International Journal of Science, Engineering & Environmental Technology (IJOSEET), 5(3): 23-33, 2020
ISSN 0794-9650
www.repcomseet.com

Comparative study of Nitrogen and Phosphorus mineralization in Field and incubated compost mulch berms on simulated Military training landscapes

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Abstract- Mineralization of Field and incubated compost mulches can lead to pollution of the environment by supplying nutrients such as nitrate and ammonium N, phosphorous, and toxic heavy metals. This study compared the potential for using Field and incubated 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% S and Treatment 6 (25% each of Compost, Wood Chips, Pine Barks and Soil while Treatment 4 (100% Soil) supplies least P to the environment. An incubated study on the berm materials gave similar pH and NH_4^+-N values but higher NO_3^-N. In conclusion Grasses and other cover crops are planted not only to provide vegetative cover but also reduce loss of nutrients and sediments that would otherwise leach below the root zone.

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

1.0 Introduction

Training by the Military is land intensive and could be damaging to landscapes.(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). Vegetation cutting 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). Degradation of soil aggregates exposes the land 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.
Inspite of the 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 compare mineralization of nitrogen (N) and phosphorous (P) of compost mulch berms materials sampled from the Field and under controlled incubated laboratory conditions of the simulated military training landscapes.

2. Materials and methods

2.1 Study Location

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

2.2 Treatments and Experimental Design

Treatments studied consisted of three organic materials: compost (Compost), wood chips (Wood Chips), and pine bark(Pine Barks) mixed with soil The compost was yard waste compost, the wood chips were hard wood chips from tree trimming operations and the pine bark were shreaded pine bark from pine trees. Different proportions of these materials were thoroughly mixed with the aid of a Bob-Cat front end loader; and were moved using a track loader to an open space where combinations of the materials in different proportions were developed to make eight treatments, (Table1). The treatments were replicated three times giving a total of 24 experimental units arranged in a randomized complete block (RCB) design used for the study.The organic materials and soil were used for constructing berms compacted by the track loader to simulate military training landscape. The berms were spaced out at 3.05 meters intervals to prevent movement of materials between berms. The dimension 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 for space conservation.

2.3 Sample processing and Analysis

Samples from the berms were collected using a probe at three random locations every month. The samples collected from each berm were combined and dried to constant weight in an oven at 38ºC. The dried samples were ground and sieved using a 2mm sieve and kept in labeled Ziploc for analysis involving pH, electrical conductivity (EC), NH_4^+-N and NO_3^--N, as well as that of total C and N. Internal berm temperature was measured weekly using 45.7cm probe compost thermometers model AL 2P-0-100f-12. Berm moisture content was measured monthly by the gravimetric method. The pH of berm materials was measured using a 1:1 ratio 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 EC of berm materials was measured using a 1:10 ratio of sample and deionized water. The mixtures were shaken for 30 minutes on an electric shaker before taking reading using the Acumet LX pH/conductivity meter.

For each berm, 20 ml of 2M KCl were added to two grams of dried and ground samples and shaken for 30 minutes followed by filteration with a #42 Whatman filter paper. Filterate collected was measured for Ammonium N (NH_4^+-N) and nitrate N (NO_3^--N) using the Timber Line 2800 Ammonia Analyzer. Total C and N of dried berm powdered samples were measured using the LECO TruSpec CN analyzer (LECO CN analyzer – LECO Corp, St. Joseph Michigan). This data was used to calculate the C/N ratio of the compost berm materials. The data collected in this study were analyzed using the General Linear Models (GLM) procedures of the SAS ver. 9.3.1 software (SAS, 2007). Treatment means was compared using the LSD mean separation procedure.

3. Results and discussion

3.1 pH

Conducive Environmental conditions for rapid decomposition and mineralization include a near-neutral pH of 6 and 8 favorable to growth of diverse bacterial population (Murray, 1981). Table 2 shows the pH values for the Field treatments. Treatments 1 (100% Compost), 6 (25% each of Compost, Wood Chips, Pine Barks, and Soil); 7 (30% each of Compost, Wood Chips, Pine Barks, and 10% Soil as well as Treatment 8 (33.3% each of Compost, Wood Chips, and Pine Barks) with pH in the optimum range of 6 to 8 for mineralization have high levels of NH_4-N and NO_3-N while Treatment 2 [100% Wood Chips], Treatment 3 [100 % Pine Barks] with relatively lower pH value in the near acid range were enhanced by the factor of plant residue for C supply to have high values of NH_4-N and NO_3-N. The low values of NH_4^+-N and NO_3^--N in the Treatment 4 (100 % Soil) could result from the low pH value in the acid range which limited the microbial activities.

Compared with the pH of Incubated samples study there was no significant difference in the pH values of both the Bern sample on the field and bern samples incubated. Both have Treatment 3 (100 % Pine Barks) having the pH values in the near acid range and Treatment 1 (100 % Compost) having the highest pH values (Tables 2 and 3). Treatment 2 (100 % Wood Chips), Treatment 5 (20 % each Compost, Wood Chips, Pine Barks and 40 % Soil) Treatment 6 (25 % each of Compost, Wood Chips, Pine Barks and Soil) and Treatment 7 (30 % each of Compost, Wood Chips, Pine Barks and 10 Soil) all have similar pH values (Table 3). As discussed earlier, the pH values recorded indicated evidence of mineralization taking place also in the incubated samples (Table 3).

3.2 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 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 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 order (Figure 3). 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 3). Wet samples lose nitrites rapidly producing gaseous nitrogen in alkaline environment and nitrogen oxides in acid soils (Van Cleamput, 1971) Comparing Ammonium N (NH_4 – N) and Nitrate N (NO^-_3 – N) production for the incubated samples at the begining of the study to the end of week 8, there was no significant difference in the amount of NH_4^+-N mineralized between the field Berm samples and the incubated samples. However, after week 8, while these was a rise in value of NH_4^+-N and NO_3^--N produced in the field samples (figures 1 and figure 2), there was less production of NH_4^+-N in the incubated samples. Although there was also less NO_3^--N from the incubated samples there was a noticeable irregular rise and fall in values on monthly basis (figure 4). Despite the irregular NO_3^--N formation in incubated samples, the values recorded were relatively higher than those from NO_3^--N for the field samples. This could be due to absence of leaching for possible loses in the incubated samples.

3.3 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 35°C), 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 % S) was the least. (Figure 9).

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.
Compared with the incubated samples there was no significant difference in the values of orthophosphate P from Treatment 4 (100 % Soil) for the field and that from the same Treatment for the incubated samples.(figure 10) .

Generally low values like those for field samples were recorded for Treatment 3 (100 % Pine Barks), Treatment 5 (20 % each of Compost, Wood Chips, Pine Barks and 40 % Soil). However the values obtained for the incubated samples were generally lower than those of the field samples at the begining of the study but similar fall in values occured for the incubated samples as from the week 4. (figure 10). Treatment 1 (100 % Compost) Treatment 2 (100 % Wood Chips) and Treatment 8 (33,3 % each of Compost, Wood Chips, and Pine Barks) have high values of orthophosphate P for the incubated samples as in the field berm samples. As discussed earlier, although both Treatment 3 (100 % Pine Barks) and Treatment 2 (100 % Wood Chips) have high values for carbon content (figure 5), the lower pH values for Treatment 3 (100 % Pine Barks) in the acid range could hinder microbial activity for the orthophosphate P formation.

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 al, 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. Treatment1 (100% Compost) and Treatment 2 (100 % Wood Chips) consistently have high values of electrical conductivity, (Figure 7): 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). For the Incubated there were generally no significant differences in the Pattern of conductivity for both the field berms samples and those for the incubated samples (figure 7). The relatively lower values recorded in the incubated samples could be attributed to the comparatively irregular operation of the Green house as earlier discussed before the samples were relocated to the laboratory for the observed improvement in microbial activities from week 28 (figure 8).

4.0. Conclusion and Recommendation

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.
NO_3^--N content was higher for incubated berm samples because leaching was not taking place. Therefore field studies may under-estimate $NO^{3\,-}$- N produced. The Orthophosphate P contents of the incubated berm samples did not differ significantly from those for the field samples in the pattern of production though generally lower in quantity. Conductivity measurement for the incubated berm samples followed similar pattern of measurement for the field samples except that they were comparatively lower in values.

In conclusion, 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 run-off that does occurs, the cover crops help remove both sediments and nutrients by the same mechanism that operate in a buffer strip.

. Table1.List of treatments used in the study showing the percentage by volume of each material taken to make a treatment

Compost (CP)	Wood Chips (WC)	Pine Bark (PB)	Soil (S)
---------------------	---------------------%	----------------------	----------------------
100.0	0.0	0.0	0.0
0.0	100.0	0.0	0.0
0.0	0.0	100.0	0.0
0.0	0.0	0.0	100.0
20.0	20.0	20.0	40.0
25.0	25.0	25.0	25.0
30.0	30.0	30.0	10.0

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

Table 3. pH values of incubated berms samples

	Number of weeks									
	0	4	8	12	16	20	24	28	32	36
Treatment 1	7.49	7.67	7.83	8.08	7.77	7.91	7.56	7.73	7.64	7.47
Treatment 2	6.8	6.82	6.9	7.2	6.86	7.08	6.82	6.61	6.44	6.47
Treatment 3	5.06	5.17	5.31	5.51	5	5.68	5.1	5.17	5.36	5.19
Treatment 4	5.88	6.44	5.82	6.24	5.21	6.1	5.87	6.32	5.74	6.13
Treatment 5	6.79	7.07	7.86	7.56	7.43	7.31	6.94	6.98	7.14	7.04
Treatment 6	6.94	7.01	7.06	7.31	6.53	7.28	6.88	7.2	7.28	7.16

Treatment 7	6.75	7.04	7.41	7.97	7.38	7.58	7.35	7.47	7.33	7.22
Treatment 8	6.84	7.25	7.47	7.89	7.44	7.68	7.36	7.47	7.42	7.31

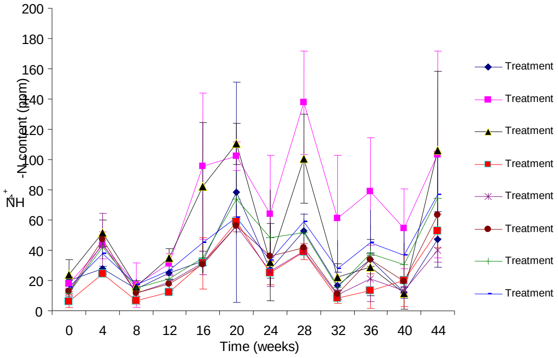


Figure 2. Ammonium N (NH4+-N) content of Incubated berm samples

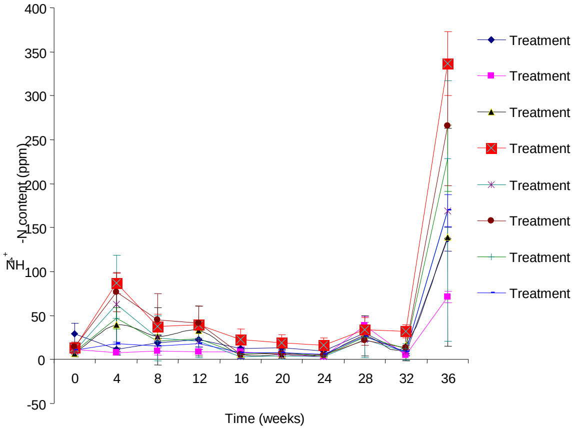


Figure 1. Ammonium N (NH-N)content mineralized by the field berm samples

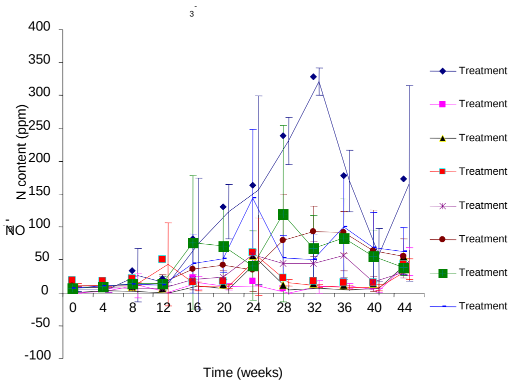


Figure 3. Nitrate N (NO-N) content mineralized by field berm samples

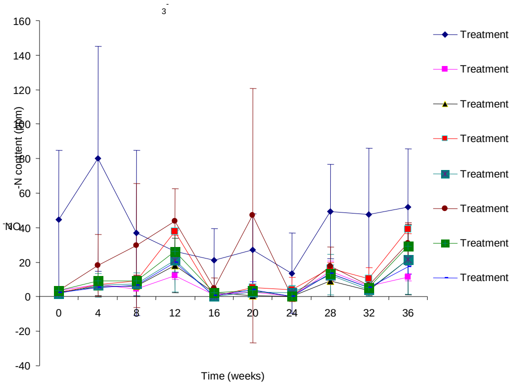
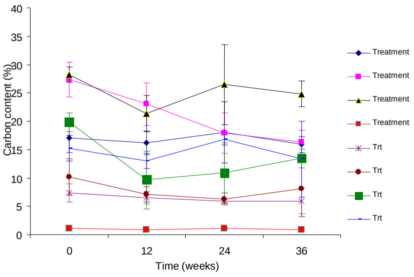


Figure 4: Nitrate N (NO -N) Content of mineralized incubated samples



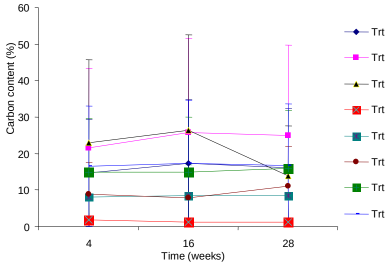


Figure 5. Total Carbon Content of field berm samples

Figure 6. Total Carbon content of Incubated berm samples

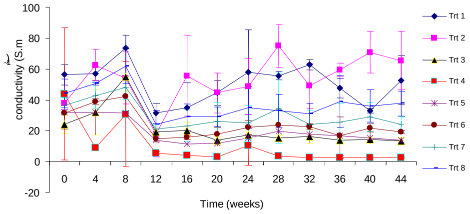


Figure 7: Electrical Conductivity (EC) value of field berm samples

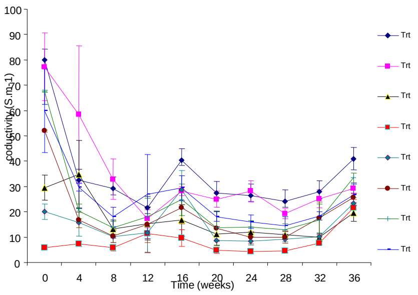


Figure 8: Conductivity Values of Incubated berm samples

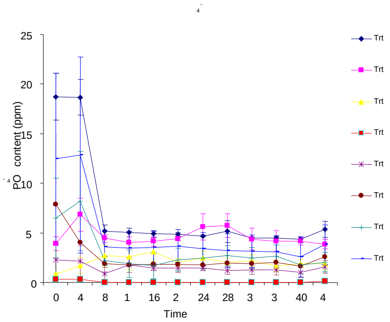


Figure 9. Ortho-phosphate P (PO) content mineralized by field berm samples

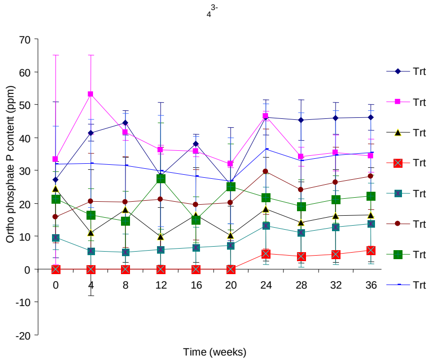


Figure 10. Ortho phosphate P (PO) content of Incubated berm samples

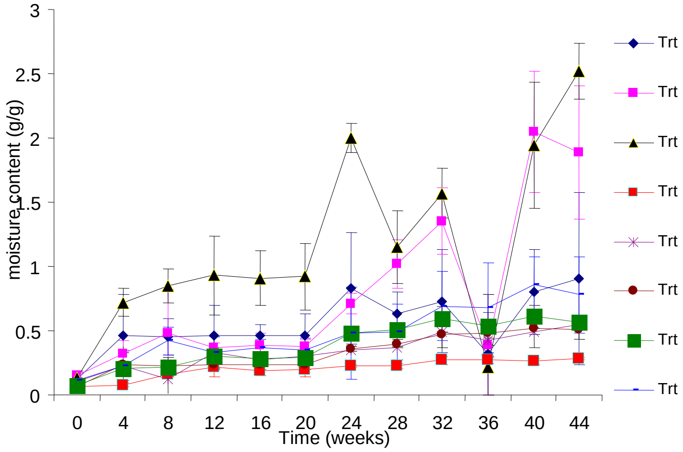


Figure 11: Gravimetric Moisture content of field berm samples

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