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RESPONSE OF TOMATOES TO MICROIRRIGATION RATES, COMPOST PLACEMENT AND RATES, AND N AND K SOURCES

A. A. CSIZINSZKY AND C. D. STANLEY
Gulf Coast Research and Education Center
University of Florida, IFAS
Bradenton, FL 34203

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Abstract. **Tomatoes, cv. Florida 47, were grown in fall 1997 with the full-bed polyethylene mulch system with two microirrigation rates: 1.0× open pan evaporation (PE) and 0.6× PE; two compost placements: banded or broadcast on the pre-bed; two N and K sources: 100% liquid or 30% pre-plant dry + 70% liquid; and four compost rates: 0, 1×, 2×, and 3× [1× = 5 ton/acre (Acre = 8712 linear bed ft)]. Phosphorus, from a 0-8.74-0 (N-P-K) superphosphate, was banded on the top of the compost layer at 30.5 lb/acre in the 30% pre-plant dry + 70% liquid fertilized plots only. Plants were tallest ($P \leq 0.05$) with the 30% dry + 70% liquid fertilizer treatment. Plant heights increased linearly ($P \leq 0.05$) with compost rates. Early yields were higher with 1.0× PE irrigation and 5 or 10 ton/acre compost than 0.6× PE irrigation and 15 ton/acre compost. Early yields with 30% pre-plant dry + 70% liquid fertilizers with 0 compost were higher than dry + liquid fertilizers and 15 ton/acre compost, or 100% liquid fertilizers and 0 compost. Seasonal total yield was best with 0.6× PE irrigation and 10 ton/acre compost and 30% pre-plant dry + 70% liquid fertilizers and 10 ton/acre compost. Residual concentrations of P, K, Mg, and Fe were very high in the soil treated with compost.**

Introduction

The light sandy soils in west-central Florida have low cation-exchange and water-holding capacity and less than 2% organic matter (U.S. Dept. of Agriculture, 1980). The application of organic amendments, therefore, would improve water-holding capacity and the retention of nutrients in the soil (Parr and Wilson, 1980). In greenhouse studies however, low compost rates (≤14 ton/acre) required added fertilizers for satisfactory growth of turnip and radish because of tie-up of nitrogen (Hortenstine and Rothwell, 1969). In field studies, large quantities (60 ton/acre) of municipal solid waste (MSW) compost did not result in an increased yield of bell peppers in the fall due to the immature state of the compost (Clark et al., 1995). In the spring, however, tomatoes with a ripe MSW compost plus inorganic pre-plant N fertilizer had greater yields of extra-large and marketable fruit than tomatoes with inorganic N-fertilizer alone. In other studies in Florida, composts have delayed emergence of vegetable seedlings (Roe et al., 1997a) and early growth of tomatoes after transplanting in the field (Csizinszky, 1998a and 1998b).

Studies were initiated, therefore, to investigate the feasibility of using small quantities of compost in the plastic mulched beds with microirrigation for tomato production and to measure the macro and microelemental concentrations in the soil, tomato shoots, and tomato fruits.

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Materials and Methods

The study was conducted during the summer-fall-winter (Aug. 1997-Jan. 1998) at the Gulf Coast Research and Education Center, Bradenton, FL. Soil was an Eau Gallie fine sand (USDA 1980) and the production system was the full-bed polyethylene mulch with micro- (trickle) irrigation. Soil samples, collected before land preparation, were extracted by the saturated paste method (Geraldson, 1967) and pH and total soluble salts (TSS) were determined on the extract. Nitrogen was determined by the Kjeldahl method with the Kjeltic system (Tecator, Inc., 1987) and other elements on the Mehlich-1 extract (Hanlon et al., 1990). The soil had a pH of 6.15 and (in ppm) 952 TSS, 0.3 NH_4-N, 1.6 NO_3-N, 28.9 P, 11.3 K, 538.0 Ca, 84.0 Mg, 25.0 Al, 2.8 Cu, 6.5 Fe, 3.0 Mn, and 7.5 Zn.

The experimental design was a split-split-split plot, arranged in a randomized complete block with three replications. Main plots, each 200-ft long and 10-ft wide, established on 32-inch wide and 8-inch high beds formed 5-ft center to center spacing, were two irrigation rates 1.0× (HI) and 0.75× (LO) the previous day's open pan evaporation (PE). Subplots, each 200-ft long and 5-ft wide were two compost placements: banded (BA) or broadcast (BR). Sub-sub plots, each 100-ft long and 5-ft wide, were two pre-plant dry fertilizer treatments: N-P-K were either applied (FE) or not applied (NF) to the plots. Sub-sub-sub plots each 25-ft long and 5-ft wide were four compost rates: 0×, 1×, 2×, and 3× (where 1× = 5 ton/acre) (acre = 8712 linear bed ft).

The compost source was a Disney World compost (NutriSource, Inc., Orlando, FL) (Table 1) that was applied either in a 6- to 10-inches wide band in the center of the pre-beds, or broadcast in the full-width of the pre-beds. Next, a 0-8.74-0 (N-P-K) analysis superphosphate at 30.5 lb per acre P was applied in a 3-4 inches wide band in the bed center in the FE sub-sub plots. The superphosphate also contained micronutrients as F503, that provided (in lb per acre) 1.2 B, 1.2 Cu, 7.2 Fe, 3.0 Mn, 0.1 Mo, and 2.8 Zn. Beds were formed and the microirrigation tube (T-tape, 8-in emitter spacing, 0.67 gpm at 8 psi) was laid in the bed center in a narrow, 2-inches deep furrow. Above the irrigation tube a 15-0-24.9 (N-P-K) analysis fertilizer that supplied N at 88 and K at 145 lb per acre (each 33% of the season's total) was banded in the FE sub-sub plots. The remaining amounts of N, 174 lb per acre, and K, 286 lb per acre, were injected through the trickle tubing during the season from a 5-0-8.3 (N-P-K) liquid source derived from NH_4NO_3 and KNO_3. The NF sub-sub plots received N at 174 and K at 286 lb per acre from the liquid source only during the season.

Soil was fumigated with 66.3% methylbromide and 33.3% chloropicrin then covered with a white-on-black 0.032 mm thick polyethylene film. Five-week old 'Florida 47' tomato seedlings were planted on 27 Aug., 1997 in holes punched through the plastic mulch, in a single row at 18-inch plant spacing (5808 plants per acre). Soil moisture in the beds was

Table 1. Concentration of selected elements in 'Disney World' compost and their amounts applied for tomatoes from the compost.

Element		Compost applied (T/A)[y]		
		5	10	15
	%DW[z]		lb/A	
N	3.40	165	330	495
P	1.87	91	182	273
K	0.89	43	86	129
Ca	2.10	102	204	306
Mg	0.34	16	32	48
	ppm DW[z]			
B	37.0	0.18	0.36	0.54
Cu	251.0	1.21	2.42	3.63
Fe	8850.0	42.83	85.7	128.5
Mn	232.0	1.12	2.24	3.36
Mo	14.0	0.07	0.14	0.21
Zn	232.0	1.12	2.24	3.36
Al	2650.0	12.83	25.66	38.50
As	0.40	0.002	0.004	0.006
Ba	63.0	0.30	0.60	0.91
Cd	1.0	0.005	0.010	0.0145
Cr	2.30	0.011	0.022	0.033
Hg	0.05	0.0002	0.0004	0.0007
Ni	20.0	0.097	0.194	0.290
Pb	18.0	0.087	0.174	0.261
Si	911.0	4.41	8.82	13.23

[z]Moisture: 51.6%.
[y]Acre: 8712 linear bed ft.

Table 2. Main effects of irrigation rates, compost placement methods, pre-plant fertilizer applications, and compost rates on tomato plant heights.

	Days after planting		
	22	47	68
		cm	
Irrigation[z]			
HI	29.2	77.4	94.9
LO	30.4	84.7	104.5
$LSD_{0.05}$[y]	ns	ns	ns
Compost placement[x]			
Banded	29.9	81.5	99.9
Broadcast	29.7	80.6	99.5
$LSD_{0.05}$[y]	ns	ns	ns
Pre-plant fertilizer[w]			
FE	30.2	85.0	106.6
NF	29.4	77.2	92.8
$LSD_{0.05}$[y]	ns	2.5	6.3
Compost rates (T/A)[v]			
0.0	26.9	71.8	86.7
5.0	30.9	80.1	95.5
10.0	31.2	85.5	105.3
15.0	30.2	86.9	111.2
Signif.[u]	L*Q*	L*Q*	L*

[z]Averaged over two compost placements, two pre-plant fertilizer applications, four compost-rates and three replications.
[y]LSD is significant at $P \leq 0.05$, or non-significant (ns).
[x]Averaged over two irrigation rates, two pre-plant fertilizer applications, four compost rates, and three replications.
[w]Averaged over two irrigation rates, two compost placements, four compost rates, and three replications.
[v]Averaged over two irrigation rates, two compost placements, two pre-plant fertilizer applications and three replications.
[u]Significance is linear (L), quadratic (Q), or non-significant at $P \leq 0.05$.

monitored by tensiometers (Irrometer Co., Riverside, CA) placed at 6-inches depth. Pesticides, labeled for tomatoes, were applied weekly. Tomato plants were pruned by removing the first two or three adaxial shoots and trellised. Soil samples for determination of pH, TSS, and macro- and microelements were taken 14 and 139 days after planting. Dry matter and elemental concentrations on recently matured young compound leaves were determined at 48 and at 139 days after planting and on fruits at harvest (AOAC, 1980; Hanlon and deVore, 1989). Fruits were harvested on 17 and 25 Nov., 8, 18, 29, Dec. 1997, and 5 Jan. 1998. Fruits were separated into marketable and cull (USDA, 1981), then marketable fruits were size-graded as extra-large (≥2.75 inch diameter), large (2.50-2.78 inch), and medium (2.25-2.53 inch), counted and weighed. Data were analyzed using ANOVA procedure (SAS Institute, 1988) and, when F values were significant, a regression analysis was performed on the compost rates.

Results

During the 130-day long season 35.1 inch of rain and 15.0 inch of PE was recorded at the GCREC-Bradenton. The tomato crop received 14.4 inch water in the HI and 10.4 inch water with the LO irrigation rate. Irrigation rates and compost placements had no significant effect on plant heights (Table 2). Plants were taller with pre-plant dry fertilizers ($P \leq 0.05$) and with increasing compost rates.

Early yields were similar with the two irrigation rates, compost placements, and pre-plant fertilizer applications, but increased quadratically with compost rates (Table 3). Both extra-large and marketable fruit yields were similar with 5 or 10 ton/acre and lower with 0 and 15 ton/acre compost rates. Season's total yields were greater with pre-plant dry + injected liquid, than with liquid fertilizer alone ($P \leq 0.05$). Extra-large and marketable total yields for the season increased linearly ($P \leq 0.01$) with increasing compost rates (Table 3). The interaction of irrigation and compost rates and the interaction of pre-plant fertilizer application and compost rates affected early and seasonal fruit yields (Table 4 and 5). Early yields of extra-large fruits were higher with HI irrigation and 5, 10 or 15 ton/acre compost than with LO irrigation and 15 ton/acre compost (Table 4). Marketable yields in the early harvest were also higher with HI irrigation and 5 or 10 ton/acre compost, than with LO irrigation and 15 ton/acre compost. For the season, the highest yields of extra-large and marketable fruits were recorded with the LO irrigation and 10 ton/acre compost (Table 4). However, yields with HI or LO irrigation and 15 ton/acre compost were similar to that yield ($P \leq 0.05$).

The early yields of extra-large and marketable fruits with the interaction of pre-plant fertilizer application and compost rates were highest with the pre-plant dry fertilizer application and no compost and lowest with no pre-plant dry fertilizers and no compost, or with pre-plant dry fertilizers and 15 ton/acre compost (Table 5). Seasonal total yields of extra-large and marketable fruits were best with pre-plant dry fertilizers and 10 ton/acre compost. Similar yields of extra-large and marketable fruits for the season were also recorded with or without pre-plant dry fertilizers at the 15 ton/acre compost rate (Table 5).

Tomato yields with all other interactions were similar (data not presented). In the shoots and in the fruits, the compost rates had the greatest effect on macro- and microelemental concentrations. Other variables, irrigation rates, compost placements and pre-plant dry fertilizer application, had little or no effect on the elemental concentrations. There were no apparent nutrient deficiency symptoms on the plants during the season with any of the four treatment combinations.

Table 3. Main effects of irrigation rates, compost placement methods, pre-plant fertilizer applications, and compost rates on tomato yields.

	Early yield				Season's total yield			
	xlg	mkt	cull	mkt + cull	xlg	mkt	cull	mkt + cull
				25-lb ctn/A[z]				
Irrigation[y]								
HI	446	489	105	595	1738	2273	843	3116
LO	375	409	92	501	2080	2696	948	3644
$LSD_{0.05}$[x]	ns	ns	ns	ns	ns	ns	ns	ns
Compost placement[w]								
Banded	402	441	101	542	1936	2504	900	3403
Broadcast	419	457	96	553	1882	2465	892	3357
$LSD_{0.05}$[x]	ns	ns	ns	ns	ns	ns	ns	ns
Pre-plant fertilizer[v]								
FE	430	465	98	563	2148	2815	967	3782
NF	390	433	99	532	1669	2153	824	2978
$LSD_{0.05}$[x]	ns	ns	ns	ns	217	222	134	344
Compost rate (T/A)[u]								
0.0	377	417	93	510	1433	1831	747	2578
5.0	445	490	117	609	1847	2319	840	3159
10.0	441	478	104	581	2145	2784	974	3758
15.0	378	412	79	491	2209	3004	1021	4025
Signif.[t]	Q**	Q**	Q**	Q**	L***	L***	L***	L***

[z]Acre = 8712 linear bed ft; 5808 plants.
[y]Yields averaged over two compost placements, two pre-plant fertilizer applications, four compost rates and three replications.
[x]LSD is significant at $P \leq 0.05$, or non-significant (ns).
[w]Yields averaged over two irrigation rates, two pre-plant fertilizer applications, four compost rates, and three replications.
[v]Yields averaged over two irrigation rates, two compost placements, four compost rates, and three replications.
[u]Yields averaged over two irrigation rates, two compost placements, two pre-plant fertilizer applications, and three replications.
[t]Significance is linear (L) or quadratic (Q) at $P \leq 0.05$.

Table 4. Interaction of irrigation and compost rates on tomato yields.

		Early yield				Season's total yield			
Irrigation[z]	Compost rate (TA)	xlg	mkt	cull	mkt. + cull	xlg	mkt	cull	mkt. + cull
					25-lb ctn/A[y]				
HI	0.0	396	441	95	535	1209	1567	678	2245
	5.0	466	521	123	643	1594	2043	789	2832
	10.0	477	519	112	631	1886	2452	931	3383
	15.0	444	477	89	566	2264	3028	974	4002
LO	0.0	358	394	91	484	1658	2095	816	2911
	5.0	424	460	112	572	2102	2595	891	3486
	10.0	410	436	96	531	2404	3116	1018	4133
	15.0	313	347	69	416	2154	2980	1067	4047
$LSD_{0.05}$		129	137	30	154	374	419	146	517

[z]Irrigation: HI = 1.0× pan evaporation; LO = 0.75× pan evaporation.
[y]Yields averaged over two compost placements, two pre-plant fertilizer applications and three replications.

Table 5. Interaction of pre-plant fertilizer application and compost rates on tomato yields.

		Early yield				Season's total yield			
Pre-plant fertilizer application	Compost rate (T/A)	xlg	mkt	cull	mkt. + cull	xlg	mkt	cull	mkt. + cull
					25-lb ctn/A[z]				
FE [y]	0.0	499	548	113	661	1736	2144	776	2919
	5.0	482	524	119	643	2215	2765	911	3676
	10.0	418	439	91	530	2438	3204	1086	4290
	15.0	322	350	69	419	2205	3149	1095	4243
NF [x]	0.0	255	286	73	359	1131	1518	716	2237
	5.0	409	457	116	573	1481	1873	769	2642
	10.0	464	516	116	632	1852	2363	863	3226
	15.0	435	473	89	562	2213	2859	947	3806
$LSD_{0.05}$		119	125	29	141	342	364	138	449

[z]Yields averaged over two irrigation rates, two compost placements, and three replications.
[y]FE = plots received N-P-K from dry fertilizers prior to planting.
[x]NF = plots did not receive N-P-K from dry fertilizers prior to planting.

Table 6. Seasonal variation of dry matter and macroelement concentrations in tomato shoots grown in compost-amended soil.

Compost rate (T/A)	DM	Element				
		N	P	K	Ca	Mg
	%					
48 days after planting[z]						
0.0	12.01	4.10	0.37	4.14	1.95	0.64
5.0	11.70	4.15	0.50	4.24	1.92	0.65
10.0	11.58	4.21	0.56	4.45	1.82	0.63
15.0	11.33	4.57	0.61	4.74	1.80	0.67
Signif.[y]	L*	L*	L*Q*	L*	L*	ns
139 days after planting[z]						
0.0	10.73	3.18	0.20	4.03	3.05	0.62
5.0	10.30	3.30	0.29	3.98	2.56	0.49
10.0	10.24	3.31	0.36	3.81	2.86	0.52
15.0	10.00	3.35	0.39	3.83	3.07	0.57
Signif.[y]	L*	ns	L*Q*	ns	Q**	Q**

[z]Averaged over two irrigation rates, two compost placements, two pre-plant N-P-K rates, and three replications.
[y]Significance is linear (L) or quadratic (Q) at P ≤ 0.05, or non-significant (ns).

In the shoots, dry matter content decreased linearly with increasing compost rates at both sampling dates (Table 6). At 48 days after planting (DAP), N, P and K concentrations increased while Ca decreased as compost rates increased. At the end of the season (139 DAP), P concentrations increased linearly and quadratically with increasing compost rates. Calcium and Mg concentrations in the shoots were higher at 0 and 15 ton/acre than at 5 or 10 ton/acre compost rates (Table 6).

There were small, but significant differences in shoot microelement concentrations with the compost rates (Table 7). At 48 DAP, Al and Cu concentrations decreased with increasing compost rates. At the end of the season (139 DAP) Fe concentrations in the shoots increased and Zn concentrations decreased with increasing compost rates. Aluminum, Cu and Mn concentrations were higher with 0 and 15 ton/acre than with 5 or 10 ton/acre compost.

In the fruits there were small but significant differences in macro- and microelement concentrations with compost rates (Table 8). Phosphorus, K, Ca and Mn increased and N, Mg and B decreased with increasing compost rates. Copper and Zn concentrations were highest with 0 or 15 ton/acre compost. Aluminum concentrations were very high in the fruits with or without compost.

The soil macro- and microelements increased linearly with increasing compost rates (Table 9 and 10). At the end of the season (139 DAP) very high concentrations of P, K and Mg were detected in the soil samples from all compost-treated plots, and medium to high K concentrations in the plots which received 10 and 15 ton/acre compost, respectively. Among the micronutrients, high concentrations of Fe and Al remained in the soil in the compost treated plots.

Discussion

In this study, the beneficial effect of 5 or 10 ton/acre compost, combined with the pre-plant applied dry fertilizers, over the control plots was realized only in the season's total yields. Tomato fruit prices early in the season are usually higher than late season prices. Therefore, the added cost of compost may not be economical for the tomato growers.

Early yields, except with 15 ton/acre compost, were similar with HI or LO irrigation rates. Seasonal total yields, however, with or without compost application, were higher at the LO than at the HI irrigation rate. The similar early season yields and higher seasonal total yields at the LO (0.6× PE) than at the HI (1.0× PE) irrigation rate are important for the tomato industry, since water allotments for agricultural uses in Florida may be reduced in the near future by the regulatory agencies.

The high residual concentrations of P, K, Ca, Mg, and Fe in the soil after the harvest point out the problems of using compost as a soil amendment. There is little or no control over the amounts of fertilizer elements that are applied for the crop from the compost. For example, in our study, the amount of residual soil P at the very low, 5 ton/acre compost rate should be sufficient for 4 or 5 more tomato crops. The danger exists, therefore, that some of the macro and microelements that are not used by the crop and remain in the soil will be leached into

Table 7. Seasonal variation of microelement concentrations in tomato shoots grown in compost- amended soil.

Compost rate (T/A)	Element				
	Al	Cu	Fe	Mn	Zn
	ppm				
48 days after planting[z]					
0.0	26.0	89.2	71.5	65.1	47.8
5.0	26.5	103.4	65.0	78.1	48.1
10.0	22.9	62.8	66.7	73.0	46.3
15.0	19.4	46.6	68.1	69.2	49.9
Signif.[y]	L*Q*	L*Q*	ns	Q*	ns
139 days after planting[z]					
0.0	55.0	176.7	75.8	97.0	35.8
5.0	43.8	134.7	78.1	59.4	28.1
10.0	46.3	146.0	85.4	72.8	27.0
15.0	53.1	162.4	94.3	82.0	27.1
Signif.[y]	Q*	Q*	L*	Q*	L*Q*

[z]Averaged over two irrigation rates, two compost placements, two pre-plant N-P-K rates, and three replications.
[y]Significance is linear (L) or quadratic (Q) at P ≤ 0.05 or non-significant (ns).

Table 8. Dry matter and elemental concentrations in the tomato fruit as affected by compost rates.[z]

Compost rate (T/A)	DM	Element				
		N	P	K	Ca	Mg
		%				
0.0	4.89	2.96	0.45	5.15	0.24	0.26
5.0	4.88	2.80	0.57	5.22	0.26	0.25
10.0	4.84	2.70	0.63	5.25	0.26	0.24
15.0	4.96	2.76	0.65	5.45	0.26	0.24
Signif.[y]	ns	L*	L*Q*	L*	L*	L*
	Al	B	Cu	Fe	Mn	Zn
	ppm					
0.0	275.00	17.67	17.17	52.06	14.81	32.00
5.0	289.80	16.23	15.52	53.31	15.25	29.85
10.0	284.60	15.48	15.23	53.46	16.04	30.04
15.0	311.70	15.63	16.13	54.83	16.31	30.75
Signif.[y]	ns	L*	Q*	ns	L*	Q*

[z]Averaged over two irrigation rates, two compost placements, two pre-plant N-P-K rates, and three replications.
[y]Significance is linear (L) or quadratic (Q) at P ≤ 0.05 (*) or non-significant (ns).

Table 9. Seasonal variation of pH, electrical conductivity and macroelement concentrations in the compost-amended soil.

Compost rate (T/A)	pH	TSS	Macroelement NH_4-N	NO_3-N	P	K	Ca	Mg
			ppm					
Pre-plant	6.15	952	0.3	1.6	28.9	11.3	538.0	84.0
	14 days after planting[z]							
0.0	5.93	956	1.17	7.23	39.0	55.0	553.0	87.0
5.0	5.89	1128	2.03	10.61	89.0	73.0	662.0	100.0
10.0	5.90	1492	2.87	15.43	144.0	103.0	753.0	118.0
15.0	5.89	1975	4.74	19.31	248.0	172.0	1055.0	169.0
Signif.[y]	ns	L*	L*	L*	L*	L*	L*	L*
	139 days after planting[z]							
0.0	6.31	455	0.69	1.92	52.0	21.0	659.0	90.0
5.0	6.24	610	0.97	2.08	168.0	33.0	935.0	116.0
10.0	6.21	764	1.05	2.23	283.0	51.0	1224.0	146.0
15.0	6.17	1001	1.24	2.58	387.0	85.0	1508.0	191.0
Signif.[y]	ns	L*	L*	L*	L*	L*	L*	L*

[z]Table 10. Seasonal variation of microelement concentrations in the compost-amended soil.

Compost rate (T/A)	Element Al	Cu	Fe	Mn	Zn
Pre-plant	25.0	2.8	6.5	3.0	7.5
	14 days after planting[z]				
0.0	25.6	2.6	6.5	3.5	7.6
5.0	30.7	2.9	19.5	6.8	9.5
10.0	37.3	2.5	34.2	11.3	11.1
15.0	49.1	2.7	51.0	19.6	14.4
Signif.	L*	ns	L*	L*	L*
	139 days after planting[z]				
0.0	29.2	4.5	16.2	5.6	8.8
5.0	44.6	4.9	66.1	12.2	12.0
10.0	58.1	3.9	100.1	18.7	13.4
15.0	72.1	3.8	117.0	25.7	16.6
Signif.	L*	L*	L*	L*	L*

[z]Averaged over two irrigation rates, two compost placements, two pre-plant N-P-K rates, and three replications.
[y]Significance is linear (L) at $P \leq 0.05$ (*) or non-significant (ns).

the aquifer. Studies are under way to utilize the residual nutrients in the compost-amended soil by planting several crops in sequence without additional fertilizers.

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