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Effects of Biodynamic Preparations on Compost Development

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ABSTRACT

Biodynamic (BD) agriculture is an organic farming system that relies heavily on compost as a fertilizer. Six herbal preparations are added to composting materials in order to make BD compost. Proponents claim these additions produce higher quality compost under farm conditions. In this study, BD compost preparations were applied to 3.5 t compost piles made of dairy manure and woodshaving bedding. Application of the BD preparations also requires 6 l soil and 8 l water; therefore control piles received the same additions of soil and water as BD compost piles, but no BD preparations. Biodynamic-treated composts maintained an average 3.4°C higher temperature throughout the eight-week active composting period, suggesting more thermophilic microbial activity and/or faster development of compost with BD treatment. Final samples were taken when active composting slowed and the piles entered a ripening stage. At the final sampling, BD-treated piles respired CO_2 at a 10% lower rate and had a larger ratio of dehydrogenase enzyme activity to CO_2 production. Microbial communities in the finished BD and control piles were differentiated by principal component analysis of microbial phospholipid fatty acids. Final samples of BD-treated composts also had 65% more nitrate than control piles. Biodynamic preparations thus effected discernible changes in compost chemical and microbial parameters.

INTRODUCTION

Biodynamic agriculture is an organic farming system that arose out of a

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philosophical movement, anthroposophy (Steiner, 1974; Kirchmann, 1994). Biodynamic methods are distinct in that they make use of several unique fermented substances, called preparations, as field sprays and compost inoculants (Koepf *et al.*, 1976). Proponents of biodynamics claim that compost treated with the BD compost preparations develops faster, has a greater nutrient holding capacity, has a more crumbly structure, and produces only inoffensive odours (Koepf, 1993). In addition, BD compost does not need to be turned (JPI, 1995), lowering labour and energy costs. Such improvements could make compost more valuable as a fertilizer and make the composting process cheaper, faster, and more socially acceptable.

Biodynamic preparations numbered 502 to 507 are used as compost additives. The preparations consist of plant parts or extracts treated with animal tissues, water and/or soil, as described by Steiner (1974) (Table 1). Most are temporarily buried in the soil to undergo decomposition. The finished preparations are humus-like with a fine crumb structure, except preparation 507, which is a liquid extract. One set of preparations contains approximately 5–15 cm^3 or 1–5 g (moist weight) of each preparation and is used to treat up to 13.6 t of raw material (JPI, 1995).

Previous research has found that BD preparations can speed composting and provide a higher quality product. Compost has also been found to have a narrower C:N ratio and produce less ammonia and more nitrate when it is treated with preparations 502 to 507 (von Wistinghausen, 1986). Straw treated with the BD preparations released more CO_2, suggesting more decomposition over a one-year period than untreated straw (Ahrens, 1984). Higher temperatures are commonly reported in BD-treated compost. Maturing BD compost does not always reach peak temperatures as high as those of a similar non-BD compost, but BD-treated piles maintain the peak temperature longer (von Wistinghausen, 1984). In several methods of composting, with and without the BD compost preparations 502 to 507, the BD-treated composts consistently had greater cation exchange capacity per unit organic matter (Heinze & Breda, 1978).

Most research involving BD methods has been undertaken by researchers and

TABLE 1

Biodynamic compost preparations and their main ingredients.

Preparation	Main ingredient†	Moist weight (g)
502	Yarrow blossoms (*Achillea millefolium*)	1.1
503	Chamomile blossoms (*Matricaria recucitata*)	3.0
504	Stinging nettle shoot (*Urtica dioeca*)	4.4
505	Oak bark (*Quercus robur*)	3.9
506	Dandelion flowers (*Taraxacum officinale*)	4.7
507	Valerian extract (*Valeriana officinalis*)	1.2

†Preparations 502–506 are fermented, as described by Steiner (1974).

institutions that support biodynamics (Koepf, 1993). In addition, much of the BD research literature is non-refereed. Thus, researchers and potential users of the BD methods question the validity of previous research (Kirchmann, 1994). Most previous research also has not utilized appropriate control treatments. For instance, small amounts of soil and water are added to compost in the process of applying the BD preparations. These additions alone could have resulted in the effects attributed to the preparations.

This study compared composting dairy waste with and without BD preparations 502 to 507. Both BD-treated and control compost piles received equal additions of field soil and well water. Compost development was tracked and the quality of the product was investigated.

METHODS

Compost piles

Compost raw material was dairy barn waste, consisting of manure and pine shaving bedding from the Washington State University Dairy Center. Dairy barns were cleaned daily and the materials stockpiled. One pile (delivered as one load) contained barn wastes from 1 week. The material was well mixed because it had been moved repeatedly with farm machinery and pressed to remove most of the liquid. Starting materials had a C:N ratio of 55 to 60:1, and were delivered to the experimental site within 1 week of stockpiling. Five loads of material, statistically treated as five treatment blocks due to slight variations in material composition and age and weather conditions during each composting period, were delivered to the experimental site over the course of 13 months. The experimental site was open ground in an agricultural field of Palouse series soil (fine-silty, mixed, mesic Pachic Ultic Haploxeroll). Deliveries arrived in October 1994 (one load), May 1995 (two loads) and October 1995 (two loads). Each load was thoroughly mixed and separated into two piles. Each pile measured approx. 2 × 2.5 × 1.5 m. Average mass was approximately 3.5 t per pile. One pile from each load was randomly selected to receive the BD preparations. The other served as a control pile. As per instructions from the Josephine Porter Institute (JPI, Woolwine, VA), and to simulate most on-farm conditions, compost piles were not turned during the experimental period after the initial mixing.

Application of biodynamic compost preparations

The preparations used in this study were purchased from JPI and applied immediately thereafter. Their production is based on long-term experience and

the methods used in making the preparations are consistent from year to year. Purchasing preparations from a biodynamics institute ensures the best possible standardization of the preparations (Koepf *et al.*, 1976).

Biodynamic compost preparations 502 to 507 (Table 1) were applied to one pile from each load. One packaged unit (1–5 g moist weight or 5–15 cm^3) of each preparation was applied to approximately 3.5 t compost material. As per instructions from JPI (1995), six vertical holes of 10 cm diameter were bored into the pile to the approximate vertical center of the pile. Each hole received one of the six preparations. Preparation 507, valerian extract, was first mixed with 4 l of water for 10 min. Half of the 507 solution was poured into the sixth hole and the remainder sprinkled on the pile. Soil from the surrounding farmed field was used to fill the holes, totalling approximately 6 l Palouse silt loam. Control piles received equal additions of soil and water in a similar placement and manner, but no BD preparations.

Sampling and laboratory procedures

At each sampling and temperature measurement time, four subsamples and/or four temperature readings were taken at cardinal directions at a depth of 55–60 cm in the compost piles. Samples were homogenized for 15 s in an electric coffee grinder to reduce variability of measurements. Samples were stored at 4°C until analysis. Samples were kept cold and moist during storage to reduce chemical and biological changes, but all final data are reported on a dry weight basis. Analyses were completed within 2 weeks of sampling. During compost development, temperature was measured twice weekly; respiration, pH, redox potential difference, moisture, and dehydrogenase activity were measured weekly; phospholipid fatty acids were extracted from initial, middle and final samples. Measurement of electrical conductivity, cation exchange capacity, nitrate and ammonium, available P and K, and percentage C and N occurred at the end of development for each set of piles.

Electrical conductivity was measured in a slurry of one part moist sample to three parts distilled water using a Hanna Instruments Dissolved Solids Tester. To determine cation exchange capacity (CEC), samples were flooded with neutral 1 M ammonium acetate to saturate CEC sites with NH_4. Then samples were washed with 1-propanol and NH_4 was extracted with 1 M KCl. Ammonium content in this extract, and thereby CEC, was measured using an NH_4 ion selective electrode (Phoenix Electrode Co., Maidstone, England) on an Orion Research microprocessor (Orion Research Inc., Boston, MA) (Corey, 1990). Nitrate and ammonium contents were measured in 0.1 M $MgSO_4$ extract using a NO_3 ion electrode (Orion Research Inc., Boston, MA) and an NH_4 ion electrode (Phoenix Electrode Co., Maidstone, England) on an Orion Research microprocessor (Dahnke & Johnson, 1990). Determinations of available P

(Morgan phosphorus test) and available K were made by the Holm Laboratory, University of Idaho (Teech & English, 1944; Murphy & Riley, 1962). Percentage C and N were measured by the Holm Laboratory, University of Idaho, using a Leco Analyzer (CHN-600, Leco Corp., St. Joseph, MI). Temperature readings were taken with a Reotemp thermometer with 60-cm stalk. Carbon dioxide respiration was measured from 5.0 g moist compost samples in glass vials with septa. Samples were allowed to rest in parafilm-covered vials at room temperature for 10 days. After this time, 0.5 cm^3 distilled water was added to each sample, vials were capped, and CO_2 was measured by gas chromatograph after 3 h (Zibilske, 1994). Measurements of pH and redox potential (WERL, 1991) were taken in a slurry of one part moist sample to three parts distilled water using an Orion research microprocessor pH/millivolt meter (Orion Research Inc., Boston, MA) with pH or redox electrode. Redox potential was measured immediately after mixing with water and again after 24 h. Moisture content was determined by drying samples for 24 h at 105°C. Dehydrogenase activity was measured using a colorimetric procedure utilizing reduction of triphenyl tetrazolium chloride to triphenyl formazan (TPF) (Tabatabai, 1994). Reacted products were extracted with methanol, centrifuged, and the supernatants' absorbance at 492 nm read in triplicate subsamples in a microtiter plate with a Bio-Rad (Bio-Rad, Hercules, CA) Model 2550 EIA Reader.

Phospholipid fatty acids (PLFA's) were extracted from each sample taken on the first, middle, and last sampling dates using a modification of the procedure of Petersen & Klug (1994). Phospholipid fatty acids were not extracted from the first set of piles. One g moist weight compost was extracted with 1.3 cm^3 of 0.05 mol l^{-1} K_2HPO_4, 5 cm^3 methanol, and 2.5 cm^3 dichloromethane (DCM). Then 2.5 cm^3 DCM and 10 cm^3 supersaturated NaBr solution (0.8 g cm^{-3}) were added and the solution mixed for 14 h. Tubes were centrifuged and the organic phase was transferred to fresh acid-washed tubes. Samples were evaporated under N_2 and separated on an amino propyl-bonded silica polar column. Columns were preconditioned with hexane and 1:1 hexane/chloroform before lipid extracts were transferred to the column in chloroform. Columns were washed with 2:1 chloroform/2-propanol, followed by 20 cm^3 l^{-1} acetic acid in diethyl ether. Phospholipids were eluted with methanol, dried under N_2, and then methylated by the procedure of Microbial Identification, Inc. (MIDI, 1993). Phospholipids were hydrolyzed in 1 cm^3 of 150 g l^{-1} NaOH in 50% methanol, then acidified and methylated in 2 cm^3 of 54% v/v 6N HCl in methanol. Fatty acid methyl esters were then extracted with 1 cm^3 1:1 hexane/methyl tert-butyl ether (MTBE). Tubes were centrifuged at 2000 rpm until phases separated and the upper organic phase was recovered. The organic phase was then washed with 3 cm^3 12 g l^{-1} aqueous NaOH, dried, and resuspended in 200 µl 1:1 hexane/MTBE. Extracted PLFA's were injected into a gas chromatograph (5890 GC Series II, Hewlett Packard, Wilmington, DE) equipped with 25 mm × 0.2 mm

fused silica capillary column and flame ionization detector. Phospholipids were identified and quantified using software and standard solutions of the Eukary method of MIDI.

Statistical analysis

This study was designed and analysed as randomized complete blocks. Two piles were made of each load of dairy waste, to which the two treatments (BD or control) were randomly applied. Data were analysed using GLM in SAS (SAS/STAT, 1988). Parameters measured on more than one day were analysed using univariate analysis with repeated measures. Parameters measured only in final samples were analysed using one-way ANOVA for randomized complete blocks. Data from the four subsamples per compost pile per sampling date were averaged for statistical analysis. Nitrate data were log transformed in order to meet the assumption of normal distribution of variance. Significance was at $p < 0.05$ unless otherwise noted.

Phospholipid data were analysed using principal component analysis (PCA) (Pielou, 1984). Principal component analysis identifies and compiles the PLFA's associated with most of the variance among samples. Information from PLFA analysis can thus be summarized in a few principal components (PC's). Principal component analysis was performed initially using all PLFA's. To enhance PCA and sample differentiation, those PLFA's with a loading value $> |0.5|$ were used in a second iteration of PCA.

RESULTS

Temperature in BD compost piles was higher than in control piles ($p < 0.05$) (Figure 1). Higher temperature was a consistent effect of BD treatment among all sets of compost. Higher temperature suggests more microbial activity, which can lead to a faster maturation of compost (Waksman *et al.*, 1939) and greater reduction of pathogens (US EPA, 1981). Temperatures were highest at the initial sampling time (average 60°C), indicating that the material was actively decomposing at time of delivery and/or was stimulated by the initial mixing.

Moisture content in fresh delivered material averaged 70%, and slowly decreased during compost development to an average 67% at final sampling. Moisture was not different between treatments at any time (data not shown), although it was different among loads of material ($p < 0.05$). Compost maturing in summer tended to have lower final moisture (60 to 65%) than compost maturing in autumn (66 to 72%), due to reduced evaporation and increased rainfall in autumn. Moisture contents were ideal to high for maximum microbial

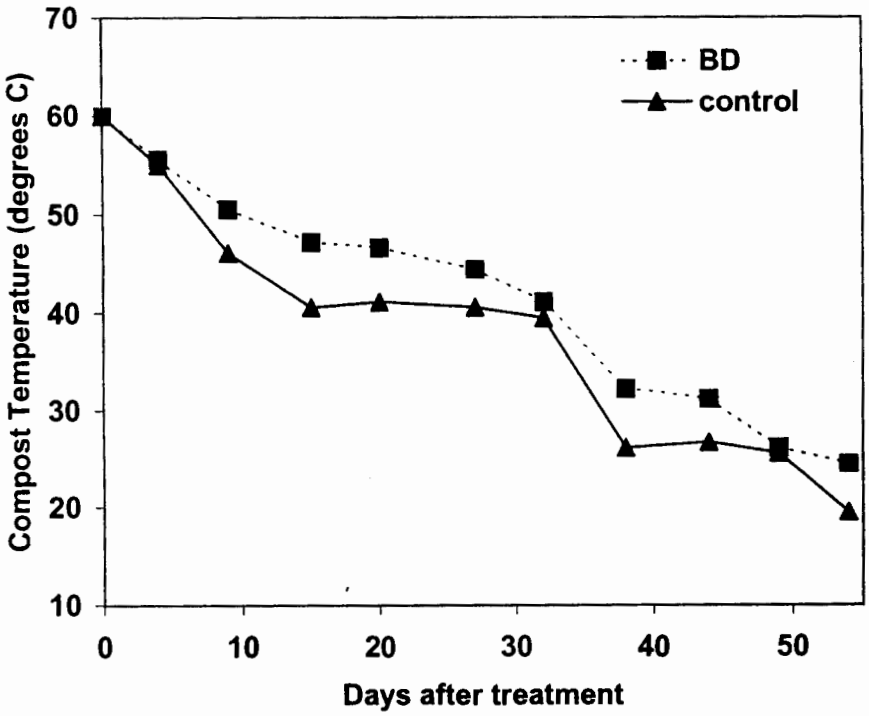

FIGURE 1. Compost temperature changes at 60 cm depth after application of biodynamic preparations 502 to 507 plus soil and water (BD) or soil and water, but no biodynamic preparations (control). Data represents average of five replicates, with four measurements of each pile at each measurement time.

activity (Poincelot, 1972), and may have supported microaerophilic or anaerobic activity (Wiley & Pierce, 1955).

Starting materials had an average pH of 8.8, and pH was above neutral throughout composting (Figure 2). Final samples had an average pH of 8.4. Sets (loads) of compost had different pH's, not related to season of development. Compost pH was generally not different between treatments, but near the end of active composting pH often temporarily dropped in BD composts, giving a more neutral pH in BD-treated piles ($p < 0.05$). Potential enzymatic and biological activity is generally greater at a more neutral pH. At lower pH, compost is also less likely to lose significant amounts of N through ammonia volatilization. It is unknown, however, whether the temporary drop in pH of BD composts could effect lasting changes in the compost.

A biologically and chemically active solution will undergo a large shift in available electrons over a given time period, which will be shown by a great change in redox potential. More stable compost shows less change in redox

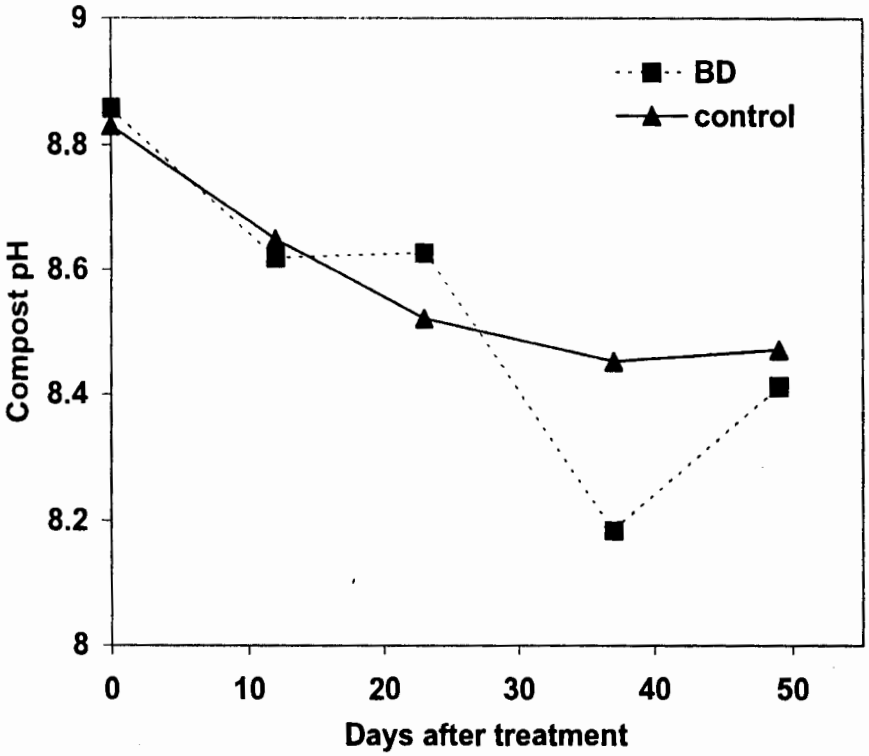

FIGURE 2. Compost pH after application of BD and control treatments (n = 5), measured at 60 cm depth with four subsamples per pile at each sampling time.

potential over 24 h (WERL, 1991). All composts became more chemically stable over the experiment period, evidenced by decreasing redox changes (Figure 3). Redox change measurements were never different between BD and control piles at $p = 0.05$, although on days 12 and 37, BD piles had a lower redox difference at the $p = 0.10$ level. This may indicate faster or more complete development of the BD compost, although this difference was not maintained.

Microbial respiration of CO_2 was similar in BD and control composts over the period of most active development (Figure 4). Decreasing CO_2 release indicated a decline in biological activity as piles approached chemical stability. Lowest respiration rates were seen on average sampling day 37, at the time BD piles dropped in pH. This may represent a turnover in the biological community or a lull in activity due to some limiting factor. As per instructions from JPI, these piles were not turned. High initial activity thus could have limited the available oxygen supply. Respiration rose again on day 49, particularly in control piles. An increase in respiration at this stage may indicate a resurgence in microbial activity.

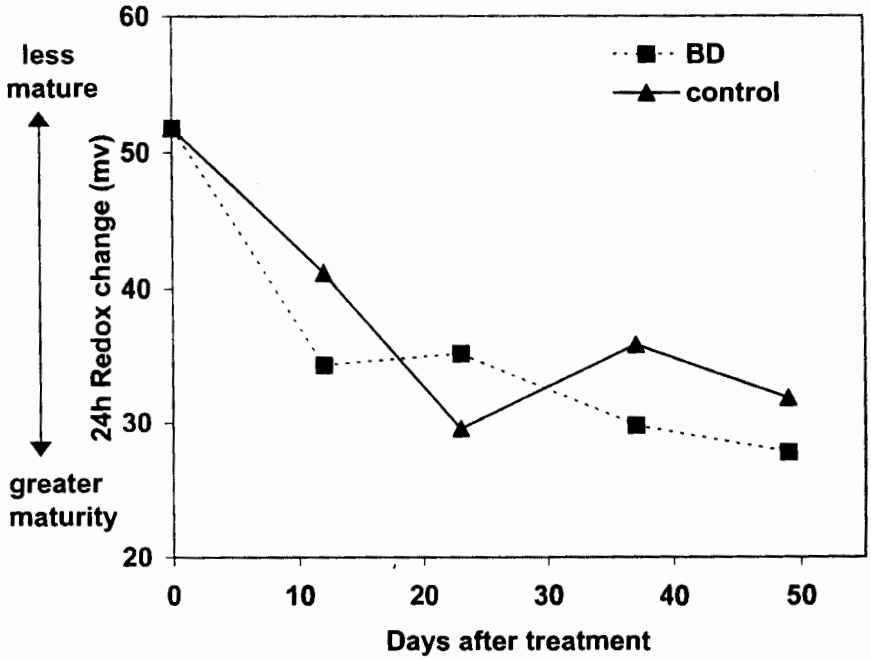

FIGURE 3. Redox potential change over 24 h, a measurement of compost chemical stability, after application of BD and control treatments (n = 5). Measured at 60 cm depth with four subsamples per pile at each sampling time.

Dehydrogenase enzyme activity was also similar between treatments (Figure 5). There was again a drop in activity at the day 37 measurement. In the subsequent small rise in activity, the BD-treated piles tended to show slightly greater dehydrogenase activity. Slightly greater dehydrogenase activity and slightly lower CO_2 respiration give the BD-treated compost a higher ratio of dehydrogenase: CO_2 release on the final day of sampling ($p < 0.10$) (Table 2).

Nitrate content of final compost samples was on average 65% greater in the BD-treated compost than in control compost (Table 2). Neither total N, total C, nor C:N ratio was statistically different between treatments, although in four of the five trials, BD-treated compost finished with more N and a lower C:N. All starting materials had a C:N ratio of 55 to 60:1, which may be higher than ideal for composting (Waksman, 1938; Rynk, 1992), due to the high content of wood shavings. Ammonium content, available phosphorus, available potassium, and electrical conductivity were similar between treatments. Previous researchers have found CEC and CEC per unit C in compost is enhanced by BD treatment (Koepf, 1966; Heinze & Breda, 1978). Neither of these parameters was significantly different between treatments in these trials.

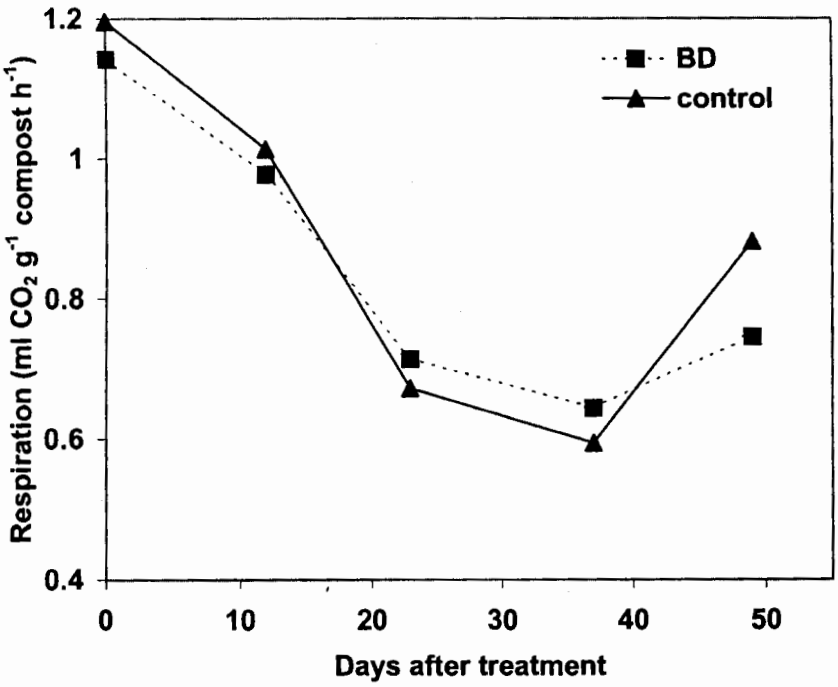

FIGURE 4. CO_2 respiration from composts after application of BD and control treatments (n = 5). Measured at 60 cm depth with four subsamples per pile at each sampling time.

TABLE 2

Final compost samples at 60 cm sampling depth after 8 weeks development (n = 5).

Parameter	BD	Control
Dehydrogenase : CO_2 (μg TPF ml CO_2^{-1})	165a†	125b
Total C (%)	33.2	35.4
C : N	25.6	30.1
Nitrate (mg kg^{-1})	699a‡	417b
Ammonium (mg kg^{-1})	342	319
Available P (mg kg^{-1})	349	348
Available K (mg kg^{-1})	7550	6802
CEC (meq $100g^{-1}$)	56.3	52.4
CEC : C (meq g^{-1})	1.94	1.5
EC (μS cm^{-1})	207	197

†Means with a different letter are significantly different at $p < 0.10$.
‡Means with a different letter are significantly different at $p < 0.05$.

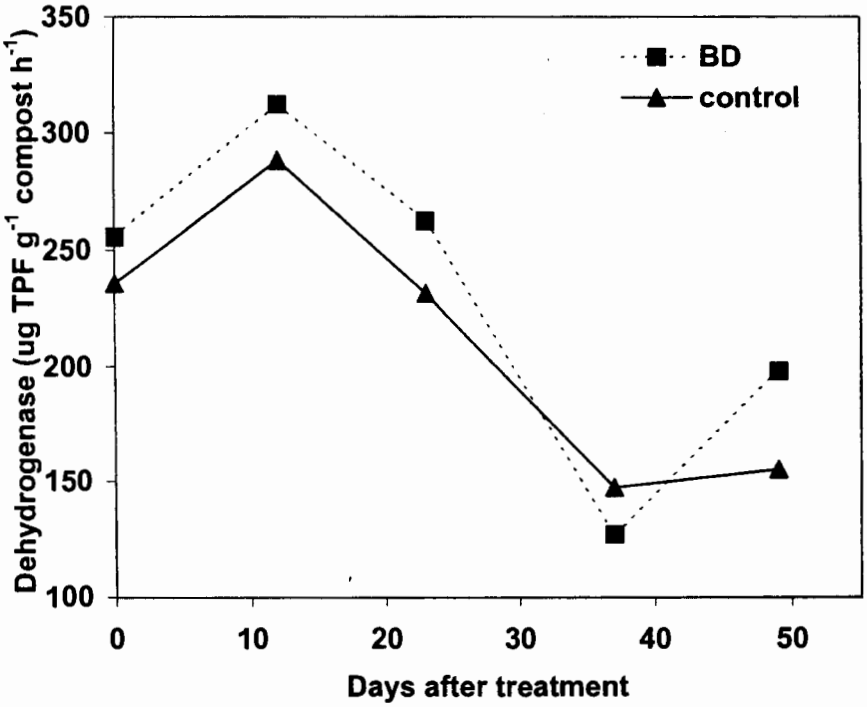

FIGURE 5. Dehydrogenase enzyme activity in composts after application of BD and control treatments (n = 5). Measured at 60 cm depth with four subsamples per pile at each sampling time.

Phospholipid fatty acid profiles and PCA can differentiate among soils under differing management systems (Zelles *et al.*, 1995), or among compost in various stages of development (Carpenter-Boggs *et al.*, 1998). In the present study, PCA of PLFA's was used to distinguish between two types of compost. Principal components 1 and 3 distinguished samples by the time of sampling and by the load from which its raw materials came (data not shown). Initial and middle samples were not different between treatments, but final samples differed by treatment in PC2 ($p < 0.01$) (Figure 6). This shows some alteration in the microbial community of BD-treated composts. Of the seven PLFA's with a loading value $> |0.5|$ in PC2, four are positively correlated and three are negatively correlated with PC2 (Table 3). Two PLFA's that are positively correlated with PC2, 17:0 iso and 17:0 anteiso, are indicators of eubacteria (Vestal & White, 1989). Two PLFA's that are negatively correlated with PC2, 18:1 ω9c and 18:2 ω6c, are indicators of fungi (Vestal & White, 1989). A higher ranking of BD compost in PC2 suggests a larger proportion of bacteria and smaller proportion of fungi in BD composts. The fungal indicator 18:1 ω9c was significantly lower ($p < .05$), and 18:2 ω6c also tended to be lower in finished

TABLE 3

Phospholipid fatty acids that differ between BD and control composts and/or contribute to Principal Component 2 (PC2).

PLFA	Input to PC2	Mole % in BD	Mole % in control	p value	Indicates microbial group†
12:0	NA	0.03	0.12	0.01	NA
15:1 iso	NA	0.00	0.11	0.07	NA
16:0 iso	+	5.40	4.20	NS	NA
16:1 ω7c	NA	1.90	2.10	0.06	Aerobic bacteria
16:1 ω9c	NA	0.22	0.37	0.05	Eubacteria
17:0 anteiso	+	3.00	2.50	0.08	Eubacteria
17:0 iso	+	5.60	4.70	NS	Eubacteria
17:1 ω6c	NA	0.35	0.10	0.02	SO_4-reducing bacteria
18:0	+	5.00	5.00	NS	NA
18:1 ω9c	–	2.80	4.50	0.05	Fungi, algae
18:1 ω9t	–	2.10	2.60	NS	NA
18:2 ω6c	–	3.50	4.40	NS	Fungi
19:0 OH	NA	0.12	0.00	0.01	NA
20:0	NA	0.10	0.45	0.01	NA

†Vestal & White (1989).

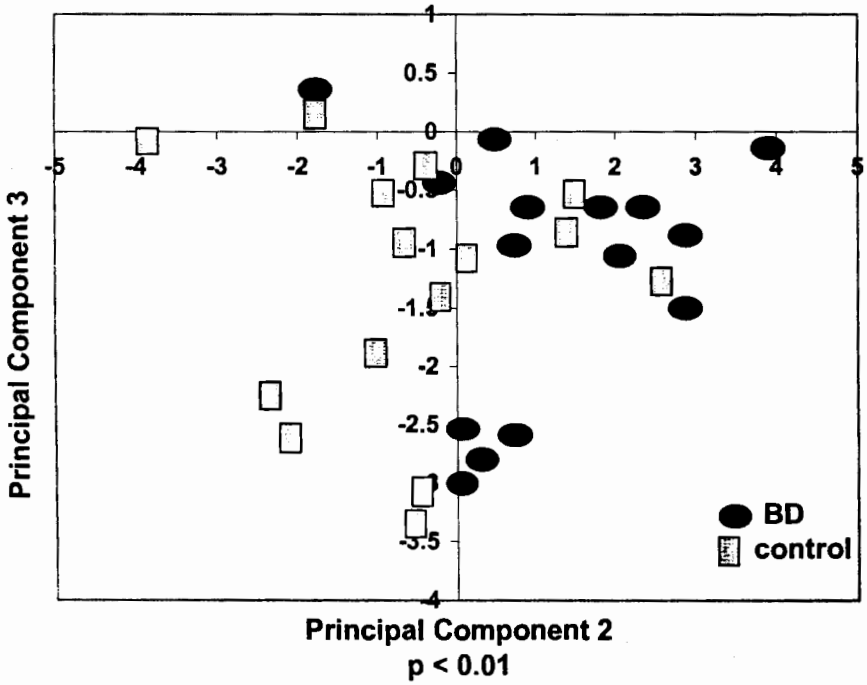

FIGURE 6. Phospholipid fatty acid principal components 2 and 3 for final compost samples at 60 cm depth in piles. Data represents four subsamples of each pile in four replicates (PLFA's not extracted from initial set).

BD composts. The PLFA indicators of bacteria 17:0 anteiso, 17:0 iso, and 17:1 ω6c were greater while 16:1 ω7c was lower in BD composts vs. control composts.

DISCUSSION AND CONCLUSIONS

Several measurements suggested that BD composting was different from non-BD composting. Biodynamic-treated compost was consistently hotter than non-BD compost. Higher compost temperature is generally caused by more microbial activity and generally results in faster decomposition and better control of weed seeds and pathogens. Nitrate increases in compost toward the time of full compost maturity (Poincelot, 1972). That final samples of BD compost held 65% more nitrate than control compost suggests the BD-treated compost was more mature than untreated compost. More nitrate retained in the BD-treated compost could allow the microbial community greater access to N, often a limiting nutrient, allowing more complete decomposition to occur. The BD preparations or other treatments that increase temperature may thereby enhance the process or product of composting.

Biological tests revealed no differences in microbial activity or microbial community structure until the final sampling. Phospholipid fatty acid analysis indicated a different microbial community in final samples of BD-treated compost than in untreated compost. These data suggest that BD composts, more than control composts, may have favoured a larger proportion of bacteria and lower proportion of fungi. At this final stage, the BD-treated compost had a higher ratio of dehydrogenase: CO_2 release. This ratio indicates level of potential enzymatic activity per unit respiratory demand. The higher ratio in BD-treated compost suggests that the BD compost supported either a more efficient community and/or a larger proportion of anaerobic metabolism. Although all compost piles had moderately high moisture contents, there was no difference in moisture between treatments; both treatments should support similar proportions of aerobic and anaerobic metabolism. However, there are some PLFA indications that BD composts did support a larger proportion of anaerobic metabolism. Biodynamically treated composts had lower proportions of 16:1 ω7c, an indicator of aerobic bacteria, and a larger proportion of 17:1 ω6c, an indicator of sulfate-reducing bacteria. Still, BD composts held 65% more nitrate than control piles, indicating healthy activity by obligate aerobic nitrifying bacteria.

One point of contention between many BD practitioners and non-practitioners is the use of such small amounts of the preparations (Stoutemyer, 1981). The BD compost preparations, total moist weight 15–20 g, are applied to up to 13.6 t of composting material, giving a concentration as low as 1.1 mg preparations kg^{-1} compost. This concentration seems too small to cause notable effects. Yet,

many bioactive compounds that affect the growth of agriculturally important organisms are most effective in trace amounts. Plant hormones such as brassins (Sasse, 1989) or triacontanol (Ries, 1984) applied at rates less than 1 mg l^{-1} can significantly increase plant growth. One to five μg l^{-1} of geosmin or 2-methylisoborneol in air can stimulate growth of VA mycorrhizal fungal spores (Carpenter-Boggs *et al.*, 1995). Herbicides such as chlorsulfuron are applied at 2–7 g ha^{-1} to control weeds in wheat (Zimdahl, 1993), among other examples.

Effects of the BD preparations could similarly be caused by gaseous or liquid chemical factors. Yarrow, chamomile, stinging nettle and valerian, main ingredients of four BD preparations, are well known as medicinal plants containing a variety of bioactive compounds (Hornok, 1992). Extracts of chamomile, for instance, have antibacterial and antifungal properties (Foster, 1990). Cytokinins have also been detected in the BD field spray preparations (Stearn, 1976). These or other biologically active substances, which act at very low concentrations, might be present in the BD compost preparations and cause the effects seen. Potential bioactive ingredients in the BD compost preparations have not been investigated.

Biodynamic preparations may have affected compost temperature, nitrate content and community structure by serving as a microbial inoculant. Sivapalan *et al.* (1994) found that inoculation of compost with fungal spores at the rate of 6.7×10^4 cfu g^{-1} compost increased the total fungal population and changed the fungal community structure. Using data from Pfeiffer (1956), the estimated inoculation rate from the BD preparations is 1×10^3 bacterial cfu g^{-1} compost.

Chemical or biological effects of the BD preparations may be common to any fermented or composted addition. Nakasaki *et al.* (1985) found that seeding fresh composting material with finished compost caused changes in the composting process. With increasing levels of finished compost added, thermophilic temperatures were maintained longer, thermophilic actinomycetes were active sooner, and maximum CO_2 respiration was maintained for a shorter period. However, the seeding material tested by Nagasaki *et al.* (1985) was added at 10% of fresh material weight, whereas the six BD preparations used in this study equated approximately 0.0005% of fresh material weight.

These results suggest that the BD compost preparations might be useful in enhancing the ease or value of composting. Additions of other commercial or non-commercial products may cause similar effects. This study was followed by field testing of BD and untreated composts for their effects on soil biological and fertility parameters and crop yield (Carpenter-Boggs, 1997; Carpenter-Boggs *et al.*, 2000a, 2000b).

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