Growth Response and Mineral Uptake of Vegetable Transplants Growing in Composted Sewage Sludge Amended Medium. II. Influenced by Time of Application of N and K[1]

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Abstract

Six species of vegetable transplants were grown in market packs filled with peat moss, perlite and screened sewage sludge compost (equal parts by vol.). Compost was made from lime-dewatered sludge and woodchips. Seedlings were fertilized at 1, 2, 3 and 4 wks after transplanting in single, split and multiple applications of varying levels of N and K in factorial combinations. Fertilizer applications could be delayed 1 to 2 wks after transplanting without a loss of top growth. Lettuce, broccoli and cabbage plants were grown to marketable size with only N fertilizer. However, eggplants, tomato and pepper plants grew best when fertilized with both N and K. Acceptable levels of P, Ca, Mg, Md, Zn and Fe, as measured in tissues, were provided by the growth medium and tissue Cd levels were within acceptable limits.

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 and *Solanum melongena esculentum* L., eggplant, P, Ca, Mg, Mn, Fe, Zn, Cd

Introduction

Nitrogen and K appear to be the primary limiting essential plant nutrients when growing vegetable transplants and summer annuals in media amended with screened compost made from lime dewatered composted sewage sludge and woodchips (compost) (2). When compost is used at one-third by volume in a peat-perlite potting medium, there appears to be adequate release of N and K to supply the needs of young seedlings for the first few wks of growth (3). The objectives of this research were to measure the growth response and mineral uptake of selected vegetable transplants growing in a compost amended medium and supplied only with varying levels of N and K.

Materials and Methods

All studies were conducted using the same greenhouse facilities and compost described by Falahi-Ardakani et al. (3). Plants were grown in 16.3 × 11.8 × 3.8 cm (6.5 × 4.5 × 1.5 in) plastic market packs filled with 800 cm^3 (50 in^3) peat moss, perlite and compost (equal parts by vol). Six uniform size seedlings of each species were transplanted into each market pack and thoroughly irrigated with tap water immediately after transplanting and later as necessary.

When the plants reached marketable size for transplants, the tops (stems and leaves) were cut at the surface of the medium, oven dried at 70°C (158°F) and weighed. Stems and leaves of samples for tissue analysis were washed in 1% "Tween 20" (ICI American Inc., Wilmington, DE 19899) and rinsed in deionized water before oven drying. The dried samples were ground through a 40 mesh stainless steel screen and stored in air-tight, acid-washed bottles.

Plant tissues were analyzed for K, Ca, Mg, Fe, Zn, and Cd (4), N by semimicro Kjeldahl, and P (2, 4). Soluble salt levels and pH of the medium were measured by saturated paste extract and 1:4 (medium:0.01M Ca Cl_2) extracts (1), respectively.

Experiment 1. To establish a time period for the initial application of fertilizer and fertilizer concentrations, seedlings of broccoli, cabbage, eggplant, lettuce, peppers and tomato were transplanted and grown for 6 wks starting in September. Nitrogen was applied at 45 and 90 mg/market pack and K applied at 0, 23, and 45 mg/market pack per application starting at 1, 2, 3 and 4 weeks after transplanting. Nutrients were supplied using USP Grade NH_4NO_3 and KCl. At harvest only lettuce and tomato plants were washed prior to drying and ashed for tissue analysis. Dry weight data were analyzed as a 2 × 3 factorial nested within 4 initial application periods and replicated 4 times.

Experiment 2. The effects of delayed, single split and multiple applications of N and K were measured using lettuce and tomato transplanted in April. Nitrogen was applied at 90, 180, and 270 mg/market packs and K at 0, 23, and 45 mg/market packs as single applications at 1, 2 or 3 wks after transplanting, as split applications at ½ concentrations at 1 and 3 wks, or 2 and 3 wks after transplanting, or as multiple applications each at ⅓ concentrations at 1, 2 and 3 wks after transplanting. All treatments and species were randomized and replicated 4 times. After 4 wks of growth, the plants were harvested and washed prior to drying. The data were analyzed as a 3 × 3 × 7 factorial.

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Results and Discussion

Experiment 1. All species except eggplant responded equally well to fertilizer applications made at 1 or 2 wks after transplanting (Table 1). Delaying the initial fertilizer application 3 or 4 wks resulted in less top growth of all species.

Eggplant and tomato benefited from being fertilized with 90 mg of N and 45 mg of K supplied at 1 or 2 wks after transplanting (Table 1). Top growth of broccoli, cabbage, and lettuce were not affected by increasing levels of K when 90 mg of N was applied. Delaying the initial application of N for 3 or 4 wks reduced the effects of supplemental K on the top growth of eggplant, pepper, and tomato plants indicating an interaction.

Applying 90 mg of N 1 or 2 wks after transplanting increased the N concentration of lettuce tissues regardless of the amount of K applied (Table 2). Tissue concentration of P, Mn and Cd were unaffected by fertilizers while Zn levels were reduced when 45 and 23 mg of N and K applications were applied 3 wks after transplanting.

Except for tissue N concentrations, transplants of tomato responded differently than lettuce when fertilized with N and K (Table 3). Tissue concentration of P, K, Mg, Mn, and Zn were the highest in plants fertilized with N and K applied 2 or 3 wks after transplanting while tissue concentrations of Ca and Fe exhibited no change regardless of treatment. Cadmium concentrations in tissues fluctuated regardless of treatments.

Experiment 2. Only N fertilization increased the dry wt of lettuce transplants while K had little effect (Figure 1). Fertilizing with N caused an increase in tissue N and a decrease in tissue P and K. Fertilizing with K caused an increase only in the K concentration of tissues.

The top growth of tomato was increased by fertilizing with N and with K, only when 270 mg of N was applied per market packs (Figure 2). Increasing fertilizer N resulted in an increase in the N and P, and a decrease in K concentration of tissues. Increasing the K in the fertilizer solution resulted in increased K concentration only when N was applied at 90 mg/market packs.

Making split applications at 2 and 3 wks or multiple applications at 1, 2 and 3 wks produced tomato plants with the greatest amount of top dry wt (Figure 3). Lettuce plants responded equally well to a single fertilizer application 2 wks after transplanting, split applications 2 and 3 wks after transplanting or to multiple applications. Delaying the initial fertilizer application for 3 wks produced the smallest plants but resulted in highest tissue concentrations of N, P, and K for both species.

Table 1. Dry weight (g) of vegetable transplants (stem and leaves) after 6 wks of growth in equal parts by volume of CSS, peat moss, and perlite in market pack as influenced by varying levels of N and K as single or multiple treatments applied from 1 to 4 wks (initial application) after transplanting.

			mg/market packs/Application					
			45 N			90 N		
Species	Treatment[z]	Treatment mean	0 K	23 K	45 K	0 K	23 K	45 K
Broccoli	1	13.0A[y]	11.3c[x]	11.6bc	13.0abc	12.5bc	15.4a	14.1ab
	2	12.4A	13.3a	10.4b	11.3ab	12.5ab	13.8a	13.2a
	3	11.2B	10.3b	10.0b	12.4a	11.9ab	13.1a	12.1ab
	4	9.7C	9.4a	9.6a	9.6a	9.2a	8.9a	8.7a
Cabbage	1	12.4A	10.0c	11.7bc	11.3bc	13.3ab	13.5ab	14.6a
	2	11.5AB	11.2a	10.9a	11.1b	10.4a	12.7a	12.9a
	3	11.4B	10.2b	11.1b	9.8b	10.8b	13.9a	12.6ab
	4	8.7C	8.2a	7.8a	9.9a	7.9a	9.4a	9.1a
Lettuce	1	7.5A	5.8c	7.0abc	7.1ab	8.6a	8.3ab	8.2ab
	2	7.0A	6.1b	6.5ab	6.7ab	7.4ab	7.8a	7.5ab
	3	6.2B	5.1b	5.7ab	5.8ab	7.1a	6.8a	6.9a
	4	5.3C	4.8a	5.1a	4.7a	5.7a	5.6a	5.7a
Eggplant	1	9.2A	6.0d	7.6c	7.6c	10.4b	11.6ab	11.8a
	2	8.6B	6.6c	6.9c	7.6c	5.4b	10.2ab	11.2a
	3	7.2C	6.4b	6.0b	6.4b	8.0a	7.8a	9.0a
	4	5.2D	5.0ab	4.1b	5.5ab	5.5ab	5.4ab	6.6a
Pepper	1	7.5A	4.5c	5.4bc	5.9b	5.6bc	7.3a	8.2a
	2	7.0A	4.8c	5.5bc	5.1bc	6.0abc	6.4ab	7.1a
	3	6.2B	4.1b	5.1ab	5.0ab	5.3ab	6.3a	6.3a
	4	5.3C	4.1ab	3.7b	4.0a	4.6ab	4.6ab	5.3a
Tomato	1	6.2A	12.1c	12.9c	12.9c	14.5bc	15.9b	18.3a
	2	5.8A	11.1cd	10.9cd	9.2d	14.0ab	13.2bc	16.4a
	3	5.3B	9.9b	9.3b	7.9b	13.9a	13.3a	12.4a
	4	4.4c	8.5b	5.9b	8.7a	9.3a	8.9a	9.5a

[z]Applied 1 = 1, 2, 3 and 4 wks after transplanting; 2 = applied 2, 3, and 4 wks after transplanting, 3 = applied 3 and 4 wks after transplanting; 4 = applied 4 wks after transplanting.

[y]Mean separation within the same column for each species by the Waller Multiple Range Test (P = 0.05).

[x]Mean separation within the same row by the Waller Multiple Range Test. (P = 0.05).

Table 2. Mineral concentration of lettuce transplants grown 6 wks in medium of compost, peat and perlite in market pack as influenced by varying levels of N and K, applied weekly at 1, 2 or 3 wks (initial application) after transplanting to within 2 wks before harvesting.

Treatments			%					ppm			
initial application	mg/ application N	K	N	P	K	Ca	Mg	Mn	Fe	Zn	Cd
1	45	23	2.49d[z]	0.59a	3.27ab	2.29de	0.74g	175.2a	65.0ef	49.8ab	1.00a
	90	0	3.68a	0.59a	1.53e	2.19ef	1.08a–c	174.2a	99.4a	62.3a	1.19a
	90	23	3.82a	0.66a	3.10a–c	2.4cd	1.11a	155.8a	89.5ab	62.1a	1.11a
	90	45	3.90a	0.60a	3.40a	2.14f	0.89ef	158.8a	79.4b–e	59.9ab	1.04a
2	45	23	2.69d	0.62a	3.04b–d	2.10f	0.79fg	170.4a	58.2f	48.7ab	0.82a
	90	0	3.73ab	0.63a	1.92e	2.23d	0.15a	165.8a	91.9ab	60.4a	1.11a
	90	23	3.86a	0.62a	2.64d	2.53bc	1.10ab	192.1a	90.5ab	62.7a	1.07a
	90	45	3.72ab	0.66a	2.87b–d	2.15ef	0.93de	162.4a	79.3b–e	57.7ab	0.88a
3	45	23	2.43d	0.54a	2.7cd	2.35d	0.79fg	188.2a	65.9d–f	44.3b	0.83a
	90	0	3.17c	0.64a	1.96e	2.60b	1.00b–d	160.1a	74.6c–e	49.9ab	0.89a
	90	23	3.45bc	0.58a	2.67cd	2.83a	1.10ab	177.1a	80.1b–d	57.2ab	1.13a
	90	45	3.58ab	0.65a	3.08a–d	2.19ef	0.98c–e	147.3a	82.8bc	57.5ab	1.10a

[z]Mean separation within the same column by the Waller Multiple Range Test. (P = 0.05).

Table 3. Mineral concentration of tomato transplants grown 6 wks in medium of compost, peat and perlite in market pack as influenced by varying levels of N and K applied weekly at 1, 2 or 3 wks (initial application) after transplanting to within 2 wks before harvest.

Treatments			%					ppm			
initial application	mg/ application N	K	N	P	K	Ca	Mg	Mn	Fe	Zn	Cd
1	45	23	1.32d[z]	0.40b	1.95a	2.27ab	0.48c	33.5bc	39.7ab	47.3a–c	0.44ab
	90	0	1.76ab	0.38b	1.03d	2.04b	0.52bc	31.8c	52.6a	39.2c	0.39abc
	90	23	1.74ab	0.34b	1.20cd	2.02b	0.50c	33.3bc	52.0a	41.7bc	0.28d
	90	45	1.69ab	0.40b	1.23b–d	2.15ab	0.50c	35.6bc	44.8ab	42.3bc	0.44ab
2	45	23	1.34d	0.57a	2.07a	2.33ab	0.50c	42.5ab	36.9b	50.8ab	0.39a–c
	90	0	1.79a	0.35b	1.06d	2.15ab	0.61a	36.6bc	49.0ab	46.4a–c	0.40a–c
	90	23	1.75ab	0.42b	1.35bc	2.12ab	0.53bc	35.9bc	48.3ab	43.8a–c	0.33cd
	90	45	1.80a	0.33b	1.19cd	2.28ab	0.58ab	37.8bc	50.5ab	51.8ab	0.44ab
3	45	23	1.36d	0.61a	2.08a	2.40a	0.55a–c	49.1a	49.3ab	54.2a	0.48a
	90	0	1.53c	0.37b	1.16cd	2.24ab	0.61a	38.5bc	51.8ab	48.8a–c	0.35bc
	90	23	1.62bc	0.39b	1.43b	2.14ab	0.55a–c	40.6a–c	47.8ab	47.7a–c	0.34cd
	90	45	1.76ab	0.34b	1.20cd	2.29ab	0.55a–c	40.5a–c	48.8ab	43.4a–c	0.41a–c

[z]Mean separation within the same column by the Waller Multiple Range Test (P = 0.05).

The pH was between 6.3 and 6.5 measured at the beginning and the end of both experiments. Soluble salt levels were 2.8 mmhos/cm at the beginning of both experiments and varied slightly at harvest according to the fertilizers being applied.

Potting medium of equal parts by volume of compost, peat moss and perlite is capable of supplying P, Ca, Mg, Fe and Zn to satisfy the needs of the vegetable transplants tested for the first 4 to 6 wks of growth. Except for eggplant, the initial fertilizer application can be delayed 2 weeks after transplanting. Although the fertilizer requirements of lettuce can be satisfied with a single application of N made 2 weeks after transplantings, both species responded similarly to split and multiple applications. Plants of broccoli, cabbage and lettuce can be grown to marketable size by fertilizing only with N. Supplementing the N fertilizer with K stimulated additional top growth of tomato, eggplant and pepper. Based on tissue analysis, there is no indication that P must be included in the fertilizer program and that the compost is capable of supplying adequate amounts of trace elements.

The blending of compost in growing media for growing transplants allows for versatility in fertilizer programs and substantial savings in fertilizers. Because the initial fertilizer application can be delayed 1 to 2 wks and the fertilizer requirements of the plants can be satisfied by single or multiple applications, there is no need to follow a constant or bi-weekly feeding program. Also compost made from lime-dewatered sewage sludge raises the pH of the resulting medium sufficient to allow satisfactory plant growth as reported by Sterrett et al., (5).

Significance to the Nursery Industry

When composted sewage sludge is blended at ⅓ by volume in a potting medium, it is important that the initial application of N and K be delayed 1 to 2 wks in order for the plants to fully benefit from the nutrients released by the compost. However, delaying the initial application 3 wks will result in a decrease in plant growth at the time of marketing. It is also evident that there are some species such

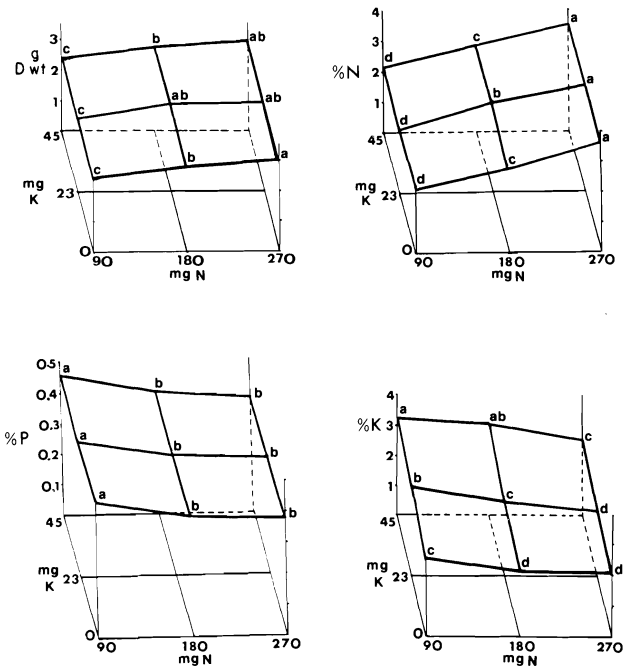

Fig. 1. Surface response of top growth (stem × leaves) (Dwt) and concentration of N, P, and K of lettuce tissue from plants grown 4 wks in equal parts by volume of compost, peat moss and perlite and fertilized with N and K (averaged over application times). Means with different letters indicated significant differences of 5% (Waller Multiple Range Test).

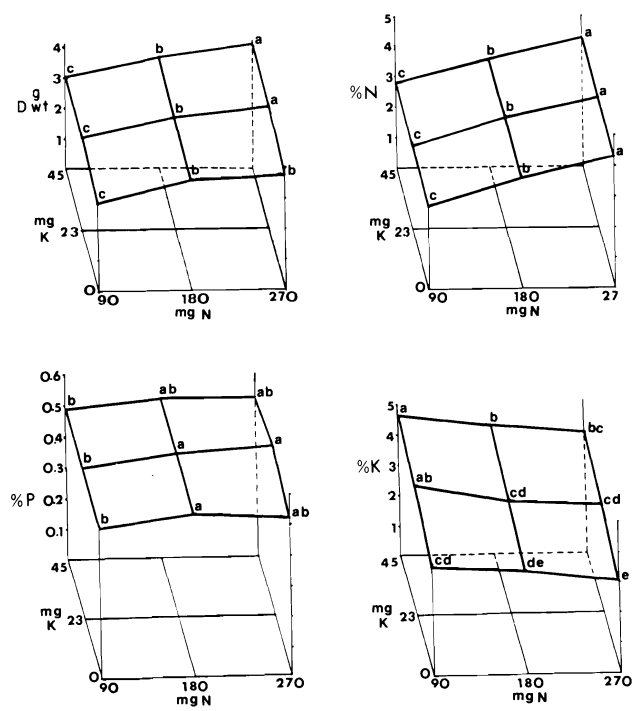

Fig. 2. Surface response of top growth (stem × leaves) (Dwt) and concentration of N, P and K of tomato plant tissues from plants grown 4 wks in equal parts by volume of compost, peat moss and perlite and fertilized with N and K (averaged over application times). Means with different letters indicate significant differences of 5% (Waller Multiple Range Test).

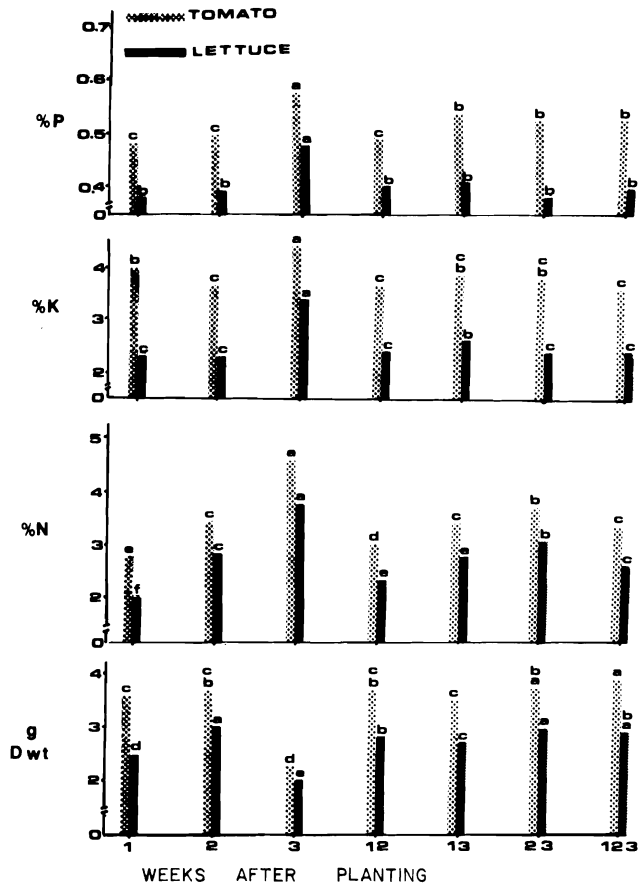

Fig. 3. Top growth response (stem × leaves) (Dwt) and N, P, and K accumulation in tissues of vegetable transplants grown in market packs of compost, peat moss and perlite with N and K (averaged over rates) applied 1, 2 and 3 wks after transplanting as single, split or multiple applications (wks after planting). Means with different letters indicate significant treatment differences of 5% (Waller Multiple Range Test).

as lettuce and cabbage that could be grown to market size using only N fertilization because there appears to be adequate P, K, Ca, Mg, and trace elements in compost to supply the needs of these species to marketable size. For plant species of tomato, eggplant and pepper, supplemental applications of K are essential within 1 to 2 wks after transplanting for optimum growth.

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