**	**
Interactions				
Compost X fertilizer		NS	NS	NS

**, *, ^{NS}: Significant at P = 0.01, P = 0.05, or not significant, respectively.

Table 4. Residual effects of compost and fertilizer rate on plant stand, total yield and yield per plant for 1997.

Treatments		Plant stand (No./4 m rows)	Bean yield ($t \cdot ha^{-1}$)	Yield/plant (g/plant)
		------------------------4-Week-old compost	----------------------	
Control		30	1.4	15.9
Compost, 2.0 cm		32	2.4	30.4
Compost, 3.8 cm		35	3.1	32.4
Compost, 7.5 cm		40	4.6	43.1
Compost, 11.3 cm		42	6.9	60.1
Compost		*	**	**
Contrast:				
Control vs. compost		*	**	**
Compost:	Linear	**	*	**
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		39	3.4	30.8
90		33	4.0	42.0
		*	*	**
Interactions				
Compost X fertilizer		NS	NS	NS
		-----------------------8-week-old compost	-----------------------	
Control		30	0.9	9.9
Compost, 2.0 cm		43	2.0	16.0
Compost, 3.8 cm		39	1.9	18.6
Compost, 7.5 cm		37	3.8	31.6
Compost, 11.3 cm		50	5.8	41.9
Compost		**	**	**
Contrast:				
Control vs. compost		**	**	**
Compost:	Linear	NS	**	**
	Quadratic	*	*	NS
Fertilizer (lb/acre)				
0		36	2.4	19.9
90		43	3.4	27.2
		*	**	**
Interactions				
Compost X fertilizer		NS	NS	NS

**, *, ^{ns}: Significant at P = 0.01, P = 0.05, or not significant, respectively.