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Growth, Yield and Nutrition of Potato in Fumigated or Nonfumigated Soil Amended with Spent Mushroom Compost and Straw Mulch

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Four cultural amendments; spent mushroom compost, straw mulch, both compost and straw mulch, or neither, were applied to soils that were either fumigated or not fumigated in a field of potatoes subject to early dying and Colorado potato beetle defoliation. Two plant samples were harvested at two week intervals to measure shoot and tuber growth and mineral nutrition, and two rows were harvested for yield at maturity. Amending the soil with compost increased vegetative growth and shoot weight more than final yield of tubers. Compost amendment delayed tuber filling by several days. Fumigation partly controlled the loss of leaf area due to early dying, but it did not increase tuber yields, and in 1994 fumigation reduced tuber yield in compost amended soils. The effects of compost and straw mulch on tuber yield were related to the concentrations of N and P in leaves. The potato crop did not benefit from compost amendment combined with fumigation, because in fumigated soil there was no improvement in plant nutrition due to compost.

Introduction

Potato yields can be reduced by early dying, a disease caused by interactions of the fungus *Verticillium dahliae* and/or *V. albo atrum* with the root lesion nematode *Pratylenchus penetrans*, and in some areas with the bacterium *Erwinia carotovora* (Martin *et al.* 1982). Yield loss may be alleviated by fumigation to control these soil-borne pathogens (Rowe *et al.* 1987). Yield loss may also be alleviated, in part, by other horticultural practices such as the use of compost. Substituting compost for conventional fertilizer may suppress Verticillium wilt in potato. The yield of eggplant declines in successive plantings due to Verticillium wilt in conventionally fertilized soil, but it does not decline in compost amended soil (Maynard 1991). Amending potting soil with compost also suppresses diseases of potted plants (Hoitink and Fahy 1986; Hoitink and Grebus 1994). Incorporating organic matter in soil reduces the population of *Pratylenchus* species in potato fields (D'Errico *et al.* 1980; Florini *et al.* 1987). For other vegetable crops, amending field soil with composted yard waste compost decreases the populations of some nematode species, but *Pratylenchus* is not affected (McSorley and Gallaher 1995).

Compost also promotes plant growth by increasing soil water holding and ion exchange capacities (Maynard 1991) and improving the mineral nutrition of the plants (Steffen *et al.* 1994; Maynard 1994). In potato, the concentrations of mineral nutrients in leaves decline from early vegetative growth to mid-tuber filling (Walworth and Muniz 1993). If compost were to increase the mineral nutrition of potato, it may improve yield under the stress of early dying, where potato leaves lose nutrients rapidly and senesce prematurely. However, this benefit of compost amendment may not be seen in soil fumigated to reduce disease pressure. For instance, the mineral content of toma-

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toes with conventional fertilizer does not differ from that with compost under disease free conditions (Auclair *et al.* 1995). It is not clear if a combination of fumigation and compost will increase the mineral nutrition and yield of potato plants.

Straw mulch is another horticultural practice that can modify the soil environment, by cooling the soil and decreasing surface crusting (Tindall *et al.* 1991; Matheny *et al.* 1992). This may increase potato yield because cool soil is more favorable for tuber growth. Cooling the soil slows the mineralization of N, which will affect plant composition and yield. Soil temperature also affects the population and activity of soil pests. Mulching with straw reduces the number of Colorado potato beetles as compared to unmulched plots (Zehnder and Hough-Goldstein 1990; Stoner 1993). However, fumigation can increase the number of Colorado potato beetles emerging from the soil later in the season (Stoner *et al.* 1996), and thus counteract this effect of straw mulch.

The objectives of this study were to determine the effect of compost and straw mulch, separately and together, on growth, yield, and nutritional status of potato. The effects of these amendments were compared in fumigated and nonfumigated soils in a field infested with Colorado potato beetles and pathogens that cause early dying.

Materials and Methods

Experimental Design

The experiment was conducted in a 0.1 ha field in Hamden, Connecticut, that was naturally infested with high populations of the Colorado potato beetle (*Leptinotarsa decemlineata* Say) the root lesion nematode (*Pratylenchus penetrans* Cobb) and the fungal pathogen (*Verticillium dahliae* Kleb.). This field was divided into four replicate blocks, with twelve treatment plots in a split-plot design within each block. The main plots within each block were pest control treatments. In the first treatment, the soil was not fumigated and Colorado potato beetles were controlled by hand removal and insecticide sprays. In the second treatment, the soil was fumigated after the previous potato crop, and Colorado potato beetles were controlled. In the third treatment, the soil was fumigated but Colorado potato beetles were not controlled. Rapid defoliation of the plants by Colorado potato beetles dominated other effects in this last treatment, so the results were not included in the analysis.

There were four cultural amendment treatments as subplots within each pest control treatment plot. Inorganic fertilizer, alone, was used in two of the subplots. In one of these, the soil surface was mulched with straw after plant emergence, and in the other the soil surface was bare. Spent mushroom compost was incorporated into the other two subplots before planting in each year. In one of the compost amended plots the soil surface was mulched with straw and in the other the soil surface was bare. Each plot was subject to only one treatment combination in the two year experimental period.

Each subplot consisted of four 4-m-long rows planted with seed pieces of potato (*Solanum tuberosum* L.) cultivar 'Superior'. Plants were spaced 25 cm apart within rows and the rows were 0.9 m apart. The red potato cultivar 'Norland' was planted in a 0.5 m-long border row at the beginning and end of each subplot, and in border rows on both sides of the field and between main plots to mark the plot boundaries at final harvest.

Treatments

A fumigant was injected into newly plowed and disked soil after the previous potato crop was harvested. On 1 October 1992, methyl isothiocyanate (Vorlex, NOR-AM, Wilmington, Delaware) was applied at 15 $g{\cdot}m^{-2}$ active ingredient. On 1 October

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1993, metam sodium (Vapam, Zeneca, Wilmington, Delaware) was applied at 45 $mL \cdot m^{-2}$. Insecticide applications and other methods to control Colorado potato beetle are described elsewhere (Stoner *et al.* 1996).

Spent mushroom compost (Franklin Mushroom Farms, Franklin, Connecticut), derived primarily from horse manure and bedding, was composted for six months outdoors in static piles that were turned monthly (Maynard 1994). The compost had a density when dry of 50 $kg \cdot m^{-3}$, a pH of 7.3, and N, P, K percentage values of 0.6, 1.0 and 1.5. Compost was applied to the plots at a rate of 0.4 m^3 per plot in a layer 2.5 cm deep (15 $Mt \cdot ha^{-1}$) and rototilled into the soil to a depth of 15 cm just before planting. Potato seed pieces were cut, treated with powdered sulfur, and planted on 30 April in 1993 and on 29 April in 1994. The rows were hilled after planting. Soil fertility and pH were assayed from five soil cores per subplot. Based on these assays, each subplot was amended with NH_4NO_3 and/or KNO_3, to establish 40 mg N and K per kg of soil. Pelleted sulfur was added at 22 $g \cdot m^{-2}$ to lower the pH of the compost amended plots to that of nonamended plots. These amendments were applied as a side dressing on 26 May in 1993 and 25 May in 1994. An 8-cm-deep layer of straw mulch (one bale per subplot) was applied on 1 June 1993 and 27 May 1994. Overhead irrigation was applied when less than 25 mm of rain fell in the preceding week.

Sampling

Plants were sampled at two weeks after emergence on 2 June in 1993 and 1994; when half the plants were in flower on 30 June 1993 and 22 June 1994; and during tuber filling on 13 July in 1993 and 1994. In 1993, a fourth sample was taken on 3 August. Two randomly selected hills (plants) were harvested from the outer rows of each subplot on each date. The length of all stems was measured, and the leaves of up to six stems per plant were classified into sizes of less than 25, 50, 100, 150, 200, and 250 cm^2 in area using a leaf area meter. The numbers of leaves in each size class times the area in that size class gave the total leaf area per stem. The above ground portions of the plant were separated into stems and leaf blades. A subsample of two leaves was freeze dried for nutrient analysis. The roots and tubers were dug, and the tubers were counted and weighed. The roots were washed free of soil and freeze dried for nutrient analysis. The rest of the plant material was heat dried and weighed. The dry weight of leaf blades, stems and petioles, and roots, and the fresh weight of tubers were determined for two hills. These values were multiplied by half the density of hills in the subplot to give values per square meter. The center two rows of each subplot were not sampled during the growing season; rather all tubers were harvested, counted, and weighed at the end of the season. This final harvest was performed on 16 August in 1993 and 1994.

Nutrient Analysis

Freeze dried plant tissue was assayed for elemental composition. The four samples within each treatment, taken from the four different blocks, were combined before grinding and subsampling. Two subsamples of each pooled sample were analyzed. A 250 mg sample was digested in 4 ml of boiling H_2SO_4 to which 10 ml of H_2O_2 was added drop wise, and the digested tissue was diluted to 100 ml. The assay for total N used Nessler reagent, and that for total P used molybdate reagent. Other elements were determined using inductively coupled plasma spectrophotometry (Stilwell 1993). The concentration of the elements is expressed in g element per kg dry weight of plant material.

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Statistics

The overall effects of the treatments, measured three or more times during the season, were analyzed using a repeated measures analysis of variance of the split-plot design. Within each replicate block, fumigation was the subplot and the straw and compost amendments were sub-subplots. The interactions between treatment effects and the block factor were used as the source of error in analysis of growth and yield. Significance of the interactions between effects of treatments and the repeated measure, harvest date, were also determined using the interaction between the block factor and harvest date as the source of error. The interactions between treatment effects and replicate samples were used as the source of error in analysis of elemental composition. Only results from those plots in which the Colorado potato beetles were controlled were included in these analyses.

Results

Leaf Area

In 1993, the leaf area increased from about 0.6 $m^2 \cdot m^{-2}$ at flowering on 30 June to about 2.0 $m^2 \cdot m^{-2}$ at mid-tuber filling on 13 July (data not shown). Plants were defoliated by Colorado potato beetles in early August. Neither spent mushroom compost nor straw mulch amendments, nor fumigation affected the leaf area when averaged over three sampling dates in 1993 (Table 1). Compost amendment did increase the leaf area on 13 July, from 1.5 to 2.2 $m^2 \cdot m^{-2}$, $P<0.05$, but it had no effect on earlier dates. After mid July, the leaves displayed the yellowing that is characteristic of Verticillium wilt. Integrated over all measurements in 1993, the fraction of sunlight that was intercepted by the canopy was greater in fumigated than nonfumigated plots (Elmer *et al.* 1994). In 1994, the leaves grew faster than in 1993, the leaf area index was greater than 1.0 $m^2 \cdot m^{-2}$ at flowering on 22 June 1994. However, there was no further increase in leaf area to mid-tuber filling, on 13 July 1994, and Colorado potato beetles defoliated the plants by late July in 1994. On 22 June 1994, fumigation increased the leaf area from 1.1

TABLE 1.
Repeated measures analysis of variance of effects of fumigation, compost, and straw mulch on leaf area, shoot and tuber weight of potato measured on three dates in two years

		Mean Squares					
		1993			1994		
Factor	Degrees Of Freedom	Leaf Area Index ($m^2 \cdot m^{-2}$)	Shoot Dry Weight ($m^2 \cdot m^{-2}$)	Tuber Fresh Weight ($m^2 \cdot m^{-2}$)	Leaf Area Index ($m^2 \cdot m^{-2}$)	Shoot Dry Weight ($m^2 \cdot m^{-2}$)	Tuber Fresh Weight ($m^2 \cdot m^{-2}$)
Block	3	0.804	0.020	2.362	1.235	0.003	1.14***Z
Fumigation (F)	1	0.043	0.006	0.003	2.197*	0.019**	0.003
Error 1	3	0.456	0.012	2.304	0.361	0.002	0.082
Compost (C)	1	0.873	0.044**	0.962	0.111	0.002	3.28***
Straw (S)	1	0.001	0.002	0.039	1.894*	0.016	0.192
CxS	1	0.004	0.000	0.300	0.415	0.001	0.415*
CxF	1	0.126	0.001	0.626	0.008	0.001	0.079
SxF	1	0.317	0.006	3.931*	0.827	0.003	0.000
SxCxF	1	0.721	0.017	0.096	0.004	0.000	0.000
Error 2	17	0.233	0.005	0.830	0.255	0.003	0.081
TimeY	2	19.475	0.241	66.949	41.909	0.437	19.241

Z *, **, *** effects significant at $P<0.05$, $P<0.01$, and $P<0.001$, respectively.
Y All effects of time significant at $P<0.001$. Interactions between the effects of time and other factors not shown.

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to 1.5 $m^2 \cdot m^{-2}$ ($P<0.05$), and straw mulch increased the leaf area by a similar amount. Compost amendment had no effect on the leaf area in 1994 and fumigation increased leaf area in both compost amended and nonamended plots.

Shoot Growth

In both 1993 and 1994, the shoot weight at flowering was about half that at mid-tuber filling. Compost amendment increased shoot weight by about 40 percent on and after 30 June 1993 (Figure 1), and on 13 July 1993, the increase in shoot weight due to compost amendment was greater in nonfumigated than in fumigated soil. In 1994, the shoot weight in fumigated plots was greater than in nonfumigated plots (Table 1), and this difference in shoot weight increased as the season progressed (Figure 1). On 13 July 1994, compost amendment increased the shoot weight by about 10 percent for plants grown in both fumigated and nonfumigated soil (Figure 1).

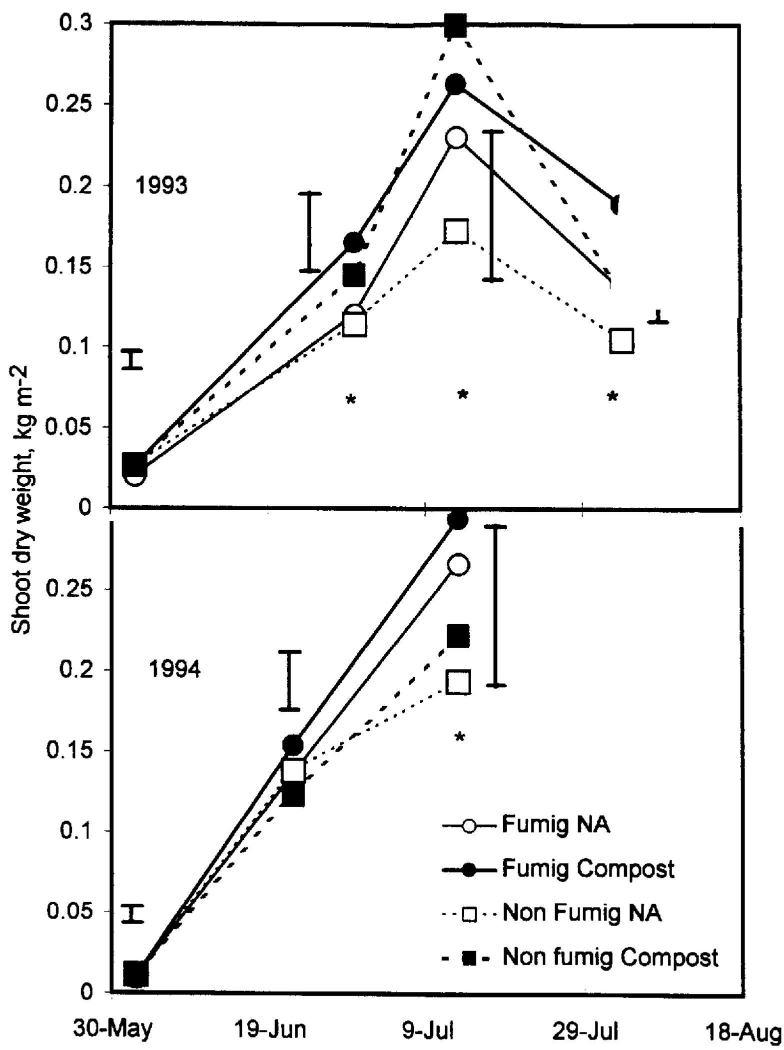

Figure 1: The effects of fumigation and compost amendment on shoot dry weight of potato in 1993 and 1994. Symbols represent the average of 8 sub-plots. * indicates significant differences at $P<0.05$ due to compost and/or fumigation. The I bar indicates the least significant difference for each date.

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Tuber Growth and Yield

The progress of tuber filling in compost amended plots differed from that in non-amended plots. On 13 July 1993, plots amended with compost had fewer tubers and the tuber weight was 0.7 kg·m^{-2} less than in control plots (Figure 2). However, the final yield of tubers did not differ among plots with and without compost amendment in 1993 (Table 1). Compost amendment appeared to delay the initial growth of tubers, but prolonged tuber filling in both fumigated and nonfumigated soil.

In 1994, plots amended with compost had 0.5 kg·m^{-2} less tuber fresh weight than plots without compost, both at mid-tuber filling on 13 July and at the final harvest on 16 August (Figure 2). Fumigation also had an effect on tuber growth. The tuber weight in fumigated soil was 0.5 kg·m^{-2} more than in nonfumigated soil at mid-tuber filling, but it was 0.4 kg·m^{-2} less at the final harvest. Tuber filling appeared to stop on 13 July for plants in fumigated soil, while plants in nonfumigated soil increased tuber weight

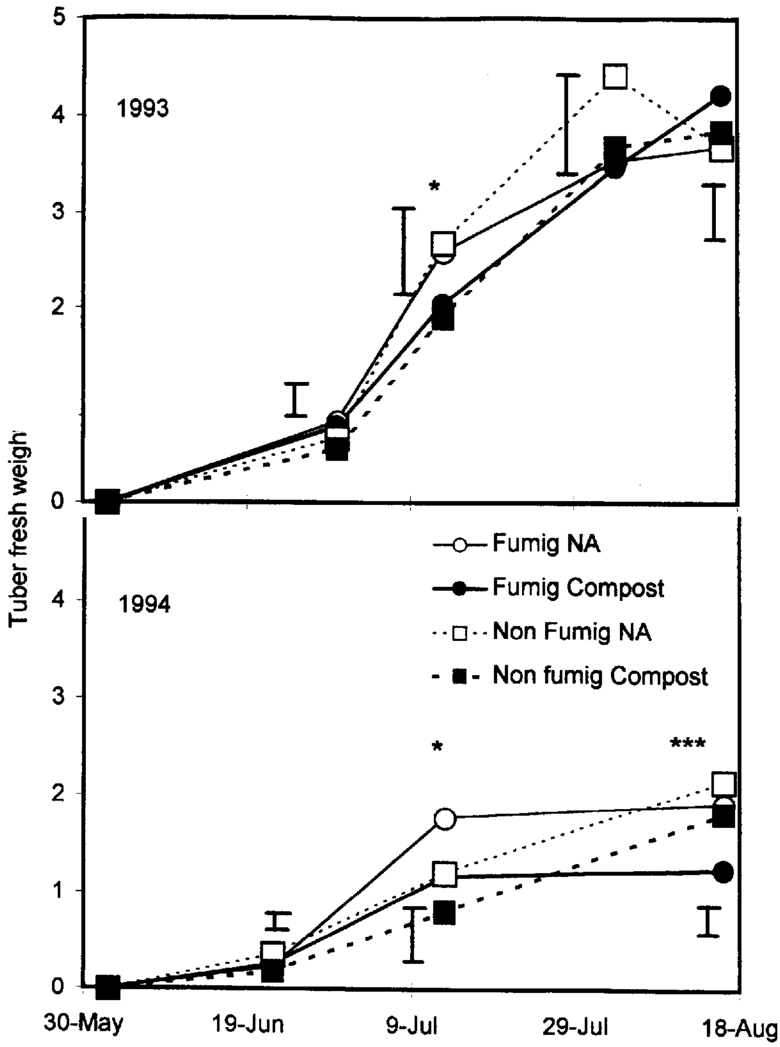

Figure 2: The effects of fumigation and compost amendment on tuber fresh weight of potato in 1993 and 1994. Symbols represent the average of 8 sub-plots. * indicates significant differences at P<0.05 due to compost and/or fumigation. The I bar indicates the least significant difference for each date.

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by two fold after 13 July. The final yield was lowered significantly by the delay in tuber filling due to compost amendment, combined with the early end to tuber filling in fumigated soil.

There was an interaction between effects of straw mulch and fumigation on yield in 1993 (Table 1). At mid-tuber filling, straw mulch decreased the tuber weight from 2.7 to 1.9 $kg{\cdot}m^{-2}$ within fumigated plots, but it increased from 2.1 to 2.4 $kg{\cdot}m^{-2}$ in nonfumigated plots (data not shown). In 1993, the final yield of potatoes in plots without fumigation or straw mulch was 0.5 $kg{\cdot}m^{-2}$ less than that in other plots. In 1994, there was an interaction between the effects of straw mulch and compost on tuber growth. Straw mulch increased tuber yield by 0.2 $kg{\cdot}m^{-2}$ in plots without compost, but had no effect on yield in plots amended with compost.

Concentration of Mineral Elements in Plant Tissue.

The concentrations of major mineral elements in leaves of potato plants grown in plots amended with compost was higher than in nonamended plots. Fumigation of the soil often prevented this increase in nutrients in the leaves. At and after flowering in 1993, leaves from plants in compost amended plots had a significantly higher concentration of N than leaves from nonamended plots (Table 2). This difference was greatest on 13 July 1993, when the concentration of N in leaves began to decrease in all the treatments (Figure 3). On this date, leaves of plants in compost amended plots had 3 g kg^{-1} more N than those in nonamended plots, if the soil was not fumigated, while this difference was less than 1 g N kg^{-1} in fumigated soil. Thus, compost had a greater effect on leaf N in nonfumigated soil.

Compost amendment prevented some of the loss of N from leaves after the first sampling date in 1994. Among plants grown in nonfumigated soil and harvested on 13 July 1994, the leaves from plots amended with compost had 3 g kg^{-1} more N than those without compost (Figure 3). Leaves from plots mulched with straw had 3 g kg^{-1} less N than those not mulched (data not shown). Neither compost amendment nor straw mulch had a significant effect on plants grown in fumigated soil, so there were significant interactions between the effects of fumigation and cultural amendments (Table 2).

On and after 30 June 1993, plants grown in compost amended soil had leaves with a

TABLE 2.
Repeated measures analysis of variance of effects of fumigation, compost, and straw mulch on composition of potato leaves measured on three dates in two years.

		Mean Squares					
	Degrees Of	1993			1994		
Factor	Freedom	N	P	K	N	P	K
		—	$g{\cdot}kg^{-1}$	—	—	$g{\cdot}kg^{-1}$	—
Fumigation (F)	1	14	0.02	4.2	0.0	0.01	66.7 ^{**Z}
Compost (C)	1	94.5*	0.41*	94.4	35.4***	0.06	230.7***
Straw (S)	1	0.8	0.03	15.2	26.1***	0.02	16.9
C x S	1	33.7	0.35*	1.2	25.0***	0.00	31.8*
C x F	1	52.7	0.00	55.9	7.1*	0.01	26.1
S x F	1	3.1	0.00	0.0	25.6***	0.54*	60.0*
S x C x F	1	8.5	0.33*	0.3	0.8	0.00	109.3**
Error	8	14.0	0.05	102.8	0.8	0.10	6.0
TimeY	2	772.2	25.8	148.2	2673.3	18.74	408.3

$^{Z\ *,\ **,\ ***}$ effects significant at P<0.05, P<0.01, and P<0.001, respectively.
^{Y} All effects of time significant at P<0.001. Interactions between the effects of time and other factors not shown.

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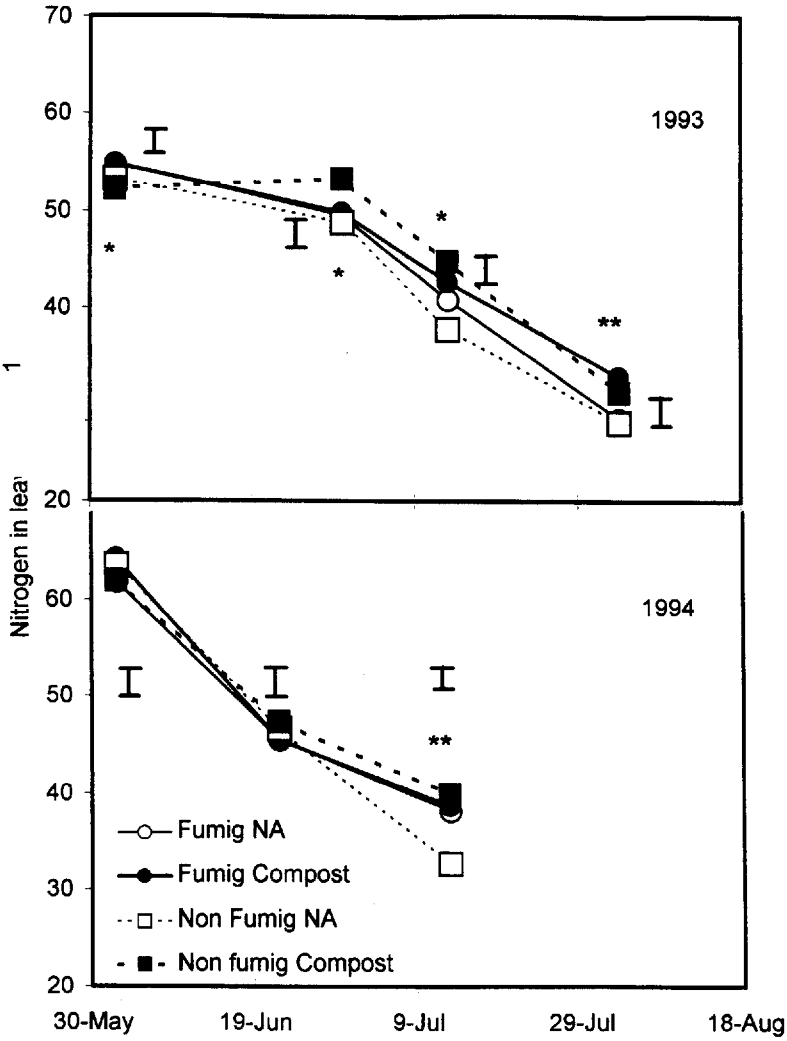

Figure 3: The effects of fumigation and compost amendment on concentration of N in leaf blades of potato in 1993 and 1994. Symbols represent the average of 8 sub-plots. * indicates significant differences at P<0.05 due to compost and/or fumigation. The I bar indicates the least significant difference for each date.

higher concentration of P than those grown in nonamended soil (Table 2). For plants grown in nonfumigated soil, this difference was 0.2 - 0.6 g P kg^{-1}, but it was only 0.0 - 0.3 g P kg^{-1} in fumigated soil. In 1993, the combination of compost and straw mulch resulted in the highest concentration of P in leaves of plants grown in nonfumigated soil, but P did not increase with straw mulch in the absence of compost. On 13 July 1994, plants grown in nonfumigated soil amended with compost had 0.3 g kg^{-1} more P than those without compost. However, compost had no effect averaged over all sampling dates in 1994.

Compost amendment increased the concentration of K in leaves on 13 July and 3 Aug 1993 (Figure 4), and on 13 July, this increase was greater in nonfumigated than in fumigated soil. Fumigation decreased the concentration of K in leaves on 2 August. On 22 June and on 13 July in 1994, both compost amendment and fumigation increased the concentration of K in leaves (Figure 4). This was the only instance where the combination of compost and fumigation increased the mineral content of leaves. Averaged

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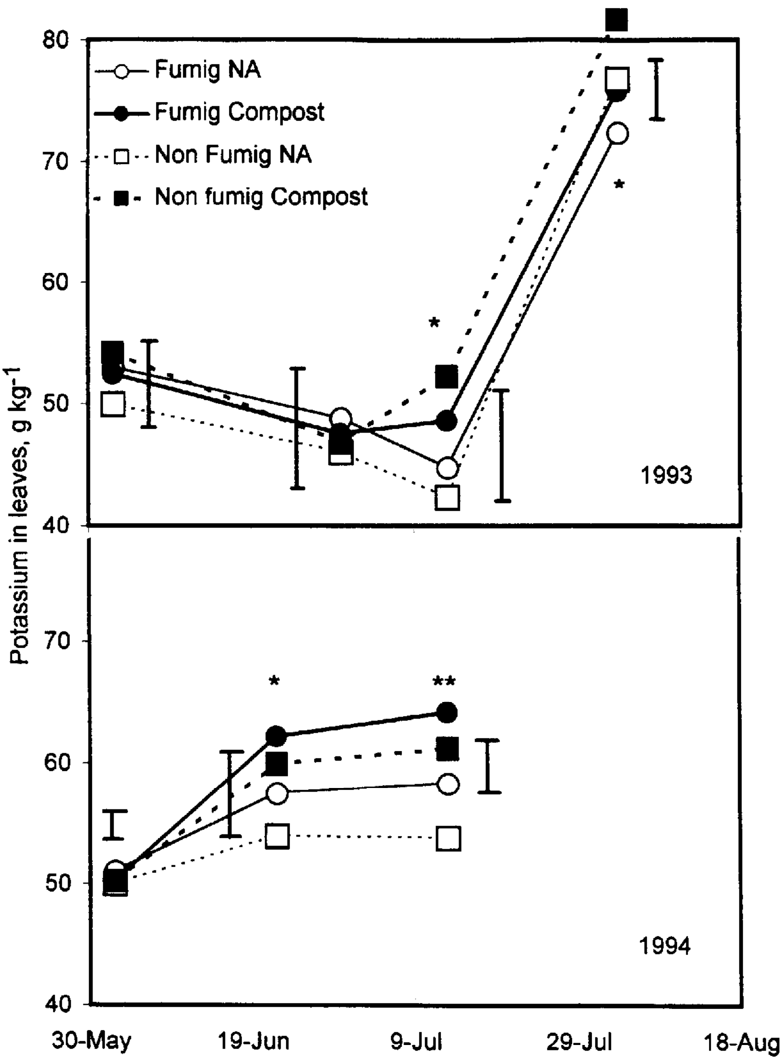

Figure 4. The effects of fumigation and compost amendment on concentration of K in leaf blades of potato in 1993 and 1994. Symbols represent the average of 8 sub-plots. * indicates significant differences at $P<0.05$ due to compost and/or fumigation. The I bar indicates the least significant difference for each date.

over sample dates in 1994, both straw mulch and compost amendment increased the concentration in leaves by 3 g K kg^{-1} for plants in nonfumigated soil, but compost and not straw increased K if the soil was fumigated. The interaction of these effects was significant (Table 2).

Discussion

Effect of Cultural Amendments

Amending the soil with spent mushroom compost increased vegetative growth of potato, as indicated by shoot weight, over all sampling dates in 1993, and during tuber filling in 1994. However, compost amendment did not increase the final yield of tubers in 1993, and amending fumigated soil with compost decreased the yield in 1994. Compost delayed tuber filling. In mid July in 1993 and 1994, the tuber weight

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in compost amended plots was less than in nonamended plots. The tubers grew more in compost amended than in nonamended plots after mid July in 1993, so the final yields were similar. However in 1994, tuber weight did not increase after mid July in fumigated plots. In this same field in 1992, when Colorado potato beetles were not controlled in the plots that compared fumigation to no fumigation, compost amendment also increased vegetative growth more than it increased the yield of tubers (Stoner *et al.* 1996). In 1992, compost delayed tuber filling, and fumigation decreased yield. In both 1992 and 1994, the delay in tuber filling due to compost amendment resulted in a low yield in fumigated soil, because the duration of tuber filling was short. Fumigation did not exacerbate the delay in tuber formation due to compost. In studies of the effects of composts on other vegetables, yields were increased after addition of composted animal manure alone (Maynard 1994), and in combination with spent mushroom compost (Steffen *et al.* 1994). However, spent mushroom compost alone did not increase yields, perhaps because it had only 6 g N kg^{-1}, which is substantially less than the 20 g N kg^{-1} contained in composted animal manure (Maynard 1994).

Application of straw mulch increased shoot weight in 1994, but did not increase tuber yield in either 1993 or 1994. Straw mulch did not increase potato yield in another study where Colorado potato beetles were controlled (Matheny *et al.* 1992), although it did increase the yield in the presence of Colorado potato beetles (Zehnder and Hough-Goldstein 1990; Stoner 1993). The latter authors attributed some part of the benefit of straw mulch to a reduction in Colorado potato beetle populations, and part to cooler, wetter soil, which promoted tuber growth. The straw mulch may have had little effect in our study, because it was conducted in two relatively cool, wet years, and we irrigated the field.

Effect of Fumigation

Fumigating the soil did not increase the final yield of potatoes in 1993, and fumigation decreased the yield in 1994. The defoliation associated with early dying was partly alleviated by fumigation, as it increased the fraction of the soil covered by the canopy averaged over the season in 1993 (Stoner *et al.* 1996). It increased the leaf area in 1994. However, even with fumigation, the leaves did not survive late in the season in 1993 or 1994. In part, fumigation failed to increase yield because Colorado potato beetles defoliated all plots by August in each year. Some plots adjacent to the ones used in this study were infested with this insect, which migrated to the noninfested plots in close proximity. Fumigation increased vegetative growth, but this was more than offset by a greater number of Colorado potato beetles that emerged in fumigated plots (Stoner *et al.* 1996). Because Colorado potato beetles defoliated the plants, our potato yields were generally low. In a study with better insect control, fumigation did increase potato yields in fields infested with *Verticillium* in combination with *Pratylenchus* (Rowe *et al.* 1987). Just one year of fumigation of a field in Connecticut infested with *Pratylenchus* but not with *Verticillium* extended the life of the crop, and increased the yield of potatoes in the next three years (Miller and Hawkins 1969).

Relation Between Treatments and Nutrition

In part, the lack of response to fumigation in our experiments may be due to an interaction between the effects of fumigation and compost amendment on mineral nutrition of the potato plants. Compost amendment, and straw mulch in combina-

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tion with compost, tended to increase the concentration of N and P in leaves of plants grown in nonfumigated soil, but these cultural treatments had less effect in fumigated soil. Fumigation may indirectly affect soil fertility through effects on soil microbial activity. In two out of three years of a study without compost amendment, fumigation reduced the concentration of soil nitrate and did not increase the yield of potato (Workman *et al.* 1977). Fumigation with methyl bromide reduced microbial activity in wheat fields for two years, and more of the soil N was mineralized (Malkomes 1996). Fumigation inhibited vascular arbuscular mycorrhizal colonization of legume roots for 90 days, and the concentration of P in the plants was reduced in a manner correlated with colonization (Udaiyan *et al.* 1995). Thus fumigation may interfere with the beneficial effects of compost on plant nutrition that arise from increased soil microbial activity. In our study, effects of the treatments on yield of potatoes were related to their effects on the concentrations of N and P in leaves, but the yield was not related to the concentration of K. Whereas compost amendment increased N and P and tuber yield, in nonfumigated plots only, it increased K in both fumigated and nonfumigated plots. Straw mulch also increased the concentration of K in leaves without increasing tuber yield.

Summary

Compost amendment improved the mineral nutrition and shoot growth of a potato crop, but did not consistently improve yield. The spent mushroom compost used in this work delayed tuber filling. Compost was not beneficial when applied in combination with fumigation, in part because fumigation negated the improvement in mineral nutrition of the leaves brought about by compost. Although there was a synergistic effect of compost amendment and straw mulch on plant nutrition in nonfumigated soil, this synergy was not observed in fumigated soil.

Acknowledgments

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