Stand deficiencies of up to 30% did not affect total or early marketable weight and fruit size of bell pepper grown on polyethylene-mulched beds during 3 years of testing. Even during years of low production due to less than favorable climatic conditions, stand deficiencies did not significantly decrease marketable fruit weight and size. Replanting 10% to 30% stand-deficient plots to complete 100% stands did not significantly improve marketable yield per acre or fruit size.

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Composted Poultry Litter as Potting Media does not Affect Transplant Nitrogen Content or Final Crop Yield

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ADDITIONAL INDEX WORDS. vegetable, fertilizer

SUMMARY. The use of composted waste materials as an alternative source of potting media has received much interest in recent years. Our objective was to incorporate composted, ground poultry litter into a standard greenhouse potting mix, and evaluate the effect of the poultry litter on vegetable transplants grown in the greenhouse and transplanted to the field. Treatments consisted of potting mixes of 100% potting media or 50/50 media/poultry litter. Collards (*Brassica oleracea* L. var. *acephala* DC.), broccoli (*Brassica oleracea* var. *italica* Plenck.), cabbage (*Brassica oleracea* L. var. *capitata* L.) and three tomato (*Lycopersicon esculentum* Mill.) cultivars were utilized as test crops. A nutrient solution treatment of 8 oz of 8N-11P-7K fertilizer or 8 oz of water was added when transplants were set in the field. Plant weight and nitrogen content were measured weekly during the greenhouse production stage, and final crop yield was recorded at harvest. Any effect from the inclusion of poultry litter in the potting media on cole crop (collards, broccoli, cabbage) transplant dry weight had disappeared by the fourth week of sampling in the greenhouse, and final yield of cole crops was unaffected by either type of

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potting mix or presence or absence of starter nutrient solution. Dry weight of tomato transplants was not affected by type of potting media. Differences in tomato yield due to type of potting mix were observed, as plots with transplants grown in the 50/50 mix had greater nonmarketable yields ('Bonnie' and 'Big Boy'). Yield of 'Big Boy' tomato was increased by the addition of starter nutrient solution. It appears that composted, uniformly prepared waste materials are suitable for production of vegetable transplants.

Five billion broiler chickens are produced yearly in the southern United States; nearly 80% of the nation's broiler chickens (USDA-NASS, 1993). From 1983 to 1992 the number of broiler chickens in the United States has increased by 65 percent (USDA-NASS, 1993). Because of this enormous increase in poultry production, outlets for environmentally safe disposal of poultry litter (a mixture of chicken excreta and bedding material) have become important. Because limited pasture and agricultural fields are available for land disposal of litter, use of poultry litter for potting media is an option that shows promise. Fresh broiler litter has fertilizer value (Stevenson et al., 1990), but its odor and heterogeneous composition (sawdust, feathers, wood chips, etc.) make it an undesirable potting material. Composted poultry litter may make suitable potting mate-

Table 1. pH, soluble salts and nutrient content of 50 poultry litter : 50 media mix and Fafard growing medium.

Element	50:50 ²	100 ²
pH		5.80
5.48		
Soluble salts		
(mg·kg ⁻¹)	2450	840
P (ppm)	177	20
K (ppm)	702	107
Mg (ppm)	110	66
Ca (ppm)	143	75
Fe (ppm)	2500	150
Mn (ppm)	255	166
Zn (ppm)	150	60
Cu (ppm)	175	50
Al (ppm)	1500	---
N (%)	1.32	1.40

²50:50 = 50 poultry litter : 50 Fafard medium; 100 = 100% Fafard medium.

rial, as composting reduces odor and subsequent grinding and sieving provide a more uniform product than fresh litter.

Composted broiler litter was an effective potting substrate component for lettuce when mixed with commercial potting media (Flynn et al., 1995). There was no evidence of problems due to metal or nutrient accumulation, although broiler litter compost containing pine bark required lime to reach optimal pH for lettuce production.

Since composted broiler litter has been shown to be a suitable potting mix for a greenhouse lettuce crop (Flynn et al., 1995), the material might also serve as a potting media for vegetable transplant production. Costs of transplant potting substrates such as peat moss, tree bark, and perlite are steadily increasing, and availability of some materials is declining (Pokorny, 1982; Wang and Pokorny, 1989). The objective of this research was to utilize a composted, ground poultry litter material in a commercial transplant production system and determine if it altered transplant size, transplant nitrogen content, or final crop yield.

Methods and materials

COMPOST PRODUCTION. The broiler litter compost was produced in an enclosed building at the Tennessee Valley Authority's Environmental Research Center, located in Muscle Shoals, Alabama. The compost was a mixture of pine sawdust and poultry litter mixed to produce an initial carbon to nitrogen ratio of 25:1. The moisture content of this mixture was adjusted to approximately 50% and maintained at this level throughout the active composting period. Compost mixing was performed with front end loaders and a compost turner,

with the mixture formed into a windrow of about 150 tons with a height of 6 feet and a width of 7 feet. Daily oxygen and temperature readings were taken, and the windrow was turned daily or whenever oxygen readings were less than 5%. Temperatures of the compost were between 120 and 150 °F for about three months, and gradually declined to between 80 and 120 °F during the next 4 months. Compost utilized for this research project was started in Jan. 1992, and passed through a 6 mesh sieve before use in 1995.

GREENHOUSE TRANSPLANT PRODUCTION. This study was conducted in 1995 with three cole crops: collards, broccoli, and cabbage, and three tomato cultivars. Plants were grown in commercial plastic-covered greenhouses (Bonnie Plant Farms, Union Springs, Ala.) with transplant trays placed on the gravel floor. Ambient light was utilized, with maximum and minimum temperatures of 77 and 55 °F, respectively. Irrigation was supplied by hand-watering, as needed. Fertility was supplied once a week by watering with a 20N-4.4P-16K soluble fertilizer. About 8.2 mg N, 1.8 mg P and 6.7 mg K were applied to each transplant cell at each fertilizer application.

Transplants were grown in flats comprised of six '6-pack' cell trays. Each cell was 4.3 in. deep and 2.8 in. wide, a total volume of 32.9 in³ (water volume). Transplant trays were filled with either standard potting medium (Fafard-Buffalo Co., Charlotte, N.C.) or a 50/50 (by volume) mixture of Fafard and composted poultry litter. Fafard is a general-purpose growing substrate containing sphagnum peat, perlite, and vermiculite, and will be referred to as 'media' for the remainder of this paper. Analysis of the media

and 50/50 mix is provided in Table 1. Trays were filled with either the 50/50 mixture or media by greenhouse employees. A 1- to 2-day-old seedling of collard, cabbage, broccoli, or tomato was placed in each cell. Selected vegetable cultivars were: 'Packman' broccoli, 'Vates' collards, 'Bonnie' cabbage, and 'Rutgers', 'Bonnie' and 'Big Boy' tomatoes.

Collard, cabbage and broccoli were transplanted to individual cells on 19 Jan. 1995 and weekly sampling began one week later. One '6-pack' was considered a sample; 9 samples (54 plants) of plants grown in media and 50/50 mix were collected at each date. Sampling of collard, cabbage and broccoli transplants continued for 5 weeks, ending on 23 Feb. 1995 when plants were removed from the greenhouse to be transplanted in the field. The aboveground portion of each seedling was clipped and saved for fresh and dry weight determinations, and analysis for total N content. Total N content of the seedlings was determined via dry combustion techniques (Leco Corporation, St. Joseph, Mo.) (Bremner and Mulvaney, 1982).

Production, sampling, and N analysis of tomato transplants was as previously described for collard, cabbage and broccoli transplants. Tomato seedlings were planted by greenhouse employees on 16 Apr. 1995. Because of warm weather and quick growth of tomato seedlings, samples were collected only once (5 May 1995), and plants were removed for field transplanting immediately thereafter. Only dry weight of tomato transplants was measured.

FIELD PRODUCTION. Collard, cabbage and broccoli production was located at the E.V. Smith Horticultural Research Unit, near Shorter, Ala. Tomatoes were grown at the Chilton Area Horticultural Research Station, near Clanton, Ala. Soil type at E.V. Smith was a Norfolk fine sandy loam (Fine-loamy, siliceous, thermic Typic Paleudult) and soil type at Chilton was a Ruston fine sandy loam (Fine-loamy, siliceous, thermic Typic Paleudult). All crops were grown on 6-inch raised beds covered with black (cole crops) or white (tomatoes) polyethylene mulch, with drip irrigation installed (Twin-wall IV, 0.36-mm wall thickness, 0.23-m emitter spacing, Chapin Watermatics, Watertown, N.Y.). All plants were hand-transplanted in single

Table 2. Dry mass of collards, cabbage, and broccoli from sampling during greenhouse transplant production as influenced by medium.

Fall crop	Treatment	Dry mass (g)				
		Days from seeding				
		9	16	23	30	37
Collards	Medium	0.4 a ^z	0.8 a	2.3 a	3.4 a	4.4 a
	50/50	0.4 a	0.7 b	1.8 b	3.2 a	4.3 a
Cabbage	Medium	0.5 b	0.8 a	2.3 a	3.3 a	5.1 a
	50/50	0.6 a	0.8 a	2.0 a	3.2 a	4.0 a
Broccoli	Medium	0.5 a	0.9 a	2.4 a	3.4 a	4.7 a
	50/50	0.5 a	0.8 b	1.7 b	3.2 a	4.2 a

^aWithin each crop and date, potting mix comparison by mean separation by Duncan's multiple range test at $P < 0.05$.

Table 3. Yield and quality of 'Rutgers', 'Bonnie' and 'Big Boy' tomato as influenced by potting medium.

Variety	Potting mix	Grade						Total
		EM ²	ENM	LM	LNM	TM	TNM	
lb A-1								
Rutgers	50/50	1185 a ^y	1401 a	4800 a	5281 a	9819 a	9692 a	19,511 a
Rutgers	Medium	826 a	1161 a	3780 a	3978 a	6708 b	7394 b	14,102 b
Bonnie	50/50	5099 a	4728 a	7473 b	3807 a	27,786 a	12,282 a	40,068 a
Bonnie	Medium	3363 b	2420 b	13,185 a	3429 a	31,965 a	8739 b	40,704 a
Big Boy	50/50	1711 a	3381 a	4457 a	2257 a	15,163 a	10,563 a	25,725 a
Big Boy	Medium	1269 a	2454 a	6250 a	2234 a	15,345 a	8082 b	23,589 a

²EM = early marketable; ENM = early nonmarketable; LM = late marketable; LNM = late nonmarketable; TM = total marketable; TNM = total nonmarketable.

³Within each variety and grade, potting mix comparison by mean separation by Duncan's multiple range test at $P < 0.05$.

rows with a within-row spacing of 12 inches (collards), 18 inches (cabbage and broccoli), or 24 inches (tomato). Between-row spacing was 5 feet. Collards, cabbage and broccoli were transplanted on 24 Feb. 1995 and tomatoes were transplanted on 12 May 1995. Recommended Alabama production practices for cole crops and tomatoes were followed (Marvel, 1985).

Each field experiment was arranged as a 2×2 factorial of transplant potting mix (100% media or 50/50 media/poultry litter) and absence or presence of starter nutrient solution. Experiments at each location were arranged as a randomized complete block design with each crop or tomato cultivar as a separate environment. The starter nutrient solution treatment consisted of a 8 oz application of liquid fertilizer (8N-11P-7K) applied at the base of each transplant immediately after planting. Treatments not receiving starter nutrient received 8 oz of water. Each treatment was replicated 4 times, a total of 16 plots of each crop.

Four whole broccoli, collard and cabbage plants were sampled one week after planting, with samples removed from the ends of each plot. These samples were analyzed for total N. Samples of tomatoes one week after transplanting were not obtained due to wet weather. New fully expanded leaves of tomatoes were sampled on 25 Aug. 1995 after harvest was completed. These samples were analyzed for total N.

Tomatoes were pruned and staked following recommended production practices. All treatments received weekly injections of N (as NH_4NO_3 34-0-0) through the drip irrigation, a total season N rate of 130 lb A-1 for each crop. Additional irrigation was applied to maintain soil moisture at -0.2 to 0.25 bars, as indicated by soil tensiometers placed 6 inches deep in

each replication. Additional fertility (P, K, Ca, Mg), or lime was not applied, as soil tests indicated there were adequate amounts of these nutrients for crop growth and development (Adams et al., 1994).

Broccoli, collard and cabbage crops were harvested on 29 Mar., 25 Apr., and 5 May, respectively. Nonmarketable plants were left in the field. Nonmarketable cabbage were those plants with a head smaller than 5 inches and nonmarketable broccoli were those plants with a head smaller than 4 in. All collard plants were harvested. All tomatoes were harvested and separated into marketable and nonmarketable classes based upon damage to the fruit. Tomatoes were harvested 8 times throughout the growing season at about 3-day intervals, beginning 17 July and ending 10 Aug. Yields were analyzed as early, late, and total marketable and nonmarketable yields, with early yield consisting of the sum of the first three harvests and late yield the last three harvests. Nonmarketable tomatoes were those fruit smaller than 2 inches or those showing evidence of insect feeding, sun scald, or disfiguring disease.

Data were analyzed using analysis of variance techniques and means separation by Duncan's multiple range test, where appropriate (SAS, Cary, N.C.).

Results

WET AND DRY WEIGHTS OF TRANSPLANTS. There were no consistent differences in broccoli, cabbage or collard transplant fresh weight (not shown) or dry weight (Table 2) due to type of potting mix. When significant differences in transplant weight did exist, collards and broccoli grown in 100% medium had a greater weight, while cabbage grown in 100% medium weighed less. These differences only

appeared at early sampling dates. At 5 weeks after planting there were no differences in fresh or dry weight of cole crop transplants between types of potting mix. Tomato transplant dry weight did not differ due to potting mix, with an average total dry weight of 0.46, 0.27 and 0.59 g for 'Bonnie', 'Big Boy' and 'Rutgers', respectively.

Although transplant fresh and dry weight were largely unaffected, observation and discussion with greenhouse employees who hand-transplanted seedlings into the 50/50 mix revealed that the gritty texture of the poultry litter made transplanting a bit more difficult, and increased the soreness of their fingers. Thus, they were more likely to slow down when transplanting germinated seedlings into flats containing 50/50 mix. Time required to transplant each flat was not recorded, so data are not available to confirm these observations.

CROP YIELD—COLE CROPS. Neither starter nutrient solution nor type of potting mix affected final crop yield of cabbage, collard, or broccoli (data not shown). There was no significant nutrient solution $\times$ potting mix interaction. Average yield of collard, cabbage, and broccoli was 16,105, 23,717, and 488 lb A-1, respectively.

CROP YIELD—TOMATO CULTIVARS. When analyzed within each tomato cultivar, total yield of 'Big Boy' in treatments receiving starter nutrient solution was 23% higher than in treatments that did not receive starter nutrient solution (data not shown). Total nonmarketable, early marketable, and early nonmarketable yield of 'Big Boy' also had greater yields when starter nutrient solution was added at transplanting (data not shown). Starter nutrient solution did not affect marketable or nonmarketable yield of 'Rutgers' or 'Bonnie' tomatoes. There was

Table 4. Total N of collards, cabbage, and broccoli from sampling during greenhouse transplant production as influenced by potting medium.

Crop	Treatment	Days after seeding				
		9	16	23	30	37
		% N				
Collards	Medium	7.5 a	7.3 a	6.3 a	5.3 b	4.2 b
	50/50	6.7 b	6.5 b	6.5 a	6.3 a	5.5 a
Cabbage	Medium	6.4 a	6.5 a	4.9 b	4.6 b	3.5 b
	50/50	6.1 b	6.0 b	6.0 a	6.0 a	5.7 a
Broccoli	Medium	7.3 a	7.3 a	5.6 b	5.3 b	4.2 b
	50/50	6.9 b	6.8 b	6.4 a	6.6 a	5.9 a

^aWithin each crop and date, potting mix comparison by mean separation by Duncan's multiple range test at $P < 0.05$.

not a nutrient solution $\times$ potting mix interaction for any cultivar.

The presence of composted poultry litter in the transplant potting media significantly affected marketable or nonmarketable yield of all three cultivars at various harvest times (Table 3). Total yield of 'Rutgers' tomato was 5,340 lb A-1 higher when the transplant potting media contained poultry litter, a result of the higher yield in the total marketable portion of the harvest. Total yield and total marketable yield of 'Bonnie' and 'Big Boy' tomatoes were unaffected by the type of transplant potting mix. Total nonmarketable yield of 'Bonnie' and 'Big Boy' tomatoes was, on average, 3,026 lb A-1 greater when the transplant potting media contained 50% poultry litter.

When analyzed over all three tomato cultivars, neither nutrient solution or potting mix affected total tomato yields (data not shown). When separated into marketable and nonmarketable components, total marketable yield was not affected by nutrient solution or potting mix, but total nonmarketable yield was affected by both potting mix and nutrient solution. Tomato transplants grown in 50/50 potting mix had greater yields of nonmarketable fruit (10,875 lb A-1 vs. 8,071 lb A-1) than transplants grown in 100% media. Transplants receiving nutrient solution at transplanting also had more nonmarketable fruit than those transplants not receiving nutrient solution (10,486 vs. 8,460 lb A-1).

Guidelines for declaring nonmarketable fruit may be less applicable in this study, because selected tomato varieties for the study were homeowner varieties, and small size would not cause the same concern as to a commercial grower. Most tomatoes that

were classified as nonmarketable were placed into that category due to their size, and not because of disease.

PLANT NITROGEN. Total N content of transplants was affected by the type of potting media (Table 4). During the first two weeks of sampling, transplants grown in 100% media had more N than those grown in 50/50 mix. By the fourth week of sampling, all transplants grown in 100% medium contained less N than those grown in 50/50 mix. It is likely that N in the poultry litter may have been initially less available for crop uptake, and as N mineralization occurred it became available for crop uptake around the third week of the study. Differences in N content observed at the greenhouse were not observed one week after field planting, as neither potting mix or starter nutrient solution significantly affected whole plant N content of collard, cabbage or broccoli.

Nitrogen content of the 'Big Boy' and 'Rutgers' tomatoes as indicated by the single greenhouse sampling was not affected by the type of potting mix (data not shown). 'Bonnie' tomatoes grown in the 50/50 mix had 15% more N than those grown in 100% media (not shown). Neither potting mix or starter nutrient solution significantly affected N content of tomato leaves at harvest. Weekly additions of N fertilizer would likely have removed any residual differences due to starter nutrient solution or potting mix.

Conclusions

Greenhouse grown broccoli, collard, and cabbage transplants did not exhibit any differences in final fresh and dry weights due to differences in growth medium (100% media vs 50/50 poultry litter). Total N content of cabbage, collard, and broccoli one week after field planting were not affected

by type of potting mix or starter nutrient solution. Final yields of cabbage, collard, or broccoli were not affected by type of potting mix or application of starter nutrient solution.

There also were no differences in dry weight of greenhouse grown tomato transplants due to type of potting mix. Total and total marketable yields of tomato were generally unaffected by nutrient solution or potting mix. Where potting mix did affect tomato yield, nonmarketable yields increased when transplants were grown in 50/50 potting mix. The only response to nutrient starter solution was that 'Big Boy' tomatoes produced a greater total yield with starter nutrient solution than without.

It appears that composted, uniformly prepared waste materials are suitable for production of vegetable transplants. As many municipalities begin to compost large amounts of yard waste and other clippings vegetable transplant production facilities may be able to include these products in their potting mixes.

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