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Carbon Dioxide Evolution From an Organically Amended Rio Puerco Soil[1]

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As a result of organic matter application, microbial populations and activity (CO_2 production) increased significantly compared to an unamended soil. Carbon dioxide evolution in the unamended soil did not increase with increases in the soil moisture content above 11% (−2 bars). This suggests that soil microbial activity may be limited more by the lack of organic matter rather than by soil moisture above −2 bars. Of the four organic amendments studied, sewage sludge had more desirable effects on soil biotic and abiotic properties than the others.

Keywords: Soils, soil amendments, range management.

The Upper Rio Puerco Watershed in northwestern New Mexico has a long history of heavy grazing (Dortignac 1960, Sheriden 1981, Vincent 1984). Overgrazing reduces the amount of plant cover and litter, decreasing the amounts of soil organic matter and plant available nitrogen (Clark and Paul 1970, Woodmansee 1978). Many soils in the Upper Rio Puerco Watershed are low in soil organic matter and plant available nitrogen[3,4,5]. These soils are usually low in fertility, have poor structure, and erode readily (Campbell 1968).

Degraded semiarid rangeland soils may be improved by adding amendments designed to improve the soil chemical, physical and biological properties. Application of organic amendments is an inexpensive and environmentally acceptable method of improving soil productivity. Organics increase the amount of soil organic matter, as well as essential plant nutrients (Aldon et al. 1975, Terry et al. 1979). The decomposition of organic substrates usually increases carbon dioxide production as soil microorganisms and their activities increase (Alexander 1977). The objective of this preliminary study was to gather information on the relationships between different organic amendments and soil microbiological activity in order to determine which organic amendment(s) would be best suited for further study.

Study Area and Methods

Field plots were established on May 10, 1981, on a degraded semiarid plant community, approximately 14 km southeast of Cuba, New Mexico. The plant community was classified as a snakeweed (*Guiterrezia sarothrae*)/galleta (*Hilaria jamesii*) - blue grama (*Bouteloua gracilis*)/alkali sacaton (*Sporobolus airoides*) western wheatgrass (*Agropyron smithii*) type (Francis 1986). The chemical analysis of the soil associated with this plant community showed low organic matter (5.4 g/kg), ammonium (0.3 μg/g), nitrate (2 μg/g) and total nitrogen (200 μg/g) contents. The texture was a sandy clay loam, and the pH was 8.2.

The experimental design was a randomized complete block design which included four blocks, each containing five treatments. Each treatment plot was 5.95 m^2 and was separated by a 0.6-m buffer zone. Amendments were surface applied and included: (1) unamended

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[3] *Aldon, Earl F., D. G. Scholl, P. R. Fresquez, and R. E. Francis. 1987. Natural production potential of some Rio Puerco soils in New Mexico.* Unpublished data.

[4] *Fresquez, P. R., R. E. Francis, and G. L. Dennis. 1987. Fungal communities associated with phyto-edaphic communities in the semi-arid Southwest.* Unpublished data.

[5] *Whitford, W., Earl F. Aldon, D. W. Freckman, Y. Steinberger, and L. W. Parker. 1987. The effects of organic amendments on soil biota on a degraded rangeland.* Unpublished data.

(control), (2) anaerobically digested dried sewage sludge (22.4 Mg/ha), (3) composted dairy cattle manure (22.4 Mg/ha), (4) wheat straw (11.2 Mg/ha), and (5) woodchips (1 cm) (11.2 Mg/ha).

An alkali trap method was used to measure microbial activity via CO_2 evolution (Fresquez 1981). Forty polyvinylchloride (PVC) tubes (two tubes per plot), 19 cm in diameter and 27 cm long were pushed 18 cm into the soil. A vial containing 20 mL of 0.5 N NaOH was placed into each tube on each of seven sampling periods. The tubes were sealed with plastic wrap and aluminum foil. Blanks were sealed on both ends of the tube and contained no soil. After 24 hours, the vials were removed and their contents were titrated. Titration included adding 3 drops of phenolphthalein indicator followed by 1 mL of saturated $BaCl_2$ and titrating slowly with 0.20 N HCl to the phenolphthalein endpoint. Data were collected from seven sampling dates during the summer growing season of 1981. Results are reported as g CO_2 m^2 d^{-1}.

Soil samples were collected (0 to 13 cm deep) and analyzed for aerobic heterotrophic bacteria, *Streptomyces* and fungal propagules for each treatment on each of the seven sampling dates. Methods used for determining the populations of bacteria, *Streptomyces* and fungal propagules have been described previously (Fresquez and Lindemann 1982). The populations of these microorganisms were pooled (an average of the seven sampling dates) and reported as such on an oven-dry weight soil basis.

Results and Discussion

Chemical properties varied among the organic amendment materials (table 1). As expected, all the organic amendments had high organic matter contents, which ranged from 105 to 500 g/kg. Although the manure amendment had the highest organic matter content, it had a high electrical conductivity (EC) and sodium absorption ratio (SAR), which may inhibit soil microorganisms (Fresquez and Lindemann 1982) and plant growth (Bohn et al. 1979). Sewage sludge, in contrast, had a lower EC and SAR compared to the manure amendment. Also, sludge contained the highest total N content, which resulted in a reduced C:N ratio (6) compared to the other amendments. Carbon to nitrogen ratios above 30 favor N immobilization (Alexander 1977). Manure, straw, and woodchips all have C:N ratios above 30 and can be expected to decay slowly.

All of the organic amendment treatments had significantly higher CO_2 production than the unamended soil on most sampling periods (table 2). Even on the first sampling period (4 days after treatment application), there were significantly higher CO_2 values observed in the manure treatment compared to the control treatment. The soil moisture content in the unamended control on the first sampling date (May 14) was 8% (– 7 bars). With an increase in soil moisture to 11% (– 2 bars) on June 3, mean CO_2 production increased two-fold in all treatments, including the control. Decomposition of the organic amendments doubled again when the moisture content increased to 32% (– 1/3 bar) on July 1. Soil microbiological activity in the unamended control, however, did not increase with further increases in soil moisture above 11% (– 2 bars), indicating the limited microbial activity of this soil without amendment.

On the last sampling date, September 4, the moisture content was 8% (– 7 bars). The organic amendment treatments on this date all were significantly higher compared to the unamended control, and were significantly higher as a group (mean = 2.7 g m^2 d^{-1}) compared to the first May 14 sampling date (mean = 1.4 g m^2 d^{-1}), which also had a similar moisture content. This suggests that microbial activity after 4 months was occurring at a higher rate in amended treatments than in the unamended treatment, even when the soil moisture content was low (– 7 bars).

The sewage sludge treatment had significantly higher populations of bacteria compared to the other organic matter treatments and the unamended control (table 3). *Streptomyces* populations were not significantly different between treatments. Significantly higher fungal populations were found in the straw and sludge treatments compared to the other organic treatments and the unamended control.

Conclusions

Soil microbiological activity, as measured by CO_2 evolution was limited by the lack of organic matter in unamended soil rather than by soil moisture above 11% (– 2 bars). Moreover, when soil moisture was low (– 7

Table 1.—Chemical properties associated with organic amendment materials.

Treatments	Water soluble cations[1]				Phosphorus and nitrogen								
	Na	Ca	Mg	K	P	NH_4-N	NO_3-N	TKN	pH	EC	SAR	Organic matter	C:N ratio
	µg/g									dS/m		g/kg	
Sewage sludge	289	843	55	234	632	204	14	10600	7.22	6.57	2.62	105	6
Manure	939	21	17	4279	1162	10	153	4190	8.57	15.40	37.20	500	69
Straw	51	46	16	1123	101	2	1	1520	7.95	3.45	1.66	375	143
Woodchips	12	21	6	121	2	7	1	520	5.74	0.53	0.58	293	327

[1]*Water soluble cations, pH, and EC determined from saturated paste extract. Soil P, NH_4-N, and NO_3-N determined from 1:5 water extract. Organic matter determined by the Walkley-Black method, and total nitrogen (TKN) determined by the macro-Kjeldahl procedure.*

Table 2.—Carbon dioxide evolution as affected by organic amendment in the field during the growing season of 1981.

Treatment	Sample dates 5/14	6/3	6/17	7/21	7/16	8/12	9/4
	g CO_2 m^2 d^{-1}						
Unamended (control)	1.20b[1]	2.60b	1.15d	2.34d	1.52c	2.22d	1.64b
Sludge (22.4 Mg/ha)	1.28b	2.77a	1.64b	6.66a	3.62a	5.90a	2.38a
Manure (22.4 Mg/ha)	1.63a	2.79a	1.41bc	4.78bc	3.68a	4.68b	2.50a
Straw (11.2 Mg/ha)	1.46ab	2.82a	1.90a	4.96b	3.63a	4.66b	2.30a
Woodchips (11.2 Mg/ha)	1.35ab	2.77a	1.37cd	4.33c	2.50b	3.55c	2.22a

[1]*Means within the same column followed by the same letter are not significantly different at the 0.05 level by the Least Significant Difference (LSD) test.*

Table 3.—Soil microbial populations as affected by organic amendment.[1]

Treatment	Aerobic heterotrophic bacteria	Streptomyces	Fungal propagules
	10^6 g^{-1}		10^3 g^{-1}
Unamended (control)	20b[2]	4.9	43b
Sludge (22.4 Mg/ha)	464a	14.0	458a
Manure (22.4 Mg/ha)	39b	9.4	112b
Straw (11.2 Mg/ha)	57b	10.7	774a
Woodchips (11.2 Mg/ha)	26b	8.5	98b

[1]*Values are an average of seven sampling dates.*
[2]*Means within the same column followed by the same letter are not significantly different at the 0.05 level by the Least Significant Difference (LSD) test.*

bars), CO_2 production in organic treatment soils was higher than in unamended soil. Of the organic amendments, sewage sludge had higher microbial populations and CO_2 activity than the others; this was probably a result of the lower C:N ratio compared to the other organic amendments. Sewage sludge warrants further research, in terms of application rates, microbial populations and activities, soil nutrients and moisture, and plant production and quality responses occurring on degraded semiarid rangelands.

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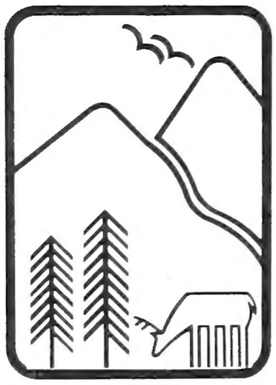

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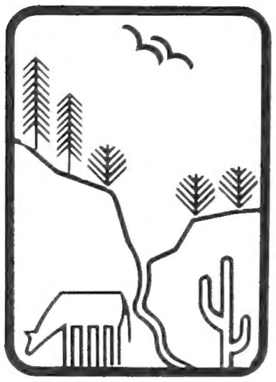

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Great Plains

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