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Container Production of Tomato with Food By-Product Compost and Mineral Fines

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ABSTRACT

Agricultural applications are sought for by-products from agricultural, municipal, and industrial operations. Incorporation into media for container production of crops is a suggested use of organic and mineral by-products. Composted food by-products generated by grocery stores and restaurants and mineral fines from the aggregate industry were assessed in the formulation of media for tomato (*Lycopersicon esculentum* Mill.) production in containers. The basic medium was compost and perlite (2 compost:1 perlite, v:v). This medium was mixed with basalt fines or glacial moraine fines added separately at 60 or 120 g L^{-1}. Nitrogen (N) fertilizer was added weekly to the media except for one treatment that included the basic medium without N. Incorporation of mineral fines into the food by-product compost produced an early stimulation of vegetative growth, but did not affect fruiting of tomatoes significantly; however, fruiting was heavy in the containers to which N was added, with an average of nearly 23 kg of total fruits per plant. Extractable (acidified sodium acetate solution) calcium (Ca) and manganese (Mn) from the media increased, but other nutrients were unaffected by additions of basalt or glacial fines. In all media, extractable nitrate and potassium (K) were almost depleted during the experiment; phosphorus (P) was moderately depleted, whereas extractable Ca, magnesium (Mg), iron (Fe), zinc (Zn), and copper (Cu) were slightly lower or unchanged during the experiment. Tissue analyses showed that leaf concentrations of N, K, Mn, and Zn were below the range needed for well-nourished plants whereas Ca exceeded concentrations necessary for adequate nutrition. Tissue concentrations of P and Mg were sufficient for proper plant nutrition. Although fertilization with N and K, were necessary to sustain optimum yields, formulations of food by-product compost and mineral fines were excellent media for container production of tomato.

INTRODUCTION

Mineral fines are mixtures of inorganic dusts that are naturally occurring or are generated as by-products from manufacture of aggregates. These fine-textured mixtures contain a broad spectrum of plant nutrients and other elements (Chesworth et al., 1983; Clemens and Singer, 1992). Increases in soil fertility and crop productivity have been suggested as benefits obtained from land applications of mineral fines, such as glacial moraine dusts and single or mixed finely ground rock dusts (Campe et al., 1997; D'Hotman de Villiers, 1961; Leipold, 1993; Leonardos et al., 1987; Korcak, 1996; Sauter and Foerst, 1987). The fine-textured property of these mineral fines is an important trait in their contribution to soil fertility, for the approximately silt-sized particles could provide a slow, sustained release of plant nutrients. Their fine texture suggests that mineral fines are superior to coarser materials, such as granite dust and greensand, which may release negligible amounts of nutrients within a growing season (Barker, 1976). The potential for supplying nutrients is sufficient that mineral fines might be considered as alternatives to uses of some manufactured fertilizers. Also, the fines are rich in Ca in forms that give the fines some potential as limes for acid soil remediation (Campe et al., 1997; Hinsinger et al., 1996). The objective of this study was to assess the ability of mineral fines used in combination with compost in the formulation of media for container production of tomatoes.

MATERIALS AND METHODS

Basalt mineral fines from a crushed-rock processor in Amherst, MA, and glacial moraine fines from an aggregate processor in Collins, NY, were used. Chemical analyses of the fines are reported (Table 1). Of each of the mineral fines, 90% of the mass was 0.05-mm (silt-sized) or smaller diameter particles. The chemical and mechanical analyses were provided by the National Aggregate Association, 5600 Branchville Road, College Park, MD.

Mature, year-old compost (Compost A) (grocery store vegetable by-products composted in windrows by Smith Vocational High School, Northampton, Massachusetts) was mixed with perlite (2 compost:1 perlite, v:v) as the base medium

TABLE 1. Composition of plant nutrients and some nonessential trace elements in mineral fines of Massachusetts basalt rock and New York glacial moraine.

Element	Concentration of element in mineral fines	
	Basalt dust	Glacial moraine
	mg/kg	
	Plant Nutrients	
Phosphorus	70	660
Potassium	4,490	14,200
Calcium	20,800	24,600
Magnesium	7,660	11,900
Iron	84,300	32,800
Manganese	1,270	1,070
Nickel	321	29
Copper	74	103
Zinc	111	222
Molybdenum	1	3
Boron	<5	<5
	Nonessential Elements	
Sodium	10,100	3,300
Cadmium	<0.1	0.2
Lead	13	26

The analyses were conducted by Elemental Research Inc., Vancouver, B.C., Canada, at the request of the National Aggregates Association, College Park, MD. Nitrogen, sulfur, and chlorine were not reported.

to grow 'Celebrity' tomatoes in 15 L nursery containers. The mass of the mix was about 12 kg in each container. Another compost (Compost B) was made by combining food by-products and basalt dust (135 kg cu yd^{-1}) at the beginning of composting. The mass of Compost B mix with perlite (2:1) in the containers was 8.25 kg. All composts were made in 1996 for use in 1997. Chemical compositions of the composts are reported (Table 2). The composts were of similar composition by volume; therefore, similar amounts of plant nutrients were added to each container by each compost. Either Massachusetts basalt fines or New York glacial fines were mixed with the base medium at 60 or 120 g L^{-1} (0.91 kg or 1.82 kg per container) to give the following treatments:

TABLE 2. Analyses of composts used for production of tomatoes.

Element	Type of compost	
	A Food waste	B Food waste with basalt fines
	% dry wt	
Nitrogen	0.85	0.79
Phosphorus	0.24	0.32
Potassium	0.20	0.21
Calcium	0.93	1.30
Magnesium	0.20	0.33
Iron	0.47	0.58
	mg/kg, dry wt	
Zinc	87	72
Copper	25	20
Manganese	320	257
Boron	14	15
Nickel	5	6
Lead	62	15
Cadmium	0	0
Chromium	5	3
pH	7.2	7.9
C:N ratio	12.3	18.6

Composts were analyzed by the Soil and Plant Tissue Testing Laboratory, University of Massachusetts, Amherst, MA.

(1) 2:1, v:v, compost A:perlite (Base Medium)
(2) 2:1, v:v, compost A:perlite+0.91 kg of basalt fines/container (60 g L^{-1})
(3) 2:1, v:v, compost A:perlite+1.82 kg of basalt fines/container (120 g L^{-1})
(4) 2:1, v:v, compost A:perlite+0.91 kg of glacial fines/container (60 g L^{-1})
(5) 2:1, v:v, compost A:perlite+1.82 kg of glacial fines/container (120 g L^{-1})
(6) 2:1, v:v, compost B:perlite
(7) 2:1, v:v, compost A:perlite (no nitrogen fertilizer)

TABLE 3. Extractable nutrients and extractable nonessential elements, pH, and cation exchange capacity of various media used in tomato production. Data are means of sampling at planting and sampling at last harvest.

Element	Media						
	1 BM	2 BM 1 RD	3 BM 2 RD	4 BM 1 GD	5 BM 2 GD	6 Compost B	7 BM No N
	----------mg/liter----------						
Ammonium-N	8c	7bcd	6d	7bcd	6cd	10a	9ab
Nitrate-N	35ab	34ab	35ab	39a	42a	28b	35ab
Phosphorus	228b	173e	126f	210cd	204d	328a	215c
Potassium	516b	496b	·499b	488b	532b	674a	500b
Calcium	2,335d	3,401b	4,518a	3,454b	4,442a	2,444c	2,283d
Magnesium	584b	586b	584b	576b	589b	615a	551c
Boron	1.8a	1.8a	1.8a	1.8a	1.8a	1.6b	1.6b
Zinc	2.7d	3.0c	3.4b	2.9c	3.0c	3.8a	2.7c
Manganese	6.4f	20.3b	40.4a	13.8e	18.0c	15.3d	6.1f
Copper	0.3b	0.4a	0.4a	0.4a	0.4a	0.4a	0.4a
Iron	5.3c	6.4b	8.2a	5.0c	5.1c	6.5b	5.0c
Nickel	0.14b	0.11b	0.15ab	0.12b	0.15ab	0.21a	0.12b
Lead	1.8b	3.5a	2.2b	1.9b	2.0b	1.8b	1.8b
Cadmium	0.12b	0.12b	0.11b	0.15ab	0.15ab	0.20a	0.11b
Chromium	0.19b	0.16b	0.20b	0.18b	0.20b	0.28a	0.16b
Aluminum	7.2b	7.2b	8.2a	6.9b	6.8b	6.5b	7.2b
pH	7.1d	7.4c	7.6b	7.5c	7.5c	7.7a	7.2d
CEC (meq/100g)	23.4f	28.1e	34.2c	29.8d	35.7b	37.3a	23.4f

Abbreviations: BM, base medium with Compost A; RD, basalt dust; GD, glacial moraine dust.

Mineral fine level 1 = 60 g L^{-1}; and level 2 = 120g L^{-1}.

Compost B was made with basalt fines added at initiation of composting.

Means followed by different letters in rows are significantly different by Duncan's multiple range test ($P \leq 0.05$).

All treatments except number 7 received 0.5 g N per container weekly as ammonium nitrate throughout the experiment. Plants were watered daily. Treatments were arranged in four randomized complete blocks. Tomato plants were transplanted to the media on June 13, 1997. Samples of the media were taken on June 9, 1997 (before planting) and at the final harvest of fruits on October 17, 1997. Media were

TABLE 4. Extractable plant nutrients from media at start of experiment and at last harvest of tomatoes.

Element	Time of sampling	
	Beginning	End
	----------mg/liter----------	
Ammonium-N	6	9*
Nitrate-N	63	9*
Phosphorus	268	160*
Potassium	970	89*
Calcium	3,336	3,229*
Magnesium	626	540*
Boron	2.7	0.8*
Zinc	3.1	3.0ns
Manganese	20.0	13.9*
Copper	0.4	0.3*
Iron	6.4	5.7*
Nickel	0.12	0.16ns
Lead	1.8	2.3ns
Cadmium	0.13	0.15ns
Chromium	0.21	0.18ns
Aluminum	7.0	7.3ns

*Means significantly different from beginning (before planting, June 9, 1997) to end of experiment (final harvest, October 17, 1997).
nsMeans are not significantly different.

extracted with universal soil extracting solution (100 g sodium acetate trihydrate L^{-1} adjusted to pH 4.7) and analyzed by plasma absorption spectrophotometry for P and metallic elements, by Kjeldahl procedures for N, and by colorimetry for nitrate and ammonium (Council on Soil Testing and Plant Analysis, 1980). Acidity was determined electrometrically on a 2:1 water:soil (w:v) extract.

Mass and numbers of fruits were recorded for 16 harvests. Caliper diameters of stems between the 4th and 5th node were measured on July 7 and on July 21, 1997, as an indication of growth before fruiting began. The first and second fully expanded leaves from the tips were taken on August 14, 1997, a time of intense fruiting, for tissue analysis.

All data were processed by analysis of variance (Steel and Torrie, 1980).

TABLE 5. Initial (I) and final (F) concentrations of extractable nutrients and nonessential elements, pH, and cation exchange capacity of various media used in tomato production.

Element	Sampling time	Media						
		1 BM	2 BM 1 RD	3 BM 2 RD	4 BM 1 GD	5 BM 2 GD	6 Compost B	7 BM No N
		mg/liter						
NH4-N	I	7.0	6.0	5.0	6.0	5.0	7.0	7.0
	F	9.0	8.5	6.5	8.5	8.0	13.5	10.8
NO3-N	I	66	61	64	67	74	40	63
	F	5.0	7.3	5.5	10.3	10.0	15.3	6.5
P	I	298	224	161	253	239	416	288
	F	158	121	92	166	169	240	142
K	I	973	891	873	896	952	1,291	914
	F	60	102	126	80	113	57	86
Ca	I	2,353	3,491	4,613	3,520	4,573	2,553	2,252
	F	2,317	3,312	4,423	3,388	4,311	2,535	2,313
Mg	I	619	629	616	610	636	690	586
	F	549	543	551	542	543	541	515
B	I	2.8	2.7	2.6	2.6	2.7	2.5	2.5
	F	0.83	0.88	0.93	0.90	1.00	0.78	0.50
Zn	I	2.7	3.1	3.5	3.0	3.1	3.7	2.7
	F	2.7	2.9	3.4	2.8	2.9	3.8	2.7
Mn	I	8.4	24.0	45.0	15.4	20.6	19.8	7.8
	F	4.5	16.6	35.8	10.2	15.5	10.8	4.3
Cu	I	0.37	0.43	0.50	0.40	0.43	0.43	0.37
	F	0.24	0.34	0.40	0.42	0.40	0.30	0.34
Fe	I	5.9	6.5	7.9	5.4	5.2	7.4	6.0
	F	5.0	6.4	8.3	4.7	5.0	6.0	4.4
Ni	I	0.10	0.10	0.13	0.10	0.13	0.20	0.10
	F	0.16	0.1	0.16	0.14	0.16	0.22	0.14
Pb	I	1.7	3.3	1.7	1.0	2.0	1.7	1.3
	F	1.8	3.6	2.6	2.4	2.0	1.8	2.0
Cd	I	0.13	0.13	0.10	0.10	0.13	0.20	0.10
	F	0.12	0.12	0.12	0.18	0.16	0.20	0.12
Cr	I	0.2	0.2	0.2	0.2	0.2	0.3	0.2
	F	0.18	0.14	0.20	0.16	0.20	0.26	0.14
Al	I	7.3	6.8	7.8	6.5	6.5	7.0	7.5
	F	7.3	7.8	8.8	7.3	7.0	6.0	7.0
pH	I	7.3	7.5	7.6	7.6	7.5	8.1	7.2
	F	7.0	7.4	7.6	7.4	7.5	7.3	7.1
CEC	I	23.9	29.1	34.6	30.4	36.3	39.7	23.7
(meq/100g)	F	22.9	27.2	33.9	29.2	35.1	34.9	23.1

Abbreviations: BM, base medium with Compost A; RD, basalt dust; GD, glacial moraine dust.

Mineral fine level 1 = 60 g L^{-1}; and level 2 = 120g L^{-1}. Compost B was made with basalt dust added at initiation of composting.

TABLE 6. Statistics for data in Tables 3, 4, and 5.

Element	Statistics			
	Results of analysis of variance			
	Media[a]	Time[b]	Time x media[c]	$LSD_{0.05}$[c] (TxM)
Ammonium-N	**	**	*	2
Nitrate-N	*	*	**	6
Phosphorus	**	**	**	16
Potassium	**	**	**	63
Calcium	**	**	ns	ns
Magnesium	**	**	*	33
Boron	**	**	ns	ns
Zinc	**	**	ns	ns
Manganese	**	**	**	1.9
Copper	**	**	ns	ns
Iron	**	**	**	0.62
Nickel	*	*	ns	ns
Lead	*	*	ns	ns
Cadmium	*	*	ns	ns
Chromium	*	*	ns	ns
Aluminum	**	**	*	1
pH	**	**	**	0.08
CEC (meq/100g)	**	**	ns	ns

*Significant, $P \leq 0.05$; **significant, $P \leq 0.01$; ns, nonsignificant, $P > 0.05$.
[a] See Table 3; [b] See Table 4; [c] See Table 5.

RESULTS AND DISCUSSION

Extractable Nutrients

Extractable nutrients varied with treatment, with extractable Ca being raised markedly by additions of basalt or glacial fines (Table 3). Extractable Mn was raised substantially also with additions of mineral fines. Other nutrients were affected significantly with additions of fines, but the magnitudes of the changes were small. Major differences occurred between nutrient concentrations at the beginning (before planting) and at the end of the experiment (final harvest) (Table 4). The trend was for the concentrations of nutrients to be lower at the end of the experiment than at the beginning. Nitrate varied significantly with time of sampling

TABLE 7. Elemental composition of leaf tissue of tomatoes grown in various media.

Element	Media						
	1 BM	2 BM 1 RD	3 BM 2 RD	4 BM 1 GD	5 BM 2 GD	6 Compost B	7 BM No N
	%, dry mass						
Nitrogen	1.84	1.77	1.82	1.84	1.97	1.87	1.87
Phosphorus	0.53b	0.48bc	0.41c	0.46bc	0.42c	0.70a	0.68a
Potassium	2.22	1.97	2.31	2.05	2.02	1.87	2.11
Calcium	3.60	4.08	3.50	3.78	4.00	3.85	4.15
Magnesium	0.78bc	0.81b	0.67c	0.69bc	0.74bc	1.01a	1.00a
	mg/kg, dry mass						
Zinc	17	18	13	14	20	18	14
Copper	13	13	14	13	15	13	14
Manganese	44	38	34	36	50	38	44
Iron	113	110	131	109	156	132	121
Boron	80	76	86	80	98	69	76
Molybdenum	12	11	14	12	16	7	13

Abbreviations: BM, base medium with Compost A; RD, basalt rock dust fines; GD, glacial moraine fines.

Mineral fine level 1 = 60g L^{-1}; and level 2 = 120g L^{-1}.

Compost B was made with basalt fines added at initiation of composting.

Means followed by different letters in rows are significantly different by Duncan's Multiple Range Test ($P \leq 0.05$).

from 63 mg N L^{-1} before planting to 9 mg N L^{-1} on the final date of harvest. These data indicate a near exhaustion of available N from the media even with N fertilization. A depletion of K occurred from the medium from 970 mg L^{-1} before planting to 89 mg L^{-1} at the final harvest. Extractable concentrations of P, Mg, and B were substantially lower at the end of the experiment than at the beginning, indicating some depletion of these nutrients. Extractable Ca, Fe, and Cu were only slightly lower at the end of the experiment than at the beginning. Extractable Zn and nickel (Ni) were unchanged with time as were the nonessential elements cadmium (Cd) and lead (Pb) (Table 4).

The effects of interactions of time (beginning and end) and media on concentrations of extractable macronutrients (except Ca) from the media were significant but small in magnitude (Tables 5 and 6). The effects of interactions of

TABLE 8. Caliper diameter of tomato stems grown on various media.

Treatment (media)	Date of measurement		
	July 7, 1997	July 21, 1997	Mean
	------------------------------cm------------------------------		
Base medium (BM)	1.05c	1.13d	1.18cd
BM 1RD	1.15bc	1.36ab	1.26bc
BM 2RD	1.35a	1.50a	1.42a
BM 1GD	1.25ab	1.45ab	1.35ab
BM 2GD	1.28ab	1.30bc	1.29bc
Compost B	1.02cd	1.15cd	1.09d
BM (No N)	0.88d	1.00d	0.94e
Mean	1.16	1.27*	

Abbreviations: BM, base media; RD, basalt rock dust fines; GD, glacial moraine fines. Mineral fine level 1 = 60g L^{-1}; and level 2 = 120g L^{-1}.
Compost B was made with basalt fines added at initiation of composting.
Tomatoes transplanted to media on June 13, 1997.
*Means of dates are significantly different ($P \leq 0.05$). Means followed by different letters in columns are significantly different ($P \leq 0.05$).

time and media on concentrations of extractable Mn, Fe, and Al were also significant but small. Extractable concentrations of other elements were not affected by the interaction. The interaction slightly affected media pH, but had no effect on CEC. In general, time had little effect on plant nutrition in interaction with the individual media.

Leaf Composition

Nitrogen and K concentrations in leaves were below the range for well-nourished plants and did not vary with any treatment (Mills and Jones, 1996) (Table 7). Tests of extractable nutrients indicated an exhaustion of available N and K from the media over the season (Table 4). The tomato foliage at times of the last harvests

Table 9. Fresh mass yields of tomato fruits from various media.

Medium	Yields		Average number of fruits per harvest
	Harvest mean	Total	
	---kg---		
Base medium (BM)	1.61a	25.78a	10.5a
BM 1RD	1.54ab	24.66ab	9.8ab
BM 2RD	1.50ab	23.97ab	9.5ab
BM 1GD	1.50ab	24.05ab	10.0a
BM 2GD	1.55ab	24.80ab	10.0a
Compost B	1.18b	18.96b	7.5b
BM (No N)	0.39c	6.18c	3.75c

Abbreviations: BM, base medium with Compost A; RD, basalt rock dust fines; GD, glacial moraine fines. Mineral fine level 1 = 60g L^{-1}; and level 2 = 120g L^{-1}.

Means followed by different letters in columns are significantly different by Duncan's Multiple Range Test ($P \leq 0.05$). Results are of 16 harvests over the season.

showed symptoms of nutrient deficiency, which based on tissue analysis were likely manifestations of N deficiency. Leaf Ca concentrations did not vary with treatment, but exceeded average concentrations considered adequate for tomato nutrition, indicating that the compost and mineral fines provided adequate Ca nutrition. Leaf concentrations of P and Mg varied with treatment and also indicated adequacy of these elements for tomato nutrition. On the basis of tissue and extract analyses, it appears that the mineral fines provided enough Ca, P, and Mg to prevent their being exhausted from the media, even with the heavy fruiting promoted by N fertilization (see growth and productivity in section below). Tissue analysis indicated that micronutrients were adequate for high productivity in all media except for Zn and Mn concentrations, which appear to be in the low range for adequate plant nutrition.

Plant Growth and Productivity

Early growth, verified by measurements of stem caliper, varied with treatment (Table 8). Mineral fines increased stem caliper above that obtained with the base medium alone. Largest calipers were with the base medium with basalt fines added at 120 g L^{-1}. Addition of glacial fines generally gave growth statistically as good as that with basalt. The lowest stem caliper was with the base medium with no N or fines added.

Fruit yields were the same among treatments with base medium and with N added, regardless of the type or amount or mineral fines added (Table 9). Yields in the compost made with basalt fines added at the initiation of composting were slightly below those in the compost made without mineral fines. The elemental composition of the composts does not indicate any factors that should affect the yields of crops grown in one compost or the other. However, possibly due to uncontrolled differences in feed stocks, the C:N ratio was slightly wider in the compost made with basalt fines. Nitrogen fertilization was the main factor affecting yields. The lowest yields were obtained with plants grown in the base medium without additions of N. Additions of N boosted yields, although leaf and media analyses indicated that more N fertilization than that added would have been beneficial in enhancing yields further (Mills and Jones, 1996).

CONCLUSIONS

Research with container-grown tomatoes showed an early stimulation of vegetative growth with additions of mineral fines. Fruiting of tomato was heavy in the containers to which N was added, with an average yield of about 23 kg of fruits per plant. Vegetative growth and fruiting exhausted the N and K from the medium. Tissue analyses indicated a deficiency of these elements in leaves. Neither the composts nor the additions of mineral fines or supplemental N fertilization met the nutritional requirements for N and K. Mineralization of compost was inadequate to provide N, and the concentration and dissolution of K from the mineral fines was not sufficient for K nutrition. Aggressive fertilization with these nutrients is needed to provide adequate nutrition to sustain the high yields of this experiment. The media provided adequate P, Ca, Mg, and most micronutrients to support the crop productivity recorded in this experiment. No detrimental effects from additions of the mineral fines were apparent.

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