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Nitrogen and Phosphorus mineralization in compost Mulch Berms on simulated Military training landscapes

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Abstract- The use of compost mulches on military training lands has multitudes of benefits which include providing alternative means of disposing and recycling organic and inorganic waste materials. However bi-products of decomposition of compost mulch can lead to pollution of the environment by supplying nutrients such as nitrate and ammonium N, phosphorous, and toxic heavy metals to the environment. These nutrients can be transported by runoff water into rivers, streams, and ground water sources. A major health hazard caused by high N concentration in drinking water is methemoglobinemia. N and P in runoff water from agriculture lands result in accumulation of nutrients causing unwanted growth of algae and weeds in aquatic ecosystem. The growth leads to loss of oxygen needed by aquatic habitats in a process of eutrophication as well as causing blooms of toxic organisms in the systems. This study investigated the potential for using composted mulch berms on simulated training landscapes on military training ranges to impact the environment through nutrient enrichment. In carrying out the study, twenty four berms of compost (Compost), wood chips (Wood Chips), pine barks (Pine Barks), soil (Soil), and mixture of the above materials in various proportions were constructed. Each month representative samples of each berm material were dried, ground and sieved. Internal temperatures and moisture content of each berm were measured at weekly intervals. The samples were analyzed for pH, conductivity , NH_4^+ -N, $N0_3^-$ -N, P and total N. Result from this study showed that Treatment1 (100% Compost) poses the greatest threat of contributing NH_4^+-N, NO_3^-—N, P followed by Treatment 8 (33.3% each of Compost, Wood Chips, and Pine Barks),Treatment7 (30% each of Compost, Wood Chips, Pine Barks with10% Soil and Treatment 6 (25% each of Compost, Wood Chips, Pine Barks and Soil while Treatment 4 (100% Soil) supplies least P to the environment. So for effective building of berms and achievement of the objective of waste disposal, it is recommended that the berms are built with mixture of soil, wood Chip and Pine bark in equal proportion for compactibility

Key words: Berm, Compost mulch, Incubation, Mineralization, Nitrate, Ammonium, Phosphorus, Carbon.

1.0 Introduction

Military mission involves training which is land intensive and can cause significant damage to landscapes. Military vehicles during training maneuvering disrupt stable soil surfaces, create ruts, and compact the soil (Braunack, 1986; Thurow *et al*., 1993; Prosser *et al.*, 2000). The vehicles also damage and kill vegetation and soil microbiota (Wilson 1988; Haugen *et al*., 2003). and displace large amounts of soil. Even when leveled after training exercises, such excavations lead to inversion of soil layers and unnatural subsidence. Cutting vegetation for camouflage also destroy woody plants while other training trends have placed additional demands on these lands (Vachta *et al*., 1990). Establishing bivouac and supply positions concentrate non-combat activity and lead to compacted soils, loss of woody under-story, and damage to roots and trunks of trees (Trunbull *et al*., 1994; Whitecotton *et al*.2000; Kade and Warren, 2002).

The degradation of soil aggregates can make the land more vulnerable to wind erosion (Prose,1985; Maston,1988; Grantham *et al*., 2001) and the disturbance of landscapes from training exercise may lead to changes in composition of plant species (Wilson, 1988; Thurow *et al*., 1993) including invasion by alien plant species (Wilson, 1988; Milchunas *et al.,* 2000) while some animal species may be adversely affected by alteration to their habitat. In such degraded landscapes, excessive run-off and eroded sediments from within the boundaries of training areas may ultimately affect lands downstream (Bohm, 2003); and, by this the army faces major land management issues in maintaining its training areas to support the training mission (Vachta *et al*., 1990).

One of the several attempts to provide alternative means of disposing and recycling organic and inorganic waste materials for reducing soil-erosion, stream pollution and off-site sedimentation is the use of compost mulches to construct berms (called an earthwork in military terms) on lands for training of the military. Compost mulches and other organic waste materials are cost effective, provide the defensive cover, control erosion and thereby reducing the adverse effects of running waters on exposed top soil.

Despite the various benefits of using berms made from compost and other organic materials and soil for simulated military training landscapes, decomposition of these materials may cause environmental degradation by supplying nutrients such as nitrate-N (NO_3^- -N) ammonium N, (NH_4^+ -N) phosphorous ($H_2PO_4^-$ and HPO_4^{2-}) and toxic heavy metals to the environment on- and off-site ecosystems. This study was carried out to investigate *in-situ* mineralization of nitrogen (N) and phosphorous (P) in compost mulch berms on simulated military training landscapes and assess the nutrient loading potential of different mixtures of mulch berms.

2.0 Materials and methods

2.1 Study Location

The study was conducted at the Winfred Thomas Agricultural Experiment Station, Hazel Green, Alabama, on a Decatur silt loam (clayey kaolinitic thermic, typic paleudults)

2.2 Treatments

Different proportions of Yard waste compost(Compost), hard wood chips(Wood Chips) from tree trimming operations and the shredded pine bark (Pine Barks) from pine trees were thoroughly mixed with soil in different proportions using a Bob-Cat front end loader to make eight treatments (Treatments) studied. These were then moved to an open space where they were used to construct compacted berms to simulate military training landscape. by a track loader. The treatments were replicated three times to give a total of 24 experimental units used for the study in an experimental design of a randomized complete block (RCB) (Table 1).

The experimental units (berms) were spaced out at 3.05 meters intervals to prevent movement of materials between berms. The dimensions of each was 9.14 meters long, 4.88 meters wide, and 1.22 meters high. The front face of the berms on the south end was at a 3:1 slope to reduce erosion and to allow for mowing of grass and other vegetation. The other side on the northern end was at 1:1 slope to conserve space.

2.3 Sample processing

Samples were collected every month at three random locations from the berms using a probe. They were combined and air dried at 80^{o}F in the Farm drying room to a constant weight, sieved using a 32 x 32 size sieve and the powdered samples were kept in labeled Ziploc for analysis. Data collected include internal berm temperature measured once every week using 45.7 cm probe compost thermometers model AL 2P-0-100f-12. gravimetric moisture content, measured once every four weeks using the gravimetric method by weighing the samples taken before and after drying at 27^{0}C. ; pH, using a 1:1ratio of sample and deionized water for soil samples, a 1:2 ratio of sample and deionized water for compost material and 1:5 ratio of sample and deionized water for woody materials. The mixtures were shaken for 30 minutes on an electric shaker before taking reading using the Acumet LX pH/conductivity meter. The electrical conductivity (EC) was measured using a 1:10 sample: deionized water ratio. Two grams of sample was measured and 20 ml deionized water added. The mixture was shaken for 30 minutes on the same shaker and the conductivity was measured using the Acumet LX pH/conductivity meter. ammonium N (NH_4^+ - N), nitrate N ($N0_3^-$ - N), for each berm, was measured by adding20 ml of 2M KCl to two grams of dried and ground samples and shaken for 30 minutes followed by filteration with a #42 Whatman filter paper using the Timber Line 2800 Ammonia Analyzer.

Inorganic ortho-phosphate ($H_2PO_4^{2-}$) was measured colorimetrically using the Easychem analyzer (Systea Scientific) (Murphy and Riley, 1984) by adding two grams of dried samples to 20 ml of Mehlich III solution (Mehlich, 1984) and shaken for 30 minutes followed by filtration with a No 42 Whatman filter paper to extract phosphorus. Total C and N content to calculate the C/N ratio were measured using the LECO TruSpec CN analyzer (LECO CN analyzer – LECO Corp, St. Joseph Michigan).

2.4 Statistical Analysis

The data collected were analyzed using the General Linear Models (GLM) procedures of the SAS ver. 9.3.1 software (SAS, 2007). Treatment means was compared using LSD and Duncan Multiple Range Test.(DMRT). Spearman's correlation coefficients were used to determine the relationships between collected data. Regression analysis was used to determine the effect of variables such as pH, temperature and moisture on mineralization parameters such as NH_4-N, NO_3-N, and P.

3.0. Results and Discussion

3.1.pH values

Rapid decomposition and mineralization is favored by a near-neutral pH of 6 to 8 resulting in the largest, most diverse bacterial population. Table 2 shows the pH values for the treatments during the study period. The pH values for Treatment I of 100 % Compost (Compost) ranged from 7 to 7.5 implying optimal conditions for mineralization process in nutrients supply.. This resulted in significantly higher levels of NH_4^+-N and NO_3^- -N compared to other treatments in spite of other contributing factors (Figures 1 and 2 respectively).Treatment 1 has the characteristic of nutrient balance sourced from various materials like wood, ashes [high in Potassium (K), Calcium (Ca), and Magnesium (Mg)], bone meat or phosphate rock powder (high in P and Ca), Sea weed (high in K, Mg and micronutrients)

Treatment 2 which is 100 % Wood Chips) and Treatment 3 of 100 % Pin Barks both have pH values in the acid range; but, the values increased as mineralization progressed. The low pH values could be attributed to organic residues containing polyphenols, proteins, soluble carbohydrates, hemicelluloses, cellulose-like, lignin-like compounds present in the plant organic residues (Thuries *et al*. 2002). Treatment 4 contains 100 % Soil and has the least pH value from 5.16 on the average. The Treatment was subsoil low in organic material and as such lacks supply of carbon (figure 3) for microbial energy. The reddish colored nature of the treatment 4 indicates the presence of Ferric ions which on hydrolyses introduced acidity into the soil environment.

In treatment 5 containing 20 % each of Compost, Wood Chips, Pine Barks and 40 % Soil treatment 6 having 25 % each of Compost, Wood Chips, Pine Barks and Soil, treatment 7 which contains 30 % each of Compost, Wood Chips, Pine Barks and 10 % Soil) and treatment 8 having 33 % each of Compost, Wood Chips and Pine Barks, there were no significant differences in the pH values ranging from 6 to 7. Hence, the amount of NH_4^+ –N produced was less than that for treatment 1(100 % Compost), treatment 2 (100 % Wood Chips) and treatment 3 (100 % Pine Barks).

3.2 Internal berm temperature

Optimum temperature of microbial activities for N mineralization ranges between 25^{o}C to 35^{o}C. This activity which generally increases with temperature (Waksman and Gerretsen, 1931 ; Kirchbaum 1995), together with soil moisture is one of the most important factor for decomposition (Stanfor and Epstein, 1974). This chemical reaction is exothermic in nature and accounts for the release of heat energy recorded during the mineralization activities. (Figure.4).

The berm materials were in general actively producing heat showing microbial activity from beginning of study to week 20. The relatively lower temperature recorded for Treatment 4 (100 % Soil) is a factor of the lower pH value and lack of biomass limiting microbial activity. Between the week 8 and 20, there was almost a double in the temperature released corresponding to a doubling of microbial activity; and, roughly a doubling of the activity with each rise can be expected in the range from 5 to 35^{o} C (Stanford *et al*, 1973, Katterer *et al*, 1998).The downward trend started from week 24 which coincided with the end of October for the winter season. Nitrification declines above 35^{o} C because nitrifying bacteria cannot tolerate high temperature and rate of ammonification can only increase above 35^{o} C by the action of heat tolerant bacteria (Thompson, 1947). Since nitrifying bacteria cannot tolerate high temperature compared to ammonification bacteria the values for NO_3^- – N are comparatively lower than those for NH_4^+ – N with exception to Treatment 1 (100^{o} Compost)

Microbial activities were highest for treatment 8 (33 % each of Compost, Wood Chips, Pine Barks) treatment 7 (30 % each of Compost, Wood Chips, Pine Barks and 10 % Soil) treatment 6 (25 % each of Compost, Wood Chips, Pine Barks and Soil) treatment 5 (20 % each of Compost, Wood Chips, Pine Barks and 40 % Soil) treatment 1 (100 % Compost) and treatment 3 (100 % Pine Barks) in that order, while treatment (100% Wood Chips) had comparatively lower values of heat released.

3.3 Ammonium N (NH^+_4 – N) and Nitrate N (NO^-_3 – N)

The values obtained for all the treatments are influenced by interplay of the pH and carbon supply from plant residue. All berm materials had higher NH_4^+ – N content compared to Treatment 4 (100 % Soil) due to its low pH values and lack of organic matter for microbial activity. Treatment 1 showed consistent mineralization of NH_4^+ – N but Treatment 2 (100 % Wood Chips) and Treatment 3 (100 % Pine Barks) showed more NH_4^+ – N compared to other materials

The increase in amount of NH_4^+ between week 16 and 28 corresponded with the increase in pH, rise in temperature to increase microbial metabolic activities. The high value for treatment 1 (100 % Compost) was attributable to the optimum pH values but treatment 2 (100 % Wood Chips) treatment 3 (100 % Pine Barks) and treatments treatment treatment 5,6,7,8 with various mixtures of Compost, Wood Chips, Pine Barks were enhanced by plants residue for C supply to the microbes. Amount of NO_3^- – N produced followed the same general pattern of NH_4^+-N production but more influenced by pH values and external temperatures. The supply of NO_3^- – N in treatment Treatment 1 (100 % Compost) was very high compared to other materials. Amount of NO_3^- – N produced was followed by treatment 5,6,7,8, in that orde (Figure 2).

There was a noticeable reduction in the amount of NO_3^--N formed compared to NH_4^+–N. This could be attributed to the phenomena of immobilization, Nitrogen cycle, erosion loses, leaching loses, volatilization. Nitrate N is easily leached from permeable soil while NH_4^+ ion is trapped in a cation exchange with negatively charged clay minerals to stabilize soil structure making it more resistant to decomposition. Volatilization process like denitrification caused NO_3^- – N to be lost when samples were saturated with water exceeding 80% water filled pore space (relative saturation) (Parkin *et al*, 1996).

By normal nitrification processes the aerated samples produced nitrates which would later be reduced to volatile products by anaerobic bacteria when the samples become water logged. This was probably the case with treatment 3 (100 % Pine Barks) from earlier part of study to week 24 and also treatment 2 (100% Wood Chips) with treatment 3 (100% Pine Barks) from week 24 upwards (figure.6). Wet samples lose nitrites rapidly producing gaseous nitrogen in alkaline environment and nitrogen oxides in acid soils (Van cleamput, 1971)

3.4 Electrical conductivity

Electrical conductivity has generally been associated with measurements of soluble nutrients (Smith and Doran, 1996) for both cations and anions, in monitoring the mineralization of organic matter (De Neve *et a*l, 2000) and an indication of the dynamics of soil available NO_3^- levels (Smiths and Doran, 1996) which may have resulted from the two-step process of organic N mineralization. Treatment 1 (100% Compost) and treatment 2 (100 % Wood Chips) consistently have high values of electrical conductivity, (Figures 5): For Treatment 1, compost material contains mixture of simple and complex organic materials which decompose further to release mineral elements and ions of various salts. The mineralization process of treatment 2 (100 % Wood Chips) and treatment 3 (100 % Pine Barks) is enhanced by the energy-rich carbon content (Figure.3) stimulating microbial growth and activity (Nyle and Ray, 1999). Hence the high NH_4^+-N content (figure 1). Conductivity is also a good indication of the dynamics of soil available NO_3 levels (Smith and Doran 1996) resulting from the two-step process of organic N mineralization. A decline in electrical conductivity in treatment 3 (100 % Pine Barks) and for all the treatments from week 12 could be associated with the loss of NO_3^- N due to leaching and denitrification that occurred after rainfall and a soil condition that approached saturation in week 12 in conformity with earliest study (Elgenberg *et al*. 2000). On the other hand, the low value of electrical conductivity recorded for treatment 4 (100% Soil) could be explained by the fact that the soil used in the study was a sub-soil low in organic material to supply energy that could enhance microbial activity for mineralization to form ions. The implication of these results is that, assuming leachate eventually ends up in off site down-stream waters resources such as streams, rivers and lakes, treatment 3 (100 % Pine Barks) followed by treatment 5 (20 % of Compost, Wood Chips, Pine Barks and 40 % Soil), through treatment 6 (25% each of Compost, Wood Chips, Pine Barks, Soil) treatment 7 (30 % each of Compost, Wood Chips, Pine Barks and 10 % Soil), to treatment 8 (33 % each of Compost, Wood Chips and Pine Barks and Pine Barks) in increasing order will be of greater threat in the contribution of NO_3^- -N to the environment. Nitrate – N concentrations in excess of 10 mg/l are considered unsafe for drinking water (Spalding *et al*, 1993).

3.5 Gravimetric moiture content

A minimum amount of water is essential for the Berm materials to initiate microbial transformation process (Harris, 1981) and there are considerable effects of soil-air/soil-water regime on aerobic and anaerobic microbial activities (Linn and Doran,1984) such that aerobic microbial activity increases with water content up until a maximum point, where any surplus of water restricts oxygen diffusion and availability (Bhaumik and Cark, 1948). Microbial activity ceases when soil water content is near the wilting point. A material that goes through the cycles of wetting and drying pump air in and out of material as a process of frequent renewal of the oxygen supply is likely to release more nitrogen than one that is continuously moist. This may accounts for high value of products for the loosely packed Treatment 2 (100 % Wood Chips) and the low values of products for the constantly moist treatment 3 (100 % Pine Barks) In the first week of sampling moisture levels were generally low.(figure 4.6) reflecting in the low amount of NH_4^+-N and NO_3^--N produced.

In the 4th week lower values of moisture were observed for treatment 4 (100 % Soil) probably due to low retention ability of the soil. Treatments 1 (100 % Compost). Treatment 7 (30 % Wood Chips, 30 % Pine Barks and 10 % Soil), treatment 8 (33 % each of Compost, Wood Chips, and Pine Barks) are favorable to microbial activities that guarantee favorable NH_4^+ – N and NO_3^- – N production.

3.6 Orthophosphate P

Mineralization of organic phosphorus is also subject to a near neutral pH (6-7) (Espinoza et al., 1995), sufficient soil moisture and aeration (about 60% of the soil pore space filled with water) warm temperature (25 to 35ºC), C:N ratio and so forth (Nyle and Ray, 1999). Under acidic pH (pH < 6) P in the inorganic form occurring mostly as orthophosphate compounds of Aluminum, Iron or Manganese is tied up while under alkaline conditions (PH > 7) phosphorus is preferentially fixed by calcium and magnesium. As such the P becomes unavailable in both instances. Should organic residues low in P but high in C and other nutrients be present, microbes would increase their activity and immobilize the phosphorous in their biomass. (Nyle and Ray,1999). Net immobilization of soluble phosphorous is most likely to occur if residues have a very high C:P ratio while net mineralization is likely at low C:P ratio. The high C content of treatment 3 (100 % Pine Barks) and that of treatment 2 (100 Wood Chips) over the P could be responsible for the lower value in the ortho-phosphate P. Further to reduction in the P levels are growth of grasses and some other cover crops.

At the beginning of the study, the amount of orthophosphate P content in the berms was highest in treatment 1 (100% Compost). This was followed, in decreasing order by Treatment 8 (33,3 % each of Compost, Wood Chips, and Pine Barks), Treatment 6 (25 % each of Compost, Wood Chips, Pine Barks and Soil) and Treatment 7 (30 % each of Compost, Wood Chips and Pine Barks and 10 % Soil) which were close in values; then Treatment 2 (100 % Wood Chips), Treatment 5 (20 % each of Compost, Wood Chips, Pine Barks and 40 % Soil) and Treatment 3 (10 % Pine Barks) while Treatment 4 (100 % Soil) was the least. (Figure.7).

By week 8, the amount of ortho-phosphate P in all the treatments dropped to similar values. However, lowest amount of orthophosphate P was found in Treatment 4 (100 % Soil), Treatment 3 (100 % Pine Barks), Treatment, 2 (100 % Wood Chips) Treatment 5 (20 % each of Compost, Wood Chips, Pine Barks and 40 % Soil) and Treatment 6 (25 % each of Compost, Wood Chips, Pine Barks and Soil). The least value of orthophosphate P in Treatment 4 (100 % Soil) could be explained by the fact that the soil used in this study consisted of subsoil, which is low in organic matter that could have mineralized to the inorganic form. Moreover, the reddish brown colored nature of the soil implies the presence of Fe [III] for acidic nature. Any orthophosphate P present was already tied up and as such made unavailable.

4.0. Conclusion and Recommendations

Results obtained from the study showed that berms made from 100 % compost materials (Treatment 1) pose the greatest threat to contribute both NH_4–N and NO_3–N to the environment. 100 % Wood Chip (Treatment 2) and 100 % Pine Bark(Treatment 3) pose the greatest threat to supply NH_4–N. Berms made from 25 % each of compost, word chip Pine Bark and soil, (Treatment 6) followed by berms from 30 % each of compost wood chip Pine Bark, 10 % soil (Treatment 7) and then berms from 33.3 % each of compost, wood chip and Pine Bark (Treatment 8) in that increasing order of values and next to 100 % compost (Treatment 1) in posing threat to contribute NO_3–N to the environment . In the case of both NH_4 – N and NO_3-N 20 % each of compost, wood Chip , Pine Bark and 40 % soil (Treatment 5) contribute less but 100% Soil (Treatment 4) pose the least threat in contribution to the environment.

In terms of orthophosphate P supply, 100 % compost (Treatment 1) pose the greatest threat to the environment followed by berms from 33.3% each of compost wood chip and Pine Bark while 100 % soil (Treatment 4) pose the least threat in the supply of orthophosphate P to the environment. This study therefore showed that compost material can play significant role in the supply of nutrients to the environment. Incorporation of compost in the building of berms in simulated Military landscapes will enhance the supply of nutrients which may result to environmental pollution. Since NH_4 – N is the ultimate product of mineralization made from 100 % Pine Bark, 100 % wood chip and 100 % soil (when erosion is prevented) were found to have the least potential to cause environmental impact from the measured pollutants and as such may hold the greatest potential for use on Army Training Landscapes.

For effective building of berms in Army Training Landscapes and achievement of the objective of waste disposal, it is recommended that the berms are built with mixture of soil, wood Chip and Pine bark in equal proportion for compactibility. Grasses and other cover crops are planted as vegetation cover to minimize or prevent erosion and runoff sediments and where compost materials are to be utilized, cover crops are necessary not only to provide vegetative cover but also reduce loss of nutrients and sediments that would otherwise leach below the root zone. This process is achieved by the fact that the vegetative cover reduces the formation of a crust at the soil surface, thus maintaining a high rate of infiltration; and in any given storm more infiltration leaves less water to run off on the soil surface. Moreover for the runoff that does occur, the cover crops help in removing both sediments and nutrients by the same mechanism that operate in a buffer strip.

Table 1. Arrangements of the berms as experimental units into plots by randomized complete block design.

Plot # N	Treatment	Description ………%............ CP	WC	PB	S	Plot #	Treatment	Description ……..%............ CP	WC	PB	S	
1	3	0.0	0.0	100	0.0	5	8	33.3	33.3	33.3	0.0	BLOCK I
2	5	20	20	20	40	6	1	100	0.0	0.0	0.0	
3	6	25	25	25	25	7	4	0.0	0.0	0.0	100	
4	7	30	30	30	10	8	2	0.0	100	0.0	0.0	
9	5	20	20	20	40	13	4	0.0	0.0	0.0	100	BLOCK II
10	8	33.3	33.3	33.3	33.3	14	6	25	25	25	25	
11	2	0.0	100	0.0	0.0	15	7	30	30	30	10	
12	1	100	0.0	0.0	0.0	16	3	0.0	0.0	100	0.0	
17	3	0.0	0.0	100	0.0	21	5	20	20	20	40	BLOCK III
18	6	25	25	25	25	22	2	0.0	100	0.0	0.0	
19	4	0.0	0.0	0.0	100	23	1	100	0.0	0.0	0.0	
20	8	33.3	33.3	33.3	33.3	24	7	30	30	30	10	

Table 2. pH values of field berm samples measured at each sampling period of every month

	Number of weeks											
	0	4	8	12	16	20	24	28	32	36	40	44
Treatment 1	7	7.1	7.3	7.5	7.3	7.4	5.85	7.2	7.3	6.9	7.6	7.2
Treatment 2	5.5	5.8	5.5	6.8	5.8	6.2	6.89	5.4	5.7	5.3	6.7	6.3
Treatment 3	4.5	4.9	4.9	5.1	5.5	5.8	5.51	5.3	5.3	5.5	5.9	5.4
Treatment 4	4.9	4.7	4.9	5.9	4.9	5.7	5.9	4.9	4.9	4.8	5.3	5.1
Treatment 5	6	6.4	6.3	6.8	6.4	7	6.78	6.6	6.7	6.3	6.9	7
Treatment 6	6.3	6.6	6.6	6.9	6.6	7.2	6.85	6.7	6.8	6.5	6.7	6.8
Treatment 7	6.3	6.5	6.3	6.8	6.6	7.1	6.47	6.5	6.7	6.4	7	6.6
Treatment 8	6.5	6.9	6.8	6.8	6.7	7.1	6.76	6.7	6.9	6.5	7.1	6.9

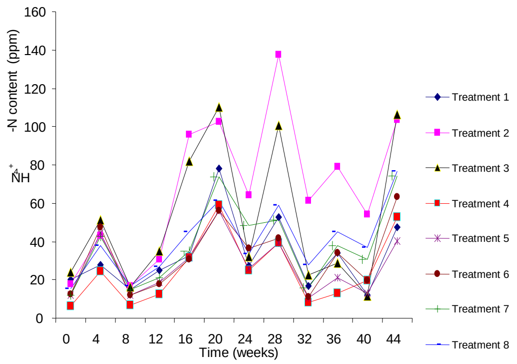

Figure 1. Ammonium $^{+}$content mineralized by the field berm samples

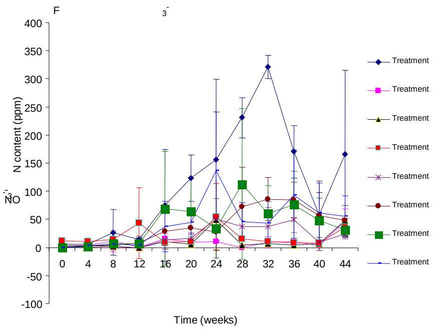

Figure 2. Nitrate N (NO -N) content mineralized by field berm samples

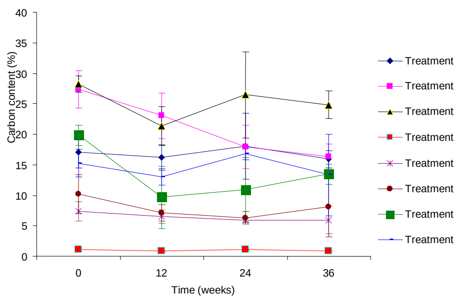

Figure 3. Total Carbon Content of field berm samples

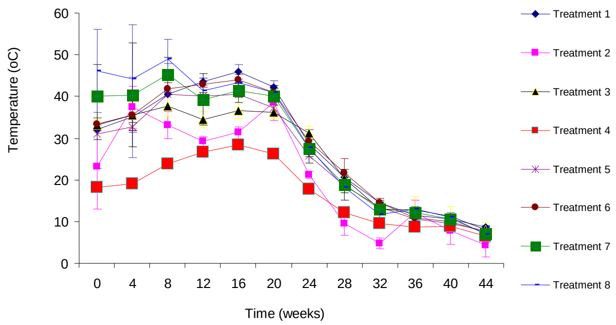

Figure 4: Heat energy released during mineralization of field berm samples

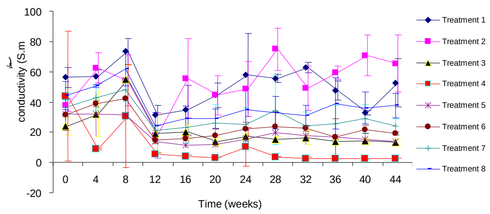

Figure 5.Electrical Conductivity (EC) value of field berm samples

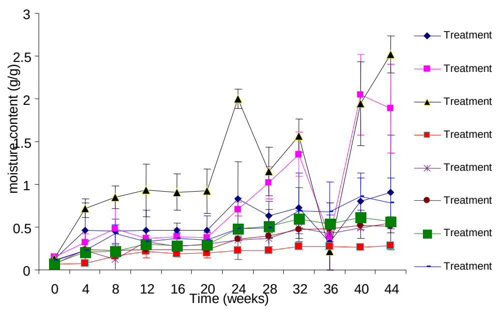

Figure 6. Gravimetric Moisture content of field berm samples

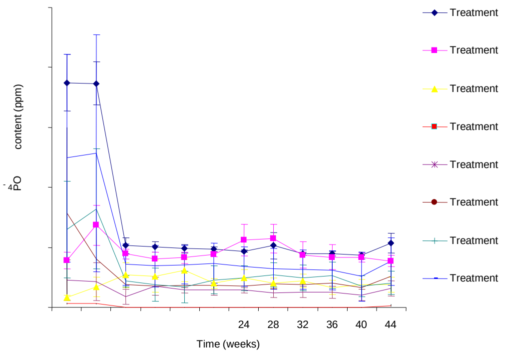

Figure 7. Ortho-phosphate P (PO)$_4$ content mineralized by field berm samples

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