

UTILIZATION OF COMPOSTED ORGANIC WASTES IN VEGETABLE PRODUCTION SYSTEMS

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ABSTRACT

This Bulletin discusses the use of compost in vegetable production systems in Florida, United States. It discusses the surface application of compost as a mulch, soil amendment, and as a method of weed control. N mineralization in compost after application, and the leaching of N from compost, particularly in compost applied to sandy soils, are described.

INTRODUCTION

In Florida, of the 20.3 million mt of municipal solid wastes produced in 1992 (Florida DEP 1993), nearly 60% were biodegradable organic materials (Smith 1994). Compost facilities for municipal wastes, and compost production rates should dramatically increase in the future in the United States. There are a growing number of state regulations which limit the disposal of biodegradable materials in land fills. There are also cost-effective compost production facilities, both private and public, producing a high-quality end product, while commercial agriculture is making increasing use of compost.

Rynk (1992) has defined composting as 'a biological process in which microorganisms convert organic materials such as manure, sludge, leaves, paper, and food waste into a soil-like material called compost'.

Materials used for compost may include mixtures of garden refuse, wood chips, paper, food wastes, and sewage sludge (biosolids). Production methods vary from inexpensive and simply operated static piles to very expensive, highly technical and computerized in-vessel operations, as described by Rynk (1992) and Hughes (1980). Feedstock materials, composition, method of production, and size and time of production, all affect the chemical, biological, and physical characteristics of compost.

Keywords: Biosolids, compost, municipal solid wastes, organic wastes, vegetable crops

He *et al.* (1995) have reported differences in the physical and chemical properties of ten composts collected in production facilities in different parts of the United States.

Compost application to commercial vegetable crops is relatively new in the United States. Research has demonstrated that compost can serve as a soil amendment to improve soil moisture and nutrient holding capacity, particularly in sandy soils; increase soil organic matter; and ultimately improve plant growth and yields. Compost may be utilized as an alternative to polyethylene mulches, serve as an alternative form of weed control, and increase soil fertility in vegetable crop production systems. This Bulletin presents information on organic waste composts used as mulches and soil amendments in vegetable crop production systems in Florida.

COMPOST AS A POTENTIAL MULCH

Polyethylene is utilized as a mulch in many commercial vegetable production systems in Florida. The polyethylene is used as a cover on raised beds to increase or decrease soil temperatures, conserve soil moisture, provide an effective weed control barrier, reduce leaching of inorganic nutrients, particularly in the heavy rainfall (>100 cm/year) of the subtropical and tropical production areas, and serve as a vapor barrier for soil fumigants such as methyl bromide. In Florida alone, more than 9.5 million kg of polyethylene are used for agricultural production each year (Servis 1992). The disposal of plastic through collection and disposal in landfill or direct burning with propane is becoming increasingly costly. Therefore, we have investigated the potential use of compost in combination with living mulches as an alternative to polyethylene mulch in an intensive vegetable crop production system in south Florida.

The use of organic materials as mulches can slow the evaporation of water from the soil surface, moderate soil temperatures, serve as a source of slow release nutrients, reduce the germination of weed seeds and subsequent weed growth, and protect soil from erosion and structural breakdown by sun, wind, and rainfall. Many composts, especially those high in fiber or with larger particles, can be used as mulches, although research results on this application are limited. Palada *et al.* (1992) reported slightly higher fresh weight yields of basil (*Ocimum basilicum*) when a compost mulch was used, compared with black polyethylene mulch. They suggested that soil temperatures under the black polyethylene mulch may have been too high for optimum basil production. Roe *et al.* (1993b) reported that

plots with organic mulches contained higher levels of moisture, but soil temperatures were not significantly different, when compared with plots covered with polyethylene (Table 1).

A compost of sewage sludge and garden refuse was applied to the surfaces of raised beds, (1.7 m center to center, 90 cm wide and 20 cm high) at rates of 112 and 224 mt/ha before the transplanting of bell pepper (*Capsicum annuum* L.) (Roe *et al.* 1992). St. Augustine grass (*Stenotaphrum secundatum*) sod was planted on the sides of half the beds to serve as a living structural support to the beds. Control plots were mulched with white polyethylene, since planting dates were in late summer. The Ca and Mg contents were higher in leaf tissue from plants grown under polyethylene than from other treatments, but all were within an adequate range (Roe *et al.* 1993b). Pepper fruit yields with compost mulch were higher than those without mulch, but lower than those from plots mulched with polyethylene (Table 2). Fruits from plots mulched with polyethylene were larger than those from plots with compost mulch or no mulch.

Spaghetti squash (*Cucurbita pepo* 'Tivoli') was seeded into raised beds covered with white polyethylene or organic mulches of composted municipal wastes, a dried sewage sludge product, or aged wood chips, at a rate of 224 or 336 mt/ha (Roe *et al.* 1993b). Although initial squash plant stands were higher in plots with a polyethylene mulch, plants had poorer growth after 36 days (Table 3). The production of fruit per plant was higher from plants mulched with polyethylene, but plant death in those plots was relatively common. As a result, plants that had a mulch application of municipal wastes or wood chips had higher yields. High salt levels in the dried sewage sludge resulted in plant stunting and subsequent plant death.

After the final squash harvest, bell pepper seedlings were transplanted into the same beds. The yield and size of peppers from plants in the plots mulched with polyethylene were generally higher than in organic mulch plots (Table 3). Of the organic mulches, yields were highest from the plots with composted municipal wastes.

Yields from vegetable crops grown with compost mulches were generally higher than those from unmulched plots, but not as high as yields from plots mulched with polyethylene. However, in some growing situations, organic mulches, and particularly compost mulches, may be preferable to the use of polyethylene (eg. where suitable mulch and application equipment are available, or there are problems with the disposal of polyethylene mulch).

Table 1. Soil moisture and temperatures under white polyethylene mulch and organic mulches (Roe *et al.* 1993b)

Mulch	Percent water (w/w) at soil depths (cm)		Mean temperatures ¹ (C)		
	0-7.5	7.5-15	Morning	Midday	Afternoon
Polyethylene mulch	5.2	5.8	23.5	25.0	26.2
Organic mulches (ORM)					
Municipal solid wastes	6.0	6.3	24.5	24.9 b*	26.1 b
Wood chips	6.1	6.5	26.5	24.1 c	24.6 c
Dried sewage sludge	6.5	6.4	24.7	25.8 a	27.7 a
Rate (mt/ha) (R)					
224	6.1	6.3	-	-	-
336	6.3	6.5	-	-	-
Significance	NS	NS	-	-	-
ORM*R	NS	NS	-	-	-
Contrasts					
PM vs ORM	**	**	NS	NS	NS

NS** Nonsignificant or significant at P = 0.01.

1 Temperatures were recorded from 17 April - 18 June, 1992. Recording times were: morning 6-9 AM; midday 11 AM - 1PM; afternoon 4-7 PM.

2 Mean separation in columns by Duncan's multiple range test, P = 0.05.

These results suggest that organic mulches may serve as a potential alternative to polyethylene mulch. Organic mulches can have a beneficial response in reducing populations of some soil-borne pathogens, enhancing soil fertility, increasing soil organic matter, and reducing weed growth. However, whether organic mulches can achieve yields similar to, or higher than, a crop mulched with polyethylene, will depend on the characteristics of the organic mulch, the amount applied, the soil microorganisms, and the vegetable crop grown.

COMPOST AS A SOIL AMENDMENT TO IMPROVE SOIL FERTILITY

Fertilizer is an essential part of any vegetable production system. In intensive production systems, inorganic forms of nutrients are usually applied either before sowing or transplanting, or just afterwards. Systems with drip irrigation utilize fertigation as a method of delivering nutrients. Concern exists over the environmental effect of nutrients leaching into groundwater in areas of intensive production, particularly in vulnerable soils such as the sandy soils of south Florida. As a result, alternatives

to chemical fertilizers are being investigated. 'Best Management Practices' (BMP) are being developed as a result of these investigations.

Compost applied as a soil amendment can improve the soil organic content, the water and nutrient retention in soils susceptible to leaching, and stabilize soil pH. Compost can be a source of both macro- and micro-nutrients. However, these benefits can be reduced in hot humid climates, in which the decomposition of organic matter is faster than in temperate climates (Dick and McCoy 1993).

Stoffella and Graetz (1996) reported that total tomato yields, and also early marketable yields, were higher and mean fruit size (g/fruit) was larger, in plots amended with sugarcane filtercake compost (224 mt/ha) as compared to control plots without compost. This occurred whether 0, 50, or 100% (153N-134P-280K kg/ha) of a standard fertilizer was used. Green pepper plots amended with compost (sewage sludge/garden refuse) (134mt/ha) gave higher marketable yields than unamended plots, regardless if 0 or 50% (354N-39P-322K) of a standard growers' fertilizer was used (Roe *et al.* 1997). After the final pepper harvest, cucumber (*Cucumis sativa*) was subsequently sown in the same plots. Plots

Table 2. Mean marketable fruit yield and fruit size of green peppers grown with compost or polyethylene mulches

No. treatment	Total marketable fruit (mt/ha)	Mean fruit size (g/fruit)
1. No mulch	32.7	174
2. No mulch, sods on sides and top of ridge	24.5	181
3. Strip of plastic	33.1	174
4. Strip of plastic, sod on sides	37.7	173
5. Full polyethylene cover + fumigation	39.1	188
6. Full polyethylene cover	38.0	180
7. 112 mt/ha compost	31.1	170
8. 112 mt/ha compost and sod sides	32.9	175
9. 224 mt/ha compost and sod sides	34.4	167
10. 224 mt/ha compost and sod sides	34.3	166
Orthogonal contrasts		
1&2 vs 3,4 & 7-10	**	*
1 vs 2	**	NS
3&4 vs 7-10	NS	*
3 vs 4	NS	NS
5&6 vs 1-4&7-10	**	**
5 vs 6	NS	NS
7&8 vs 9&10	NS	NS
7 vs 8	NS	NS
9 vs 10	NS	NS

NS, **, *: Nonsignificant, significant at 1 (**) or 5% (*) levels, respectively
Source: Roe *et al.* 1992

Table 3. Yield of squash and green pepper under white polyethylene mulch and organic mulches

Mulch	% stand (36 DAS)	Squash			Bell pepper	
		Fruit yield mt/ha	kg/plant	Size kg/fruit	Fruit yield mt/ha	Size g/fruit
Polyethylene mulch	21	8	3.6	1.3	47.0	176
Organic mulches (ORM)						
Municipal solid wastes	69 az	12 a	1.1 b	0.9 b	44.7 a	171
Wood chips	49 b	13 a	2.0 a	1.1 a	32.9 b	173
Dried sewage sludge	56 ab	5 b	0.5 c	0.9 b	26.9 b	173
Rate (mt/ha) (R)						
224	63	10	1.1	1.0	35.3	173
336	53	10	1.3	1.0	34.4	172
Significance	NS	NS	NS	NS	NS	NS
ORM * R	NS	NS	*	NS	NS	NS
Contrasts						
PM vs ORM	*	NS	**	NS	**	NS

NS, **, *: Nonsignificant, significant at P = 0.05, or P = 0.01, respectively.
z Mean separation in columns by Duncan's multiple range test, P = 0.05

Source: Roe *et al.* 1993

amended with compost gave higher marketable yields than those without, regardless of fertilizer rate (Roe *et al.* 1997).

Green peppers were transplanted into plots amended with a compost of sewage sludge/garden refuse/mixed paper (MWP compost) and compost of a sewage sludge and garden refuse at 0 and 134 mt/ha with 0, 50, or 100% standard growers' fertilizer (354N-39P-322K kg/ha). The experimental design, methods, and procedures were reported by Roe *et al.* (1997). The physical, chemical, and nutrient composition of the two composts are shown in Table 4. Plots with both types of compost gave a higher early and total marketable yield, as compared to plots given neither compost nor fertilizer. In plots where 50% fertilizer was applied, yields did not differ between compost treatments. However, in plots where 100% fertilizer was applied, the compost of sewage sludge/garden refuse/paper gave higher yields and larger fruit (g/fruit) than unamended plots with 100% fertilizer applied.

These results suggest that the sandy soil amended with compost generally had higher vegetable yields than unamended soil, regardless of the levels of inorganic fertilizer applied. Compost may provide supplemental nutrients, particularly when inputs of chemical fertilizer are low. However, even at higher rates of chemical fertilizer, compost may improve water retention, reduce nutrient leaching, and/or provide an additional source of organic matter, particularly in infertile soils.

COMPOST AS PART OF AN INTEGRATED WEED MANAGEMENT PROGRAM

There is an estimated 13% average annual loss of potential production due to weeds in the United States (Dusky *et al.* 1988). Herbicides are the most widely used pesticide. Their popularity is due to the savings they bring in farm labor, their selectivity with regard to weed species, and their ability to increase yield and reduce production costs. Although, the application of herbicides contributes to high productivity, long-term herbicide usage can have a negative impact on the environment. In Florida, the Environmental Protection Agency (EPA) has removed several herbicides from the market, because of groundwater contamination and harmful effects on wildlife and human health (Crnko *et al.* 1992).

Organic mulches were an important method of weed control before the development of herbicides in commercial vegetable production. A layer of 10-15 cm of mulch was needed to discourage weed

growth (Anonymous 1992). In general, weed seed germination declines as the depth of the covering layer increases, probably due to unfavorable conditions such as high or low temperature, absence of sufficient moisture, O₂, light, and high CO₂ levels (Baskin and Baskin 1987). Organic mulches can be as effective as conventional herbicides in controlling weeds (Aparbal-Singh *et al.* 1985). Since growers now have access to fewer registered herbicides, and many weed species are becoming tolerant to herbicides, growers are becoming willing to try alternatives to chemical weed control.

Suppression of weed growth is one of the most important effects of organic mulches (Anonymous 1987, Grantzau 1987). Weed reduction by organic mulches may be only partly the result of an unfavorable environment for weed germination or growth associated with the physical presence of the material on the soil surface. It may also be partly due to the action of phytotoxic compounds produced during the composting process. Identification of phytotoxins in water extracted from immature compost indicated the presence of acetic, propionic, and butyric acid in high concentrations (DeVleeschauwer *et al.* 1981). The total concentration of acetic acid in immature compost made of sewage sludge, garden refuse, and paper was between 6,000 and 28,000 ppm (Keeling *et al.* 1994). The addition of nitrogen to the immature compost did not improve germination rates. This suggests that poor seed germination and growth inhibition were not due to the high C:N ratio, but to phytotoxicity (Keeling *et al.* 1994). Applications of mature compost were found to reduce weed growth between rows of vegetable crops, as compared to an untreated control (no compost application). However, plots treated with herbicide had improved weed control than those with compost (Roe *et al.* 1993a).

Organic mulches also improve the soil, by reducing erosion by heavy rain, minimizing compaction, increasing the water-holding capacity of the soil, slowing the release of nutrients, increasing microbial activity in the soil, and controlling soil temperature (Anonymous 1987, Anonymous 1992, Villareal 1980).

Tests were conducted on the effectiveness of a compost made from municipal wastes, garden refuse and paper in controlling weeds between vegetable rows. The elemental content and chemical properties of the compost are presented in Table 6. To separate the physical from the chemical weed control properties, extracts were made of water and compost which ranged from three days to eight weeks in age. Compost extract prepared with 20 g

Table 4. Composition, water holding capacity, carbon:nitrogen ratio, and nutrient and heavy metal concentrations of composts.

Characteristic	Mixed waste paper	Refuse-derived fuel
Compost feedstock (% by volume)		
Sewage sludge	20.4	18.5
Yard trimmings	43.6	17.8
Mixed waste paper	36.0	-
Refuse-derived fuel	-	63.7
Water holding capacity (g·g⁻¹)		
	1.91	-
C/N ratio		
	16.9	12.7
Nutrient and heavy metal content		
		(ppm)
NH ₄ ⁺ -N	260	163
NO ₃ ⁻ -N	35	397
Mn	88	104
Zn	247	318
Cu	348	219
Cd	3.6	5.0
Pb	46	93
Ni	13	20
		(%)
C	27.2	23.5
N	1.61	1.85
P	0.88	0.98
K	0.35	0.34
Ca	4.01	4.57
Mg	0.21	0.23
Fe	1.00	1.16
pH	5.9	6.4
EC (dS·-1)	3.55	6.37

1) NH₄⁺-N, NO₃⁻-N are ppm in saturated water extracts of the composts

(dry weight) of compost and 50 mL of water was the most sensitive assay, providing the widest range of germination of Ivyleaf Morningglory (*Ipomoea hederacea*) seed of in response to compost of different maturities (Fig. 1). Extracts from immature (3-day, 4-week, and 8-week-old) compost resulted in delayed and reduced germination of a number of important economic weed species (Ozores-Hampton *et al.* 1996, Shiralipour *et al.* 1991).

The effectiveness of a bioassay at predicting Ivyleaf Morningglory injury was tested. Ivyleaf Morningglory seeds were sown in pots filled with sand at 1.0 cm depth with immature (3-day-old) compost, mature compost or commercial artificial

media, applied as a 7.5 cm deep mulch layer on the sand. A randomized complete block design with six replications per treatment was used. Plant emergence and seedling growth (shoot and root dry weight) were recorded. Immature compost (3-day-old) delayed emergence by four days and decreased percent emergence by 50% as compared to the control (data not shown). Shoot and root dry weight per pot were lower in immature compost than mature compost, artificial media and the control (Data not shown).

Similar results were reported by Chanyasak *et al.* (1983) with immature compost that inhibited the growth of Komatsuna (*Brassica rapa v.*

Table 5. Elemental concentration, chemical analysis, and volatile fatty acids concentration in compost of varying maturities.

Characteristic	Compost age			
	3 day	4 weeks	8 weeks	Mature
	% dry weight			
C	37.1	39.1	35.7	34.3
N	1.15	1.23	1.20	1.60
P	0.24	0.29	0.27	0.32
K	0.28	0.30	0.31	0.31
Ca	2.04	2.18	2.37	3.10
Mg	0.20	0.23	0.27	0.32
Fe	0.77	0.92	0.98	1.15
	mg/kg dry weight			
Cd	4.30	3.75	3.50	5.63
Cu	127	184	178	229
Mn	174	219	220	300
Pb	207	212	264	283
Ni	32.4	42.8	44.0	51.5
Zn	446	561	552	720
Moisture (%)	47.0	35.6	37.5	47.6
C/N	32:1	32:1	30:1	21:1
pH	7.2	6.8	6.3	7.7
EC (dS·m ⁻¹)	6.6	8.8	9.4	6.7
GI ^z (%)	0	0	0	100
	ppm			
Acetic	2474	1790	1776	13
Propionic	311	102	262	<10
Isobutyric	24	<10	22	<10
Butyric	171	113	265	<10
Isovaleric	62	<20	<20	<20
Valeric	33	<40	<40	<40

z Germination Index (Zucconi *et al.* 1981b).

'Pervidis'). This inhibitory effect on growth, especially in the early stages of composting, may be associated with the presence of low molecular weight fatty acids, especially propionic acids and n-butyric acid. Higher shoot dry weight occurred when mature compost was applied, and may have resulted from the higher nutrient content and absence of phytotoxins in the compost. In general, compost applications reduced the dry weight of roots, as compared to the control (no mulch). Salt content, heavy metals, and C/N ratio may be responsible for a decrease in the percent germination, percent emergence, and shoot and root dry weight. However, a chemical analysis of the composts indicated that only small chemical changes occurred in compost after it was three days old until it reached maturity (Table 5).

Under field conditions, eight-week-old compost was applied in the spaces between raised vegetable beds covered with a polyethylene mulch. The compost mulch was applied at a thickness of 3.75, 7.50, and 11.25 cm. Weed control in areas mulched with compost was evaluated visually as percentage weed cover, dominant weed species, and total weed dry weight. Immature compost was found to reduce weed cover for 240 days after treatment (DAT), as compared to the untreated control (Fig. 2). The thickness of the compost had no effect for the first 25 DAT, but from 25 to 240 DAT weed cover decreased linearly as compost thickness increased. Compost applied in a layer at least 7.5 cm thick completely inhibited weed germination and growth for 240 DAT. The effectiveness of immature com-

Table 6. Carbon content, total nitrogen, C/N ratio and mineralization rate (after four month incubation) of five composts (Stoffela *et al.* 1997)

Compost	C	N	Initial	Final	N Mineralization Rate (%)
	%		C/N ratio		
MSW + sewage sludge (MSWB1)	34.7	1.28	27	17	-2.1
MSW + sewage sludge (MSWB2)	17.9	0.91	20	12	0.6
MSW + sewage sludge (MSWB3)	23.2	1.60	14	12	1.8
Sewage sludge (B)	11.4	1.63	11	11	9.1
Sugarcane filtercake (SF)	29.5	2.22	14	13	7.6

MSW - Municipal solid waste

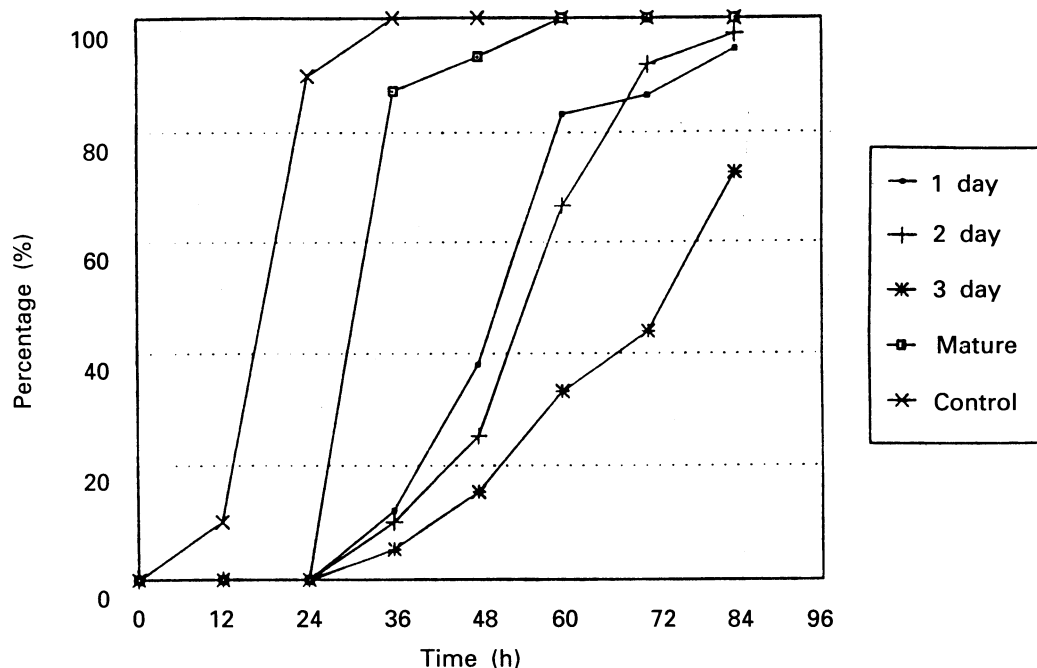


Fig. 1. Effect of compost:water (20g:50mL) extracts and compost age on germination of Ivy leaf Morning glory

post in controlling weeds shows its potential for decreasing herbicide usage in vegetable production systems.

Compost, particularly immature compost, may be a potential alternative to weed control between beds of vegetables. The immature compost will eventually mature under field conditions. Subsequently, the compost can be incorporated into the soil of vegetable beds and used for the next season's crop, with all the benefits this will bring of a mature compost application.

MINERALIZATION OF COMPOST

Compost mineralization is the biological reaction whereby organic nitrogen is converted into inorganic forms ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$). The mineralization of compost generally depends on the composition and maturity of the compost, and environmental conditions (soil moisture, soil temperature, etc.) after application. Determination of the rate of compost mineralization is essential to determine proper application rates and application frequencies, and to

predict potential N uptake by crops and off-season N losses.

Estimates of N mineralization are often based on incubation methods, either in the laboratory or under field conditions. Probably the laboratory approach that most closely simulates a field situation is the incubation/leaching method (Stanford and Smith 1972). Soil or compost is packed inside a plastic column, moistened, incubated, and periodically leached with 0.01 M CaCl₂ solution to remove mineralized N. The main criticism of this approach is that it may also leach out some of the soluble organic N (Beauchamp *et al.* 1986). The most commonly used method of determining N mineralization under field conditions is to incubate samples inside sealed polyethylene bags buried in the soil (Eno 1960). The difference in the levels of inorganic N concentrations at the beginning and end of the incubation period is the net N mineralization, or immobilization. A second method is to incubate samples in plastic or metal columns, which are inserted into the soil and covered to prevent leaching of nutrients (Raison *et al.* 1987). Moisture is exchanged between the sample and the surrounding soil through the bottom of the column or through small holes in the column. Both methods have advantages and disadvantages (Scubler *et al.* 1995). However, the two methods yield similar estimates of net N mineralization rates.

Nitrogen mineralization rates for five different composts produced in Florida were evaluated,

using the column incubation method over a five-month period. The columns were inserted into a raised bed covered with a polyethylene mulch of the kind typical of those used for tomato production in Florida. A PVC column (5 cm in diameter and 8 cm high) filled with compost was inserted into the surface soil. The top of each column was covered by a PVC cap to prevent leaching and volatilization of N. Every 30 days, four columns from each compost sample were removed from the soil, and were analyzed for organic C, total N, and inorganic N (NH₄-N and NO₃-N).

After four months' incubation under field conditions, the rates of N mineralization in the compost samples varied from -2.1 to 9.1% (Table 6). The carbon to nitrogen ratio (C/N ratio) decreased in the compost made of municipal wastes. A high initial C/N ratio in the municipal solid wastes + sewage sludge compost may have resulted in N immobilization, thereby depriving increasing microbial populations of inorganic N, contributing to the negative mineralization rate (-2.1). A C/N ratio in commercially acceptable compost is <20. This ratio is presumably a dividing line between immobilization and release of N from organic materials. Applications of composts with a C/N ratio higher than 20 may result in the immobilization of soil N during the initial decomposition process. Compost with a ratio less than 20 may release mineral N during decomposition. Sims (1995) has summarized research on mineralization rates of sewage sludge, municipal

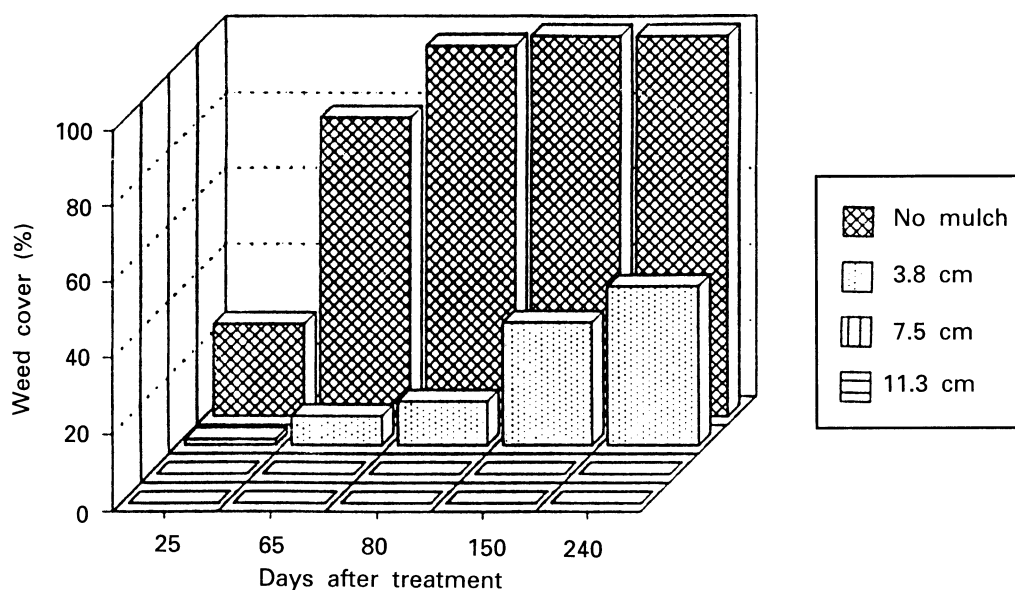


Fig. 2. Effect of 8-week-old compost mulch on percent weed cover

wastes, and sewage sludge composted together with animal wastes and industrial organic wastes. The reported N mineralization rates ranged from -44 to 67%.

NUTRIENT LEACHING FROM SOIL AMENDED WITH COMPOST

Nitrate leaching into groundwater from inorganic fertilizer has been extensively investigated and regulated in several parts of the United States. Mineralized N from compost, like inorganic N fertilizer, will move downward in the soil profile with rainfall and irrigation, and possibly move below the root zone into groundwater. High application rates have been reported to result in leaching of NO₃-N, NH₄-N, and PO₄-P from topsoil, with subsequent groundwater contamination (Peverly and Gates 1994). The field application of organic wastes such as sewage sludge (biosolids) and manure has also been reported to cause leaching of NO₃-N into the groundwater (Daliparthi *et al.* 1995).

In the USA, untreated groundwater is the source of drinking water for 50% of the total population, and 97% of those living in rural areas (National Research Council 1978). Levels of NO₃-N higher than 10 mL/L are considered to be above the permitted maximum contamination level for standard drinking water quality (USEPA 1987). Health effects associated with ingestion of nitrate-contaminated water include methemoglobinemia (blue baby syndrome) in infants (Kross *et al.* 1992), possible spontaneous abortions (USFDA 1972) and birth defects (Arbuckle *et al.* 1988).

Areas most subject to NO₃-N leaching and groundwater pollution are those with sandy, well-drained soils, a shallow water table, high rainfall, and frequent use of fertilizer and other N sources (Sims 1995). However, the over-application of organic materials and intensive irrigation has the potential to cause NO₃-N leaching, regardless of soil and climate.

Nutrient leaching is an economic and environmental concern in the agricultural coastal area of Florida, United States, because of the region's shallow water table, sandy soils and heavy rainfall (>100 cm/year), while overuse of irrigation water is common. High rates and frequent applications of compost in this area may cause leaching of nutrients to

below the root zone (<75% of citrus tree roots are found in the top 0-15 cm of topsoil in the flatwoods zone of Florida) (Zhang *et al.* 1996). Rates of compost application can vary from 25 to more than 250 mt/ha, with an N content of up to 4% (Stoffella *et al.* 1996). Therefore, it is necessary to evaluate the leaching potential of NO₃-N from compost applications in this area. We investigated the nutrient leaching rates from five types of compost in Florida (sugarcane filtercake, sewage sludge, and three mixtures of municipal solid waste and sewage sludge) applied to the surface of a fine sandy soil (sandy, siliceous, hyperthermic Alfic Arenic Haplaquods). The soil was packed in leaching columns (20 cm long and 7.5 cm inner diameter). On top, a surface layer of compost was applied at a rate equivalent to 100 mg/ha (dry weight basis). Columns were leached with deionized water at a rate of 300 mL/day for five days (equivalent to 34 cm rainfall).

Over the five-day period, leachates reached concentration of 247 mg/L of NO₃-N and 29mg/L NH₄-N (Table 7). Leached N accounted for 3.3 to 15.8% of the total N in the composts. However, leaching peaks of NO₃-N occurred after only 300-400 mL of water application (equivalent to 6.8 - 9.1 cm rainfall). Sewage sludge compost and sugarcane filtercake compost had the highest leaching rates and concentration of NO₃-N. This investigation suggests that the effects of application rates, timing, and placement should be evaluated from both an economic and an environmental point of view, before compost is applied to sandy soils in a region with high rainfall or abundant irrigation water.

CONCLUSION

Organic wastes are increasingly being converted into commercial mulches or composts. Technology has been improving compost quality, and reducing the time of production.

The reported benefits of compost include the suppression of soil-borne diseases (Hoitink and Fahy 1986, Hoitink *et al.* 1991, Hoitink *et al.* 1993), improved soil fertility (Obreza and Reeder 1994, Stoffella and Graetz 1996), and an additional source of N (Sims 1995). Compost can also serve as an alternative weed control method (Roe *et al.* 1993a), or used

Table 7. Nutrient leaching from compost amended soil columns

Compost	NO ₃ -N		NH ₄ -N		PO ₄ -P	
	Cm ^z	Cu ^y	Cm	Cu	CM	Cu
MSW + sewage sludge (MSWB1)	0.18	0.03	28.22	3.27	3.56	1.34
MSW + sewage sludge (MSWB2)	106.38	4.99	4.29	0.51	6.65	0.82
MSW + sewage sludge (MSWB3)	57.77	2.78	3.10	0.55	2.98	2.14
Sewage sludge (B)	245.89	11.07	3.54	0.36	2.57	0.16
Sugarcane filtercake (SF)	171.19	4.89	3.01	0.18	3.55	0.24

MSW - Municipal solid wastes

z Maximum concentration of NO₃-N, NH₄-N, or PO₄-P in leachates, mg/L.

Cumulative NO

instead of polyethylene mulch (Roe *et al.* 1994).

High levels of heavy metals compost made from municipal wastes, and fecal pathogens in sewage sludge, are important considerations when using compost for the production of horticultural crops (Rosen *et al.* 1993). High soluble salt concentrations can be a major concern when sewage sludge is used (Gouin 1993). Immature compost applied to crops can result in plant phytotoxicity from intermediate organic compounds (Zuconi *et al.* 1981b). If compost has a C/N ratio greater than 30, the result can be the immobilization of N (Rosen *et al.* 1993).

The application of compost to vegetable has generally, but not always, given a significant yield response. Further research should be directed towards improving compost quality and methods of application, developing methods of compost utilization as an alternative to pesticides for weeds and diseases, and developing 'Best Management Practices' for compost as a partial alternative to inorganic fertilizers in commercial vegetable production.

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