Growth Response and Mineral Uptake of Vegetable Transplants Grown in a Composted Sewage Sludge Amended Medium. I. Nutrient Supplying Power of the Medium[1]

A. Falahi-Ardakani,[2] J.C. Bouwkamp,[2] F.R. Gouin,[2] and R.L. Chaney[3]
Department of Horticulture
University of Maryland
College Park, MD 20742

Abstract

Six vegetable species, broccoli, cabbage, lettuce, eggplant, pepper, and tomato plants were grown for 8 wks on a medium of composted sewage sludge (compost), perlite, and peat (equal parts by volume). P, Ca, and Mg were adequate for the growing period, but accumulation of N and K did not increase after the 6th wk after transplanting. Cabbage and broccoli accumulated greater amounts of N and K from the medium and could be successfully grown in the medium without supplemental fertilization. Zn and Cd, potentially hazardous heavy metals present in compost, did not reach excessive levels for either plant nutrition or human consumption.

Index words: *Brassica oleraceae* botrytis L., 'Green Comet,' broccoli, *B. oleraceae capitata* L., 'Market Prize,' cabbage, *Capsicum annum* L., 'Yolo,' pepper, *Lactuca sativa* L., 'Summer Bibb,' lettuce, *Lycopersicon esculentum* Millo., 'Westover,' tomato, *Solanum melongena esculentum* L., eggplant, P, Ca, Mg, Mn, Fe, Zn, Cd

Introduction

The production of high quality vegetable transplants in containers requires a uniform, easily managed growth medium. To meet these requirements, numerous growth media have been investigated (3, 10). The ideal growth media for container culture should have excellent aeration, hold sufficient water, have a proper pH and good nutrient exchange capacity. One way to accomplish this is by using large amounts of organic matter in the medium (1). Sphagnum peat moss and milled pine bark are the major sources of organic matter used in formulating growth media and for amending soils. Cost of both materials continues to increase while their availability decreases. Because peat moss and pine bark are low in plant nutrients, horticulturists often use large quantities of fertilizers when using media containing these materials.

Compost made from sewage sludge and wood chips compost has been demonstrated to be an effective source of nutrient-rich organic matter that may be used for the production of limited numbers of horticultural crops. When properly screened, compost can be used as a partial substitute for peat moss in formulating potting mixes (5, 8, 9, 11, 12). Compost made from sewage sludge and wood chips has also been demonstrated as being capable of supplying all of the micro-nutrients needed for most pot crops to be grown to maturity (5, 8). Studies by Sterrett et al. (12) have also demonstrated that media amended with compost made from sludges of varying metal concentration can be used for starting vegetable transplants without affecting the quality of the edible portion of those vegetables when recommended agricultural practices are followed. The capacity of compost to provide a greater supply of mineral nutrients than most commonly used organic amendments suggests the

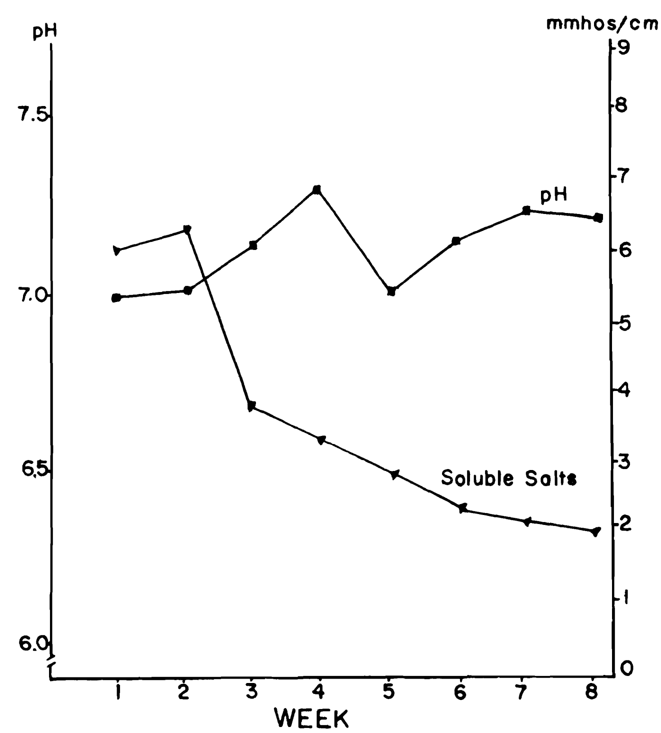


Fig. 1. **pH and soluble salt levels of the medium during the 8 wk growing period.**

[1]Received for publication October 29, 1986; in revised form March 30, 1987. Scientific Article No. A3564, Contribution No. 6639 of the Maryland Agricultural Experiment Station. This project was partially funded through a Cooperative Research agreement between the Department of Horticulture, University of Maryland and the Biological Waste Management of Organic Resources Laboratory, BARC, USDA, Beltsville, Md.

[2]Former graduate assistant, Assoc. Professor and Professor, resp.

[3]Research Agronomist, Soil-Microbial Systems Laboratory, U.S.D.A. BARC, West Bldg. 318, Beltsville, Md. 20705.

need for a regimen of fertilization which accounts for the nutrient supplying capacity of the compost. The objective of the present study was to determine the ability of several vegetable species to absorb and accumulate mineral elements from a medium amended with compost.

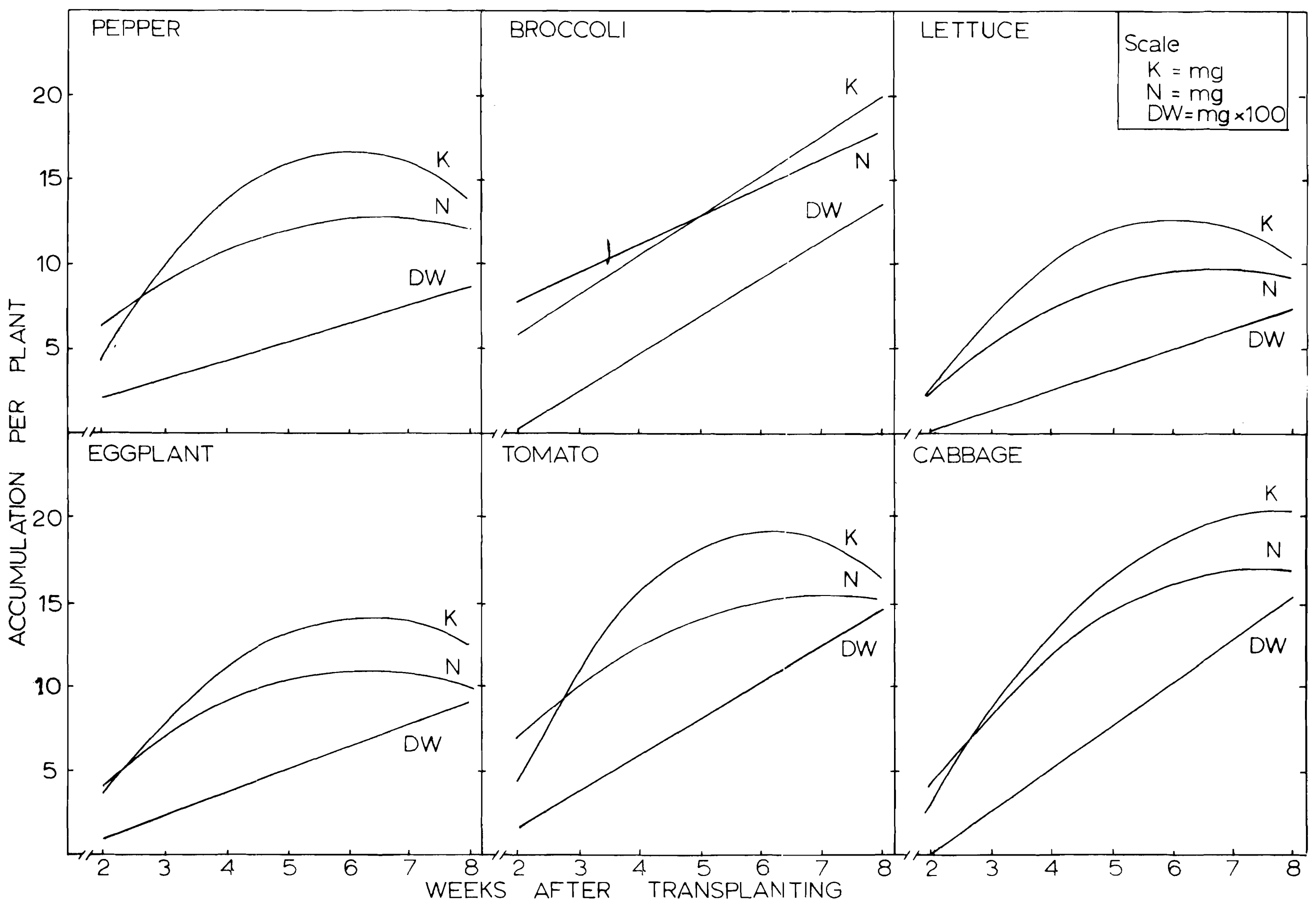
Materials and Methods

The experiment was conducted on raised benches in glass greenhouses under natural light. Greenhouses were ventilated when temperature reached 24°C (75°F) and 16°C (60°F) minimum night temperature was maintained.

Six species of vegetables 'Green Comet' broccoli, 'Market Prize' cabbage, 'Classic' eggplant, 'Summer Bibb' lettuce, 'Yolo Wonder' pepper, and 'Westover' tomato were grown in a medium of compost, sphagnum, peat moss and perlite (equal parts by vol.). Lime-dewatered raw sludge from the Blue Plains Waste Water Treatment facilities, Washington, DC was composted by Maryland Environmental Services, Annapolis, MD as outlined by Epstein et al. (7), using the "aerated pile" method. After curing, the compost was screened through a 1.6 cm (0.5 in) "Trommel rotary screen."

Initial analysis of the growth medium at planting time indicated a pH of 6.8, soluble salt concentration of 6.10 mmhos/cm, 0.9% N, 0.56% P, 1.60% K, 9.24% Ca, 1.4% Mg, 420 mg/Kg of Zn, 219 mg/Kg of Cd and a cation exchange capacity (CEC) of 9.90 meq/cm^3. Typical aerated pile compost contains, on a dry wt basis, 23% carbon, 1.6% N; 234 ppm NH_4^+; 1% P; 0.2% K; 1.4% Ca; 770 ppm Zn; 300 ppm Cu; 8 ppm Cd; 55 ppm Ni, 290 ppm Pb (13).

Seeds of each species were germinated in "Jiffy Mix" in a greenhouse at 20°C (68°F). Seedlings were graded for uniformity of size and transplanted when the first true leaves appeared. Six plants of the same species were grown in each



Crop	Nitrogen	R^2	Potassium	R^2	Dry weight	R^2
Pepper	$\hat{y} = -0.16 + 3.86x - 0.290x^2$	0.818*	$\hat{y} = -10.88 + 9.11x - 0.753x^2$	0.699	$\hat{y} = -0.006 + 0.107x$	0.911**
Eggplant	$\hat{y} = -3.62 + 4.63x - 0.369x^2$	0.719*	$\hat{y} = -8.20 + 7.13x - 0.572x^2$	0.799*	$\hat{y} = -0.169 + 0.134x$	0.994**
Broccoli	$\hat{y} = -4.39 + 1.69x$	0.987**	$\hat{y} = 1.00 + 2.37x$	0.740**	$\hat{y} = -0.417 + 0.223x$	0.960**
Tomato	$\hat{y} = -1.21 + 4.76x - 0.345x^2$	0.856*	$\hat{y} = -13.32 + 10.40x - 0.836x^2$	0.839*	$\hat{y} = -0.268 + 0.215x$	0.988**
Lettuce	$\hat{y} = -5.20 + 4.34x - 0.317x^2$	0.956**	$\hat{y} = -10.30 + 7.61x - 0.630x^2$	0.942**	$\hat{y} = -0.231 + 0.121x$	0.981**
Cabbage	$\hat{y} = -7.72 + 6.70x - 0.455x^2$	0.986**	$\hat{y} = -12.08 + 8.36x - 0.540x^2$	0.986**	$\hat{y} = -0.574 + 0.262x$	0.974**

Fig. 2. Accumulation of dry weight and N and K content (per plant) of the 6 species sampled weekly from 2 to 8 wks after transplanting, regression equations and ratios of variance accounted for by regression (R^2).

16.3 × 11.8 ×3.8 cm (6.5 × 4.5 × 1.5 in) commercial plastic market pack filled with 800 cm^3 (50 in^3) of the growing medium. The seedlings were irrigated thoroughly with tap water following transplanting and as needed throughout the 8 wk growing period. The market packs were arranged in a completely randomized design with four replications.

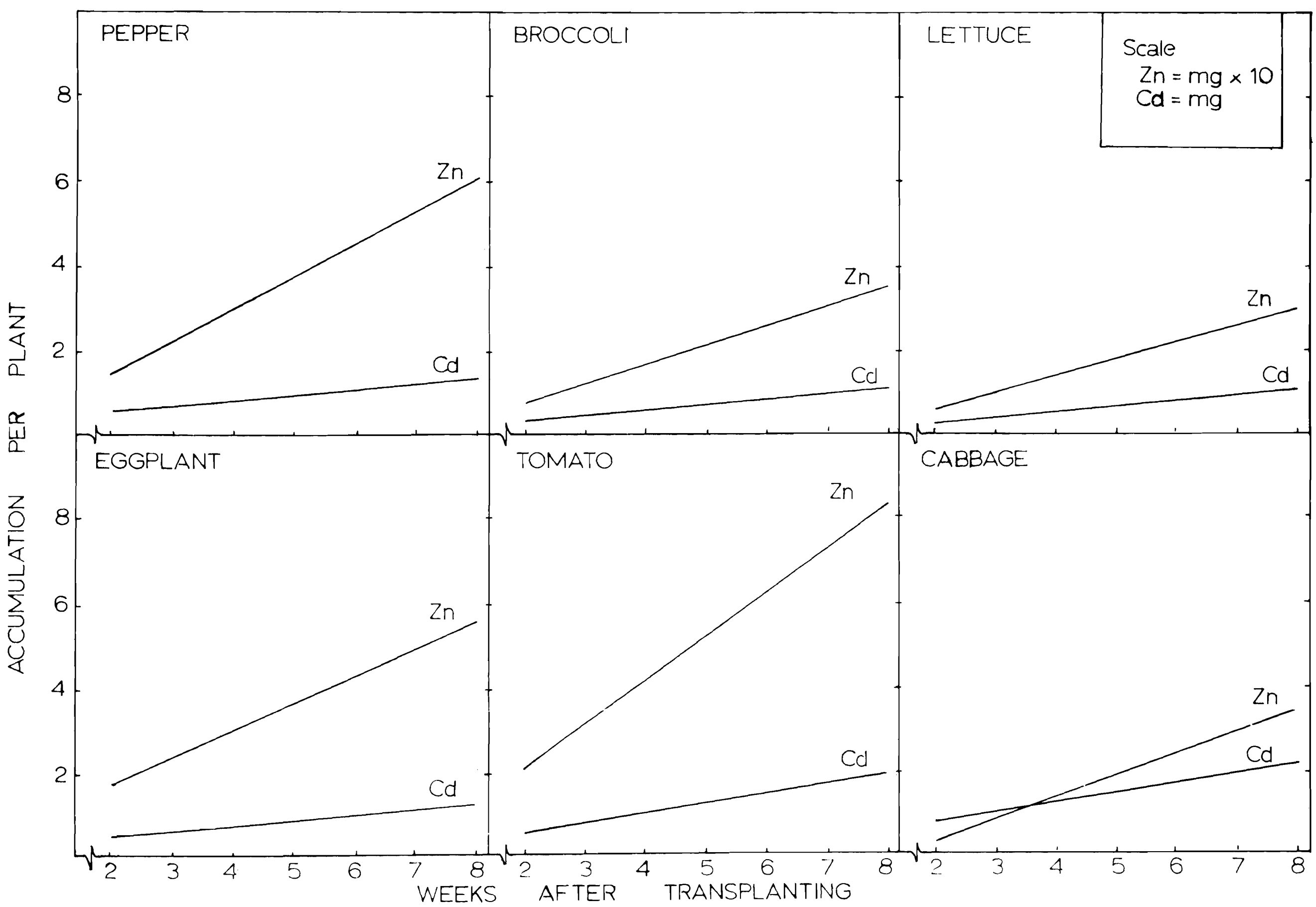
Determinations of K, Ca, Mg, Fe, Zn and Cd in soil and plant parts were carried out using the procedures described by Chaney, et al. (6). Nitrogen in soil and plant was determined by semi-micro Kjeldahl digestion (2) and P was determined by ammonium molybdate (5). Soluble salt levels in mmhos were measured on saturated paste extract, and pH determination were made using 1:4 dilution of medium and 0.01 M $CaCl_2$ as directed by Bunt (4).

Plants were harvested by removing the tops near the medium surface, washed in 1% Tween 20 (ICI Americas Inc., Wilmington, DE 19897) and rinsed in deionized water, dried in a forced-air oven at 70°C (178°F) and weighed. Plant samples for tissue analysis were ground in a stainless steel Wiley mill through a 40-mesh screen and stored in air-tight, acid washed bottles. Both plant and medium samples were taken at weekly intervals.

Element accumulation data were subjected to linear and quadratic regression analysis. The equation with a F value of greater significance was chosen as the one best describing accumulation over time.

Results and Discussion

The pH of the growing medium changed from 6.8 initially to 7.3 after 4 weeks, but stabilized at approximately 7.2 by the end of the experiment (Fig. 1). The initial soluble salts level of the medium was 6.1 mmhos/cm, decreasing to 2.1 mmhos/cm by the end of the experiment.



Crop	Cadmium	R^2	Zinc	R^2
Pepper	$\hat{y} = 0.30 + 0.130x$	0.659*	$\hat{y} = -0.90 + 7.77x$	0.797**
Eggplant	$\hat{y} = 0.20 + 0.126x$	0.784**	$\hat{y} = 4.28 + 6.39x$	0.893**
Broccoli	$\hat{y} = 0.00 + 0.134x$	0.927**	$\hat{y} = -2.12 + 4.62x$	0.957**
Tomato	$\hat{y} = 0.00 + 0.238x$	0.676*	$\hat{y} = -0.42 + 10.39x$	0.839**
Lettuce	$\hat{y} = 0.00 + 0.131x$	0.750**	$\hat{y} = -2.44 + 4.01x$	0.883**
Cabbage	$\hat{y} = 0.30 + 0.226x$	0.968**	$\hat{y} = -7.33 + 5.19x$	0.991**

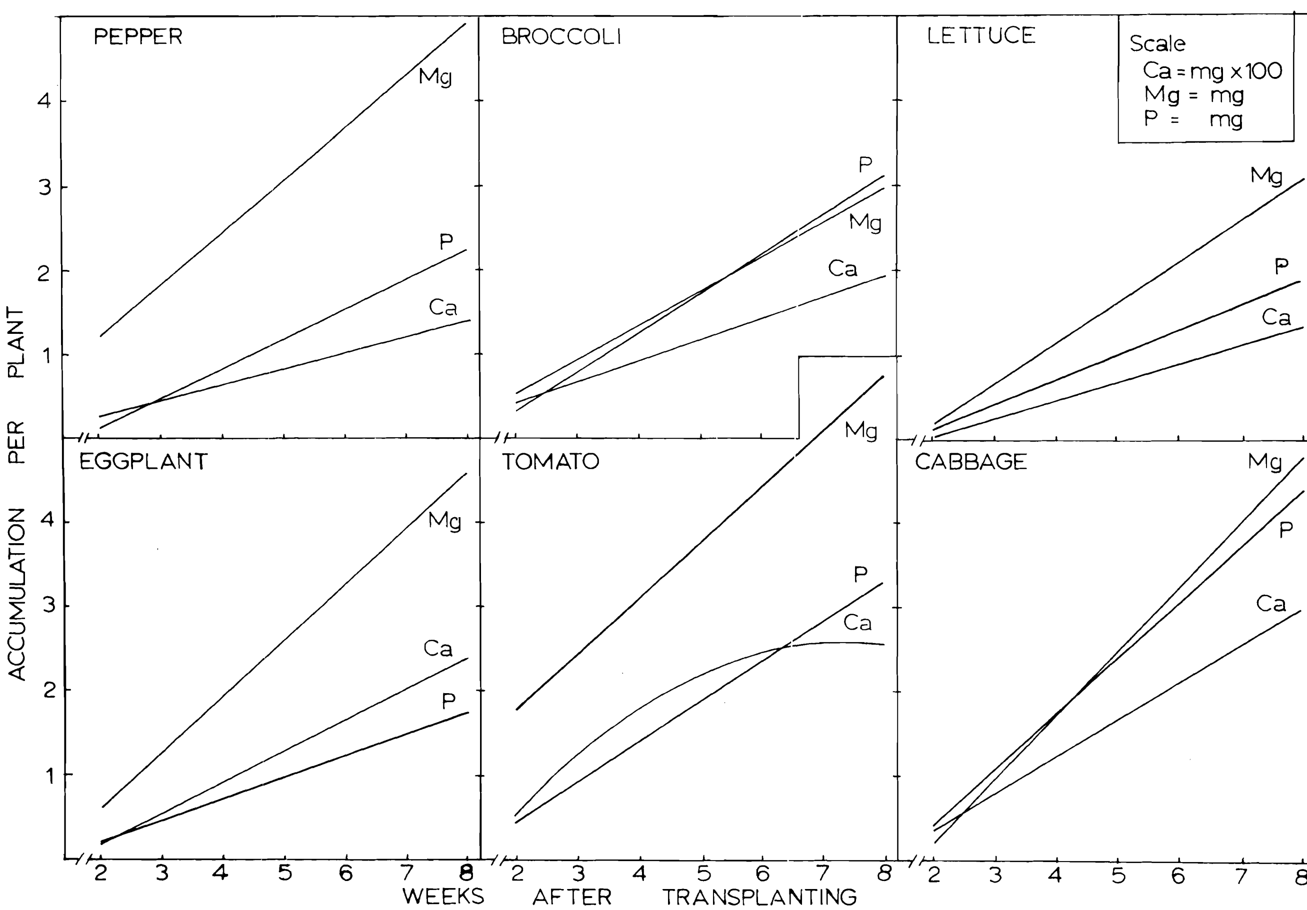
Fig. 3. Accumulation of Zn and Cd content (per plant) of the 6 species sampled weekly from 2 to 8 wks after transplanting, regression equations and ratios of variance accounted for by regression (R^2).

Growth of all species proceeded linearly throughout the growing period. Tomato, broccoli, and cabbage seedlings attained considerably greater dry wt. by the end of the experiment (1.38–1.57 g/plant) than did lettuce, pepper and eggplant (0.73–0.88 g/plant) (Fig. 2).

Accumulation of elements by the seedlings may be divided into 2 groups. P, Ca, Mg, Zn and Cd generally were accumulated. Nearly all species, resulting in contents correlated with final dry weight (Figs. 3 and 4). N and K contents, increased for 5 or 6 wks and then tended to not increase further (Fig. 2). It is possible that K was being translocated from the above ground portion to the roots by the 8th wk. However, we did not sample roots, and such conclusions seem speculative although tempting by the consistency of the data. Broccoli and cabbage were exceptions; N and K tending to increase throughout the growing period. It would appear that the medium contains N and K available to cabbage and broccoli which cannot be taken up by the other species. We interpret these data to suggest that broccoli and cabbage may be successfully grown to the transplant state in the growth medium, without supplemental fertilizer application, but that the other species may require the application of N and K. We interpret the generally linear accumulation of these minerals as suggesting that they are available to the six species and that additional applications are not required. The accumulation of Zn and Cd were not sufficient to be of concern to plant or human nutrition.

Significance to the Nursery Industry

As the availability of composted sewage sludge increases, it is attracting the attention of nurserymen and growers of greenhouse crops nationwide. It has been demonstrated that screened composted sewage sludge can be used as a potting



Crop	Calcium	R^2	Magnesium	R^2	Phosphorous	R^2
Pepper	$\hat{y} = -1.62 + 2.00x$	0.887**	$\hat{y} = -0.01 + 0.618x$	0.832**	$\hat{y} = -0.583 + 0.355x$	0.884**
Eggplant	$\hat{y} = -5.34 + 3.66x$	0.944**	$\hat{y} = -0.77 + 0.670x$	0.940**	$\hat{y} = -0.271 + 0.252x$	0.875**
Broccoli	$\hat{y} = -0.56 + 2.47x$	0.946**	$\hat{y} = -0.27 + 0.409x$	0.944**	$\hat{y} = 0.639 + 0.472x$	0.945**
Tomato	$\hat{y} = -13.18 + 10.6x - 0.716x^2$	0.961**	$\hat{y} = 0.47 + 0.659x$	0.827**	$\hat{y} = -0.521 + 0.480x$	0.931**
Lettuce	$\hat{y} = -3.90 + 2.14x$	0.981**	$\hat{y} = -0.77 + 0.481x$	0.947**	$\hat{y} = -0.454 + 0.296x$	0.973**
Cabbage	$\hat{y} = -5.35 + 4.45x$	0.982**	$\hat{y} = 1.34 + 0.777x$	0.964**	$\hat{y} = 0.912 + 0.668x$	0.985**

Fig. 4. Accumulation of P, Ca and Mg content (per pack) of the 6 species sampled weekly from 2 to 8 wks after transplanting, regression equations and ratios of variance accounted for by regression (R^2).

media amendment and as a soil amendment for growing a wide variety of landscape plants and transplants. Composted sewage sludge is a rich source of plant nutrients, which may require that fertilizers and fertilizer programs be adjusted to optimum plant growth. When compost is used at ⅓ by volume, in blending a potting medium, it can supply adequate P, Ca, Mg and trace elements for a minimum of 5 wks. However, it is necessary to apply N and K within a few wks after transplanting in order to satisfy most plant needs. The use of this information could result in substantial fertilizer savings especially to those evaluating the advantages of using composted sewage sludge in their potting medium.

Literature Cited

1. Ball, Vic. (ed.) 1972. The Ball Red Book. 12th ed. Geo. J. Ball, Inc., West Chicago, IL. pp. 7–10, 72–79, 164–170.

2. Bandel, V.A. and C.E. Rivard. 1978. Soil testing methods. University of Maryland Soil Testing Laboratory. Agronomy Mimeo No. 37, Univ. of Maryland, College Park, MD 20742.

3. Boodley, J.W. 1981. Charting one's way through the maze of soil mixes. Florist's Rev. Dec. 3rd.

4. Bunt, A.C. 1976. Modern potting composts. Penn. State Univ. Press, University Park, PA.

5. Chaney, R.L., J.B. Munns, and H.M. Cathey. 1980. Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media. J. Amer. Soc. Hort. Sci. 105:485–492.

6. Chaney, R.L., S.B. Sterrett, M.C. Morella, and C.A. Lloyd, 1982. Effect of sludge quality and rate, soil pH, and time on heavy metal residues in leafy vegetables. *In* Proc. Fifth Ann. Madison Conf. Applied Res. and Practice on Municipal and Industrial Waste. Univ. of Wis., Madison pp. 444–458.

7. Epstein, E., G.B. Willson, W.D. Burge, D.C. Mullen, and N.K. Enkiri. 1976. A forced aeration system for composting waste water sludge. J. Water Poll. Cont. Fed. 48:688–694.

8. Gouin, F.R. 1977. Using sludge to improve the soil. Amer. Nurseryman CXLIV (5):15, 110–115.

9. Gouin, F.R. 1982. Using composted wastes for growing horticultural crops. Biocycle. J. Waste Recycling. 23:45–47.

10. Lunt, O.R. and L.C. Clark. 1959. Horticultural applications for bark and wood fragments. Forest Prod. J. 9(4):39A–42A.

11. Sanderson, K.C. 1980. Use of sewage-refuse compost in the production of ornamental plants. HortScience 15:173–178.

12. Sterrett, S.B., C.W. Reynolds, F.D. Schales, R.L. Chaney, and L.W. Douglass. 1983. Transplant quality, yield, and heavy-metal accumulation of tomato, muskmelon, and cabbage grown in media containing sewage sludge compost. J. Amer. Soc. Hort. Sci. 108:36–41.

13. Willson, G.B., J.F. Parr, E. Epstein, B.P. Marsh, R.L. Chaney, D. Colacicco, W.D. Burge, L.J. Sikora, C.F. Tester, and S. Hornick. 1980. Manual of composting sewage sludge by Beltsville aerated-pile method. Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, U.S.A.