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Organic By-Product Effects on Soil Chemical Properties And Microbial Communities

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Soil management practices that contribute to increased soil productivity and long-term sustainable agricultural production have been neglected over the last four decades. The need to increase soil productivity led to the evaluation of a system of disposing of large quantities of organic by-products and poultry litter on agricultural land. Our objectives were to evaluate the effects of applying noncomposted municipal solid waste (MSW), amended with either poultry litter (PL) or NH_4NO_3 to adjust C:N ratios in the soil surface in either the spring or fall. Changes in soil chemical properties, bacteria population shifts, changes in species richness and evenness of indigenous soil bacteria, and response by cotton (*Gossypium hirsutum* L.) were evaluated. Soil P, K, Ca, and Mg were increased in the surface 0-15 cm by a factor of three or four times by application of organic by-products. After two annual applications, soil Cu increased slightly, Zn doubled, Co and Cr decreased, while Pb increased by a factor of two. Soil organic matter content increased on average by 89 percent for treatments containing newsprint, yard trimmings, and cotton gin trash. Newsprint plus NH_4NO_3 resulted in a shift to more Gram positive bacteria, while newsprint plus poultry litter resulted in a shift to more Gram negative bacteria. Both N sources resulted in a reduction in *Bacillus* sp. Shifts in the bacterial populations and changes in species richness (number of species detected) and evenness (relative abundance of each species) were induced by organic by-product additions. These shifts appear to be the result of increased substrate for C mineralization rather than any properties of biological control. Shifts in the microbial community structure towards Gram negative organisms may benefit plant growth and may be useful as an indicator of soil quality.

Introduction

Demands on soil with low or marginal productivity for increased crop production are escalating in response to increased population, loss of prime cropland to urbanization, and continued degradation through soil erosion. This is especially true for soils in the Gulf and Atlantic Coastal Plain and Appalachian Plateau region of the USA where chemical and/or physical barriers can limit crop production. Soils in these regions have sandy loam and loamy sand surface horizons, weak soil structure, low organic matter content, and acid subsoils (Adams 1981). However, the climate of the region offers the opportunity for high annual dry matter production when complimentary soil management practices are used (Edwards *et al.* 1995).

In many instances, the organic matter fraction of these soils is related to their fertility, and ultimately to their ability to sustain crop production. Soil organic matter has a major influence on soil physical and chemical properties even though it usually makes up only 0.05 to 0.10 percent (5 to 10 g kg^{-1}) of the soil mass. By returning crop residues to the soil over a three year period, soil organic matter content in the surface 15 cm was increased from 5 to 15 g kg^{-1} (Wood and Edwards 1992), and soil bulk density was decreased from 1.59 to 1.39 Mg m^{-3}. (Edwards *et al.* 1992).

On average, 67 percent of municipal solid waste (MSW) in the USA goes to landfills, 23 percent is recycled, and 10 percent is incinerated (Steuteville 1995). Average cost of disposal of MSW in landfills ranged from a low of \$8 ton^{-1} in New Mexico to \$75 ton^{-1} in New Jersey in 1994. Even though we may be willing to pay the increased cost of landfill disposal of MSW, the U.S. Environmental Protection Agency (USEPA) has established a national goal of reducing the nation's dependence on landfill disposal by source reduction or recycling (USEPA 1989). Thus, all communities in the USA must confront compliance with federally mandated laws governing the disposal of MSW, along with declining landfill space and associated increased disposal costs (USEPA 1989). Currently, about 30 to 40 percent of the MSW stream is postconsumer fiber (telephone books, third class mail, newsprint, and all other nonrecyclable paper products); these by-products are targeted to help achieve mandated recycling goals. One means of recycling the postconsumer fiber could be to apply the organic material as an amendment to agricultural land.

Organic by-products (sewage sludge, feedlot manures, poultry litter, crop residues) have been applied to agricultural land for centuries, and in many countries of the world they are the only available fertilizers for agricultural production. Land application recycles valuable nutrients and effectively disposes of the by-products. Although beneficial effects of organic by-products on crop production have been demonstrated repeatedly (Ketcheson and Beauchamp 1978; Sims 1987; Flynn *et al.* 1993; Wood *et al.* 1993), land application of such materials can promote degradation of water quality when it leaves large quantities of mineralized N at the end of the growing season (Liebhardt *et al.* 1979; Ritter and Chirnside 1984). In some states, consideration is being given to treating poultry litter with Al, Ca, and/or Fe amendments to precipitate P and reduce the risk of P contamination before it is applied to land (Moore and Miller 1994).

Addition of organic by-products to soil stimulates microbial activity or microbial biomass as evidenced by increased populations of actinomycetes, algae, bacteria, and fungi (Rodríguez-Kábana *et al.* 1987). However, variations in environmental conditions and the C:N ratio of organic by-products may exert a specific population pressure, shifting the dominance of microbial species. Very few microbial studies specifically investigated how organic by-products affect microbial species diversity, due primarily to the difficulty in identifying bacterial species using traditional biochemical tests. Little is known about the effects of soil amendments from organic by-products with high C:N ratio ($\geq$ 150:1) on the soil microflora. The objectives of this research were to evaluate the effects of repeated annual application of organic by-products on soil chemical properties, and changes in populations and structures of bacterial communities in the soil amended with organic by-products. Shifts in bacterial structure were measured by absolute changes in bacterial populations and changes in species diversity between organic by-product treatments.

Materials and Methods

Field Experiment

A field study was initiated in spring 1992, at the E.V. Smith Research Center, near Shorter, Alabama. The soil is a Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludults). The experimental area was limed to a pH of 6.3; P_2O_5 and K_2O were applied according to Auburn University soil test recommendations.

The experimental design was a randomized complete block with a 4 × 2 × 2 factorial arrangement of four noncomposted organic by-products (newsprint, woodchips, yard trimmings, or cotton gin trash), two N sources (poultry litter or NH_4NO_3), and two application times (fall or spring). Noncomposted refers to organic by-products that had not undergone significant microbial degradation. Plots were 8 rows, 9.23 m long with 1.01 m spacing between rows. 'Deltapine 90' cotton was planted at 117,205 seeds/ha approximately May 1, 1992 and 1993. Recommended practices for pest control were used throughout the season.

Ground newsprint was obtained from a commercial insulation company and contained no fire retardant. Newsprint was ground using a hammer mill equipped with a series of three screens; the smallest was approximately 0.64 cm in size. Yard clippings were simulated by grinding Coastal bermudagrass (*Cynodon dactylon* L. Persoon.) hay in a tubgrinder. Lobloly pine (*Pinus tadea* L.) woodchips (less than 5 cm diameter) were obtained from a local planing mill. Cotton gin trash was obtained from a local cotton gin in the mid-Alabama area. Poultry litter was obtained from a local poultry house and had the following nutrient composition: Total N 28.6 g kg^{-1} (NH_4-N 16.1 and $N0_3$-N 5.0 g kg^{-1}), K 27.4, P 19.0, Ca 35.1, Mg 9.4 g kg^{-1}, with < 0.2 mg kg^{-1} of Cu, Fe, Mn, and Zn. The average moisture content was 254 g kg^{-1}.

The organic by-products (newsprint, woodchips, yard trimmings, or cotton gin waste) were applied annually in the spring or fall and incorporated into the top 15 cm of soil with a vertical action tiller. When adjusted for ash and moisture content, each by-product was applied at rates equivalent to newsprint applied at 2.44 kg m^{-2} (0.5 lbs ft^{-2}). This resulted in 14,148 kg ha^{-1} of total carbon for each organic by-product. Poultry litter was applied at 4480 kg ha^{-1} (4,000 lb/acre) to supply 112 and 134 kg ha^{-1} of P and K. This poultry litter application rate was adequate to supply required amounts of P, K, Ca, and Mg for cotton, and also provided N for decomposition of the organic by-products. To promote decomposition of organic by-products receiving poultry litter, final C:N ratios of applied by-products were adjusted to 30:1 with NH_4N0_3-N. For details of experimental methods see Edwards *et al.* 1993b.

Soil samples were collected from each plot in 15 cm increments to a depth of 90 cm before application of amendments in winter 1992. Surface soil samples (0-15 cm) were also collected in September 1993, just before onset of leaf senescence, and in October 1993, after cotton harvest. The samples collected in September were processed to determine bacterial community structure for a subset of the treatments (newsprint, newsprint plus poultry litter, poultry litter and standard control). Those collected in October were processed to determine the influence of organic waste on soil N and soil organic matter content.

Greenhouse Experiment

A greenhouse experiment was conducted with soil collected from the field study area. A 3 × 2 × 6 factorial of 3 C:N ratios (20:1, 40:1 or 60:1), 2 nitrogen sources (poultry litter and NH_4NO_3) and six decomposition times (0, 2, 4, 6, 8 and 10 weeks after addition of soil amendment) arranged in a randomized complete block design with four replications was used. Samples of soil were collected nine weeks after addition of amendments to treatments that had a decomposition time of 10 weeks by removing 20g of soil from the top 5 cm of each 4 liter pot. These were used to examine microbial populations.

Chemical Analyses

Soil samples were air dried and ground to pass a 0.6 mm sieve. Soil N was determine by the Kjeldahl method (Bremner and Mulvaney 1982). Soil organic matter content was determined by Walkley-Black procedure of rapid dichromate oxidation (Nelson and Sommers 1982). A 0.5-g sample was oxidized with 1 N $K_2Cr_2O_7$ in concentrated H_2SO_4. The excess Cr_2O_7 was titrated with a 0.5 N $FeSO_4.7H_2O$ solution using a barium diphenylamine sulphonate indicator. Concentrations of P, K, Ca, Mg, Cu, Zn, Mn, B, Co, Cr and Pb were determined by ICAP spectrophotometry after extraction with a Mehlich-1 (double-acid) extracting soilution (Olsen and Sommers 1982).

Microbial Enumeration

A 10 g subsample from each soil sample was added to 250 ml flasks containing 90 ml of 0.02 M phosphate buffer. Flasks were shaken for 30 min at 200 rpm on a rotary shaker. A dilution series was prepared and plated on 5 percent tryptic soy agar (TSA) (Difco, Detroit, Michigan), chitin agar (pH 8.5 and 6.5), newsprint agar (5g newsprint/1l distilled water), and Ohio medium using a spiral plater (Spiral Biotech, Bethesda, Maryland). Plates were incubated until grown (48 h for TSA and seven days for both chitin agars and newsprint media) and were counted using either a laser counter (Spiral Biotech, Bethesda, Maryland) or visual observations to determine populations.

Bacterial Identification

Sixty colonies were randomly selected from each treatment and streaked for purity on full strength TSA. A minimum of 50 strains from each treatment in the greenhouse and a minimum of 30 strains from each experimental plot in the field experiment were identified using fatty acid analysis (Microbial ID, Inc., Newark, Delaware). Fatty acids were extracted using the method of Sasser (1990). The fatty acid methyl ester (FAME) profile of each isolate was compared to library profiles and given an identification using accompanying MIDI software (Microbial ID, Inc., Newark, Delaware).

Data Analyses

Bacterial identifications were analyzed by comparing the frequencies of each genus between treatments using least significant difference analysis (P=0.05). Bacterial populations were also compared using least significant difference analysis (P=0.05). All statistical comparisons were made using SAS (Statistical Analysis System). Richness, evenness, and diversity indices were calculated according to Ludwig and Reynolds (1988) and comparisons among treatments were made using single degree orthogonal comparisons. Unless otherwise noted, all statistical tests were reported at $P \leq 0.05$.

Results

Field Experiment

The inherent productivity of this soil is low because of low plant-available water (136 g kg^{-1}) and low soil organic matter content of 9.5 g kg^{-1} (Table 1). Soil P, K, Ca, and Mg were also extremely low, but the fertility was improved by adding P and K to eliminate this as a limiting factor in cotton production. Initial soil Cu, Zn, Mn, B, Co, Cr, and Pb and their concentrations after two annual applications of organic by-products are given in Table 1. Zinc and Pb were increased by by-product application, but their soil concentrations were still in the tolerant range for cotton production.

On the average, soil organic matter content was increased by 89 percent after two annual applications of newsprint, yard trimmings, or cotton gin trash (Table 2). Since woodchips contain a higher concentration of lignin which is more resistant to microbial degradation, soil organic matter content as measured by the Walkley-Black

TABLE 1.
Change in physical and chemical properties after two annual applications of organic by-products

Soil Properties	Initial (Winter, 1992)	After Two Applications (Fall, 1993)
Soil pH (1:1)	5.2	6.3
CEC, (cmol kg^{-1})	6.3	6.3
Field capacity (g kg^{-1})	240	240
	kg ha^{-1} soil	
K	53	296
P	32	144
Ca	306	1009
Mg	74	255
	mg kg^{-1} soil	
Cu	4.0	5.8
Zn	9.6	17.5
Mn	462	818
B	0.7	4.9
Co	6.3	4.9
Cr	3.5	0.4
Pb	6.9	16.7

method was increased only 57 percent with woodchip application. The organic by-products also increased total soil N levels by an average of 59 percent after two applications (Table 2).

Total populations of bacteria isolated from soil amended with newsprint, poultry litter, or newsprint plus poultry litter were extremely variable and not significantly different from the standard control. However, there was a significant change in bacterial community structure among treatments. Total numbers of Gram positive bacteria were significantly decreased in newsprint, poultry litter, and newsprint plus poultry litter amended soils compared to the standard control (Table 3). There was a corresponding significant increase in numbers of Gram negative genera isolated from newsprint-amended soil versus standard control soil. Richness indices were significantly higher (($P \leq 0.05$) in newsprint plus poultry litter amended soil compared to newsprint plus NH_4NO_3 amended soil, indicating a greater

TABLE 2.
Effects of noncomposted organic by-products and nitrogen sources on soil organic matter and total soil N

Organic By-products	N Sources: PL[a]	N Sources: NH_4NO_3	By-product Means	N Sources: PL	N Sources: NH_4NO_3	By-product Means
	g kg^{-1} Soil organic matter			Soil N (g kg^{-1} of soil)		
Newsprint	15.4	16.7	16.0 a[b]	1.14	1.11	1.12 a
Yard trimmings	18.4	17.5	17.9 a	1.24	1.20	1.22 a
Wood chips	16.3	13.5	14.9 b	1.26	0.98	1.13 a
Cotton gin trash	17.0	15.9	16.4 a	1.30	1.05	1.16 a
Standard	9.5	9.5	9.5 c	1.40	0.70	0.73 b
NS Means	16.7 a[a]	15.8 a		1.23 a	1.08 b	

[a]PL = Poultry litter
[b]Means within by-products and means within N sources followed by the same letter are not significantly different at the 0.05 level of probability according to DMRT.

TABLE 3.
Frequency of Gram positive and negative bacteria isolated from soil amended with newsprint and poultry litter

By-product Amendment	Field Study: Percent Gram Positive[a]	Field Study: Percent Gram Negative[a]	Greenhouse Study: Percent Gram Positive[a]	Greenhouse Study: Percent Gram Negative[a]
Newsprint	74.2	25.8	75.1	17.5
Newsprint + PL[b]	55.7[c]	44.3[c]	42.1[d]	36.5
PL	68.6	31.4	nd[e]	nd[e]
Standard	85.6	14.4	76.0	21.7

[a]Mean of three replications
[b]PL = Poultry litter
[c]Indicates significant difference from the standard treatment at P≤0.05 as determined by single degree orthogonal contrasts.
[d]Indicates significant difference from the standard treatment at P≤0.05 as determined by Chi Square analysis.
[e]nd = No data. Treatment not included in greenhouse experiment.

TABLE 4.
Species richness and evenness of the bacterial community sample isolated from soil amendment with newsprint and poultry litter

By-Product Amendment	Field Study: Richness Index[a]	Field Study: Evenness Index[b]	Field Study: Diversity Index[c]	Greenhouse Study: Richness Index[a]	Greenhouse Study: Evenness Index[b]	Greenhouse Study: Diversity Index[c]
Newsprint	2.09[*e]	0.66	4.22	2.73[f]	0.64	4.65[f]
Newsprint + PL[d]	2.24[*]	0.76[*]	5.03[*]	3.08[f]	0.87[f]	8.07[f]
PL	2.52[*]	0.82[*]	5.05[*]	nd[g]	nd[g]	nd[g]
Standard	0.88	0.58	2.24	1.02	0.59	1.85

[a]Richness is calculated according to the formula (G-1)/ln(*n*) where G=the number of genera and n=total number of isolates. Numbers represent a mean of three replications.
[b]Evenness was calculated using a Modified Hill's Ratio and numbers represent a mean of three replications.
[c]Diversity Index was the Hill's modified Simpson's diversity index $(1/(\Sigma [n_i (n_i-1)/n (n-1)])$ where n_i is the number of individuals of the *i*th genus and *n* is the total number of individuals in the sample.
[d]PL = Poultry litter
[e*]Indicates significant difference from the standard treatment at P≤0.05 as determined by single degree orthogonal contrasts.
[f]Indicates significant difference from the standard treatment at P≤0.05 as determined by Chi Square analysis.
[g]nd = No data. Treatment not included in greenhouse experiment.

genus diversity in waste-amended soils (Table 4). The bacterial communities of the newsprint plus poultry litter and poultry litter amended soils were significantly (P≤0.05) more even (equal distribution of genera) and diverse than the standard control (Table 4).

Greenhouse Experiment

Populations of actinomycetes, bacteria, and fungi were significantly affected by N source and C:N ratio. Fungal populations, determined from Ohio medium, were significantly reduced by N sources in the organic by-product amended soil relative to the standard control soil (Table 5) and showed a significant rate response to the C:N ratio. Fungal populations increased with increasing C:N ratio. Bacterial populations, determined from 5 percent TSA, also showed a significant rate response to the C:N ratio, however, the relationship was opposite that of fungal populations; bacterial populations deceased with increasing C:N ratio of the organic by-product. Soil amended with N had significantly greater populations of bacteria than standard control soil, and bacterial populations in soil amended with poultry litter were significantly greater than soil amended with NH_4NO_3-N.

TABLE 5.
The effect of nitrogen source and rate on microbial populations of soil amended with newsprint

Total Microbial Populations	C:N Ratio	Nitrogen Source: Poultry Litter		Nitrogen Source: NH_4NO_3	LSD (0.05)
Actinomycetes[a]	20:1	6.16a[d]		5.74bc	
	40:1	6.17a		5.85b	
	60:1	6.24a		5.90b	
	Control		5.54c		0.32
Bacteria[b]	20:1	7.63a		6.75d	
	40:1	7.22b		6.74de	
	60:1	7.05bc		6.81cd	
	Control		6.50e		0.24
Fungi[c]	20:1	4.63b		3.63c	
	40:1	4.99a		4.60b	
	60:1	5.00a		4.58b	
	Control		5.2a		0.2

[a]Log cfu/g soil determined from soil suspensions plated on newsprint agar.
[b]Log cfu/g soil determined from soil suspensions plated on 5 percent Tryptic Soy Agar.
[c]Log cfu/g soil determined from soil suspensions plated on OHIO agar.
[d]Mean of 4 replications. Means for each microbial group followed by the same letter are significantly different at P=0.05.

A newsprint medium (5 g newsprint/l dH_2O) was used to detect microorganisms that could use newsprint as a sole source of nutrients. Only actinomycetes were found to grow on the medium 72 h after plating. Actinomycete populations determined from newsprint medium and chitin pH 8.5 agar (data not shown), were significantly affected by amendment with N; populations in soil amended with poultry litter were significantly greater than populations in soil amended with NH_4NO_3. No significant differences were observed in the populations of chitinolytic bacteria, calculated from chitin pH 6.5 agar (data not shown).

Bacterial populations after nine weeks in newsprint-amended soil had greater diversity than populations in standard control soil (Table 6). The bacterial species in soil amended with poultry litter were different from that of standard control soil and soil amended with NH_4NO_3-N. There were more Gram positive bacterial species in soil amended with poultry litter than in soils amended with NH_4NO_3 or standard control soil.

Discussion

Application and incorporation of organic by-products into soil creates dynamic soil ecosystems by promoting microbial activity and as a result increased soil enzyme activity (Martens *et al.* 1992). The effect appears to be influenced by the C:N ratio of the organic by-products. When the C:N ratio of newsprint was increased from 20:1 to 60:1 and composted for nine weeks, total fungal population was increased. Similar results were observed with cotton growth during the first six weeks after newsprint was applied to the soil surface without adjusting the C:N ratio. Cotton plants had higher levels of plant death caused by *Sclerotium rolfsii* Sacc. (Sclerotium stem rot disease) and surviving plants were severely stunted by *Rhizoctonia solani* Kühn (Soreshin disease). Plants remained stunted, were delayed in maturity, and had lower lint yields (Edwards *et al.* 1993a). When C:N ratio of applied organic by-products was ≤ 30:1, total bacteria populations were increased in both the greenhouse and field studies. Cotton growth and yield were increased when the C:N ratio of the applied organic by-prod-

TABLE 6.
Frequency (%) of bacterial genera isolated from soil amended with newsprint and poultry litter

Genus	Field Study — Organic By-products: Newsprint	Field Study — Organic By-products: Newsprint + PL[a]	Field Study — Organic By-products: PL	Field Study: Standard	Greenhouse Study — Organic By-products: Newsprint + NH_4NO_3	Greenhouse Study — Organic By-products: Newsprint + PL	Greenhouse Study: Standard
Agrobacterium	1.0	–	1.1	–	–	–	–
Alcaligenes	–	1.9	2.1	–	–	–	–
Arthrobacter	2.1	9.5	14.8	7.7	9.3	1.3	–
Aureobacterium	–	0.9	–	–	1.3	0.7	–
Bacillus	53.6	39.6	34.0	76.9	44.0	10.0	72.0
Bordetella	–	–	1.1	–	–	–	–
Brevibacterium	–	–	1.1	–	–	–	–
Brochothrix	4.1	0.9	–	–	0.7	–	–
Burkholderia	4.1	11.4	2.1	4.4	–	6.0	–
Clavibacter	–	1.9	–	–	4.0	24.0	–
Corynebacterium	2.1	–	2.1	–	1.3	–	–
Curtobacterium	–	–	4.3	–	4.0	2.0	–
Cytophaga	–	–	1.1	1.1	–	0.7	2.0
Enterobacter	–	–	1.1	–	–	–	–
Escherichia	–	–	2.1	–	–	–	–
Flavobacterium	1.0	0.9	–	–	0.7	3.3	–
Flavimonas	–	–	–	2.2	–	–	–
Hydrogenophaga	–	1.9	–	1.1	–	–	–
Kurthia	–	0.9	–	–	–	–	–
Listeria	–	–	–	–	0.7	0.7	–
Methylobacterium	1.0	0.9	2.1	–	–	3.3	–
Microbacterium	7.2	–	9.6	–	–	2.7	–
Micrococcus	1.0	–	1.1	–	10.0	0.7	2.0
Ochrobacterium	2.1	–	–	–	1.3	–	–
Phyllobacterium	4.1	10.4	6.4	6.6	–	0.7	–
Pseudomonas	–	0.9	–	–	–	0.7	–
Rathayibacter	–	–	–	–	4.0	–	–
Rhodococcus	1.0	–	–	–	–	–	–
Salmonella	–	12.4	2.1	–	–	–	–
Sphingobacterium	6.3	–	–	–	–	0.7	–
Staphylococcus	7.3	–	11.7	–	0.7	–	–
Stenotrophomonas	1.0	–	–	–	6.0	2.7	10.0
Streptococcus	–	0.9	–	–	–	–	–
Vibrio	–	1.9	–	–	–	–	–
Weeksella	–	1.9	–	–	–	–	–
Xanthobacter	–	–	–	–	–	4.0	–
Xanthomonas	–	–	–	–	4.7	8.7	–
Other	1.0	0.9	–	–	6.7	18.7	14.0
Total	100	100	100	100	100	100	100

[a]PL = Poultry litter

ucts were adjusted to 30:1 (Edwards *et al.* 1993b; Edwards *et al.* 1994) and was related to a shift from predominately fungal population to one that was mainly composed of either bacteria or actinomycetes.

Organic by-products have been evaluated as soil amendments for control of plant pathogenic organisms since the 1930s with varying success. The control of root-knot nematodes (*Meloidogyne* spp.) has been reported by application of chitinous organic materials from the blue crab industry (Rodríguez-Kábana *et al.* 1989). Use of high concentrations of chitin as a soil amendment for control of nematodes has resulted in problems with phytotoxic effects on plants grown in the amended soil (Godoy *et al.* 1983; Mian *et al.* 1982). The phytotoxic effects to plants appeared to be caused by N compounds that yielded ammonia when the organic material was mineralized. Hemicellulosic waste reduced the phytotoxic effects of chitin presumably because the addition of carbon moieties stimulated microbial activity (Culbreath *et al.* 1985). The most effective organic materials were those with narrow C:N ratios and high protein or amine-type N content (Rodríguez-Kábana *et al.* 1987).

The dominance of Gram positive organisms in soil amended with poultry litter may indicate that the soil environment is unsuitable for coliform bacteria; thus, coliform bacteria present in the poultry litter are not detected in the soil. Soil amended with newsprint alone was not significantly greater than the standard control soil, which suggests that poultry litter was the predominant influence on the increase in evenness of Gram positive bacteria.

A few isolates belonging to the family Enterobacteriaceae were observed in soil samples but these isolates were not increased in soil amended with poultry litter compared to soil amended with NH_4NO_3. Members of the family Enterobacteriaceae are commonly isolated from nonamended soils and several strains have also been identified as beneficial to plant growth (Kloepper *et al.* 1988). Isolates of *Salmonella* spp. were not increased by poultry litter. Only one isolate belonging to the genus *Salmonella* was isolated and this strain was found in the newsprint-amended soil. Many Gram negative strains of bacteria which colonize plant roots, such as *Burkholderia* spp. and *Pseudomonas* spp., have been associated with increased plant health, yield, and biological control of many plant pathogens (Burr *et al.* 1978; Kloepper *et al.* 1988).

Soil microorganisms play an important role in improving soil nutrient levels and in the transformation of plant residues and organic by-products into the soil organic matter fraction (Parkinson and Coleman 1991). Although they account for only one to eight percent of the soil organic matter fraction, they can have a dramatic effect on crop production (Roder *et al.* 1988). Soil microorganisms influence plant availability of N, P, S, and other metals by controlling the decomposition of plant residues and organic by-products, mineralization of N and P, and immobilization of N and S (Saranthchandra *et al.* 1988).

Recognizing the diverse activities of soil microorganisms and taking advantage of those processes to reduce fertilizer, herbicide, and pesticide inputs has been shown to be an important benefit of maintaining or restoring soil quality (Doran and Parkin 1994), and has been a central theme for many sustainable agriculture research and education programs. By developing a better understanding of how to effectively work with soil microorganisms, soil and crop management practices including preservation of plant residues on the soil surface, use of cover crops during fallow periods, use of reduced tillage, crediting animal manures as nutrient sources, and use of the organic by-products generated by our societal "throw-it-away" attitude are being encouraged. Furthermore, by incorporating some of these management practices into every crop production system, significant progress can be made toward alleviating environmental concerns regarding the role of agriculture and also toward conserving our natural resource base.

Summary

Two annual applications of newsprint increased soil organic matter content and appeared to induce a shift in microbial populations. Cotton growth, survival, and yield were affected by the addition of organic by-products, with the effects being primarily

related to the N source used to adjust the C:N ratio of the various organic by-products. Nine weeks after application of newsprint and poultry litter, more Gram positive bacteria were observed in a greenhouse study. However, samples taken after the growing season in a field study showed a shift towards Gram negative bacteria. Although the bacterial community structure was determined using only one soil and sampling time, similar patterns of community structure have been observed for control soils in other field experiments in other cropping systems (Mahaffee *et al.* 1995; Kokalis-Burelle *et al.* 1995). The application of newsprint and poultry litter also induced shifts in the bacterial community structure, but increases in human pathogens that are associated with other soil amendments do not appear to be involved. Shifts in the community structure towards Gram negative organisms may benefit plant growth and may be useful as an indicator of soil quality.

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