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Effect of multi-nutrient powder and pellet formulations on nitrogen dynamics in soil

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Abstract
A laboratory incubation experiment was carried out to study the nitrogen mineralization in the soil as influenced by multi-nutrient powder and pellet formulations. Multi-nutrient powder and pellet formulations were prepared using different combinations of nutrient sources like blood meal (BM), soyabean meal (SM), rock phosphate (RP), steamed bone meal (SBM), potassium sulfate (SOP), langbeinite (L), epsom salt (ES) and borax (B) and binding agents permitted by the National Programme for Organic Production. The experimental design was completely randomized design with 8 treatments and 3 replications. The multi-nutrient powder formulations include T_1 (BM + RP + SOP + ES + B), T_2 (BM + RP + L + ES + B), T_3 (BM + SBM + SOP + ES + B), T_4 (SM+ RP + L + ES + B) and pellet formulations include T_5 (BM + RP + SOP + ES + B + 4% bentonite), T_6 (BM + RP + L + ES + B + 4% starch), T_7 (BM + SBM + SOP + ES + B + 4% bentonite) and T_8 (SM+ RP + L + ES + B + 4% bentonite) which were mixed with 5kg of soil taken in pots and incubated under field capacity. Nitrogen-release potential of all treatments were determined by measuring changes in NH_4^+-N, NO_3^--N and organic N concentration in soil periodically at 60 days interval over 300 days. Results indicated that the NH_4^+-N content was always higher than NO_3^--N throughout the incubation period. T_3 released the maximum NH_4^+ (85.87 mg kg^{-1}) and NO_3^--N (48.53 mg kg^{-1}) on 120th day. T_8 recorded the lowest NH_4^+-N content and NO_3^--N content. The organic N content showed a declining trend throughout the incubation. The highest organic N was recorded on the 60th day for T_3 (309.87 mg kg^{-1}) and the lowest was recorded on the 300th day for T_8 (201.60 mg kg^{-1}). Nitrogen mineralization was maximum from 60 to 120 days of incubation after which it decreased gradually showing signs of stabilization at the end of the incubation period.

Keywords: Organic fertilizer, multi-nutrient powder, multi-nutrient pellet, mineralization, nitrogen fractions

1. Introduction
The major soil type of Kerala is laterite soil which is acidic, sufficient in phosphorus, iron, zinc, copper and manganese and deficient in organic matter, nitrogen, potassium, calcium, magnesium, sulfur and boron (Rajasekharan *et al.*, 2014; Bhindhu and Sureshkumar, 2021) [13, 2]. Therefore, external application of these nutrients is necessary for good crop production. Soil organic matter is capable of supplying all these nutrients. Maintaining adequate soil organic matter is important to increase productivity and improve soil health and quality. It influences the biological, chemical and physical processes in soil (Wild, 1995) [14].

Nitrogen is one of the most limiting nutrient elements in agricultural soils. Nitrogen in organic manure is in organic form, which has to first be mineralized into inorganic form so that it can be taken up by plants. During organic matter decomposition, the mineralized N has 3 fates. First, mineral N may remain in the soil and may become part of the net mineralized N pool; second. the mineral N may be immobilized by microbes and become part of the microbial biomass pool and third, mineralized nitrate may denitrify and be lost from the soil as either nitrous oxide or dinitrogen gas (Calderon *et al.*, 2005) [5]. Mineralization rate of organic N depends on various factors like environmental factors (temperature, moisture content) and the chemical composition of organic N sources. Increasing soil temperature and moisture content increases the net N mineralization. High total N content, C/N ratio, lignin/N ratio and polyphenol content in organic N sources also affect the N release (Agehara and Warncke, 2005; Hartz and Johnstone, 2006) [1, 9].

Nitrogen mineralization and the kinetics of N mineralization have been studied for several organic fertilizers, such as blood meal, meat bone meal, alfalfa meal, feather meal and fish products (Gale *et al.*, 2006; Cayuela *et al.*, 2009; Cabilovski *et al.*, 2013) [8, 7, 4].

Soil amended with defatted and non-defatted meat and bone meal (MBM) shows fast mineralization during the initial days of the incubation period. Non-defatted MBM shows increasing NH_4^+ and NO_3^-- N as compared to defatted MBM. 21.5 - 33.1% of added N mineralizes during the initial days of incubation. And by the end of the incubation period, 50% of the added N is mineralized. Soil microbial count and activities increase with the rate of application of MBM (Mondini *et al.,* 2008) [12]. N mineralization is fast for organic amendments like meat powder, fish meal and alfalfa litter with high C quality coupled with high N content and slow for organic amendments like humus and alfalfa biochar with low C quality even with high N content. Organic amendments like sawdust, cellulose, wood biochar and grass litter with low C quality and low N content show a slow but long-lasting N immobilization (Bonanomi *et al.,* 2019) [3].

Studies on nitrogen mineralization of organic nutrient sources have been done only for a shorter period of incubation. Therefore, the present study is designed to evaluate the nitrogen mineralization dynamics in soil incubated under laboratory conditions upon addition of organic multi-nutrient powder and pellet formulations over a period of 300 days.

2. Materials and Methods

2.1 Incubations Study

A laboratory incubation experiment was carried out in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani to study the mineralization of nitrogen in soil while applying multi-nutrient powder and pellet formulations. The soil used in the experiment was collected from Model Organic Farm, College of Agriculture, Vellayani (AEU 8). The chemical characteristics of the experimental soil are given in Table 1. The soil was air-dried and grounded to pass through a 2mm sieve. Five kilograms of soil was taken in pots. Multi-nutrient powder and pellet formulations containing N, P, K, Ca, Mg and B were prepared using different combinations of nutrient sources and binding agents permitted by the National Programme for Organic Production and applied based on the nutrient requirement of nendran banana. The different powder formulations were T_1 (blood meal + rock phosphate + potassium sulphate+ epsom salt + borax), T_2 (blood meal + rock phosphate + langbeinite + epsom salt + borax), T_3 (blood meal + steamed bone meal + potassium sulphate+ epsom salt + borax), T_4 (soyabean meal+ rock phosphate + langbeinite+ epsom salt + borax) and pellet formulations were T_5 (blood meal + rock phosphate + potassium sulphate+ epsom salt + borax + 4% bentonite), T_6 (blood meal + rock phosphate + langbeinite + epsom salt + borax + 4% starch), T_7 (blood meal + steamed bone meal + potassium sulphate+ epsom salt + borax + 4% bentonite) and T_8 (soyabean meal + rock phosphate + langbeinite+ epsom salt + borax + 4% bentonite). The quantity of powder and pellet formulations added were 30g for T_1, T_2, T_3 T_5, T_6 and T_7 and 90g for T_4 and T_8 and were thoroughly mixed with the soil and incubated for 300 days under room temperature and field capacity moisture. The moisture content in the soil was checked daily by measuring weight loss and compensated by adding deionized water to maintain constant moisture. The experimental design selected was completely randomized design with 8 treatments and 3 replications. Soil samples were collected at 60 days intervals on the 60th, 120th, 180th, 240th and 300th day of incubation and analyzed for NH_4^+-N, NO_3^--N and organic nitrogen. The chemical characteristics of multi-nutrient powder and pellet formulations that were analyzed are presented in Table 2.

Table 1: Chemical characteristics of experimental soil

Parameters	Status
pH (1:1.5)	5.68
EC (dS m^{-1})	0.18
Organic carbon (%)	1.23
Available N (kg ha^{-1})	125.44
Available P (kg ha^{-1})	23.66
Available K (kg ha^{-1})	78.40
Exchangeable Ca (mg kg^{-1})	300
Exchangeable Mg (mg kg^{-1})	72
Available S (mg kg^{-1})	26
Texture	Sandy clay loam

Table 2: Chemical characteristics of multi-nutrient powder and pellet formulations

	pH	EC (dS m^{-1})	OC (%)	N (%)	P (%)	K (%)	C/N ratio
T_1 (BM+RP+SOP)	6.50	3.23	29.43	7.21	2.71	10.78	4.08
T_2 (BM+RP+L)	6.86	3.73	26.41	5.50	2.11	8.30	4.80
T_3 (BM+SBM+SOP)	7.47	3.37	28.34	7.11	2.68	10.68	3.98
T_4 (SM+RP+L)	6.96	2.83	34.48	4.15	1.56	6.23	8.31
T_5 (BM+RP+SOP +4% B)	6.34	3.06	23.54	6.54	2.51	10.08	3.60
T_6 (BM+RP+L+4% S)	6.58	3.54	21.18	4.72	1.77	7.36	4.49
T_7 (BM+SBM+SOP+4%B)	7.24	3.16	22.70	6.61	2.54	10.18	3.43
T_8 (SM+RP+L+4%B)	6.78	2.67	28.62	3.62	1.34	5.54	7.91

2.2 Analytical methods

The NH_4^+-N and NO_3^{2-}-N were extracted with 2M KCl (Soil to extractant ratio of 1:4) and determined by steam distillation method. The NH_4^+ content of the filtered extract was determined by steam distillation with Mg $(OH)_2$ suspension in 1% boric acid solution and titration with 0.02N sulphuric acid and mixed indicator. The nitrate in the remaining ammonium free KCl extract was reduced to ammonium by adding Devardra's alloy and the concentration was determined. Organic nitrogen was obtained by subtracting mineral N from total N (Total N – mineral N) (Hesse, 1971) [10].

2.3 Statistical analysis

The data obtained were analyzed statistically by applying the technique of one-way ANOVA to evaluate the significant difference between means. If the effect was significant, a critical difference at 5% significance level was calculated for effecting comparison among means. GRAPE 1.0.0 (General R-shiny based Analysis Platform Empowered by Statistics) software was used for all statistical analysis.

3. Results

3.1 Mineral Nitrogen ($NH4^{+}$-N and NO_3-N)

The effect of different treatments on NH_4^+-N content in soil was significant on 60th, 120th, 180th, 240th and 300th day of incubation (Table 3). The NH_4^+-N content in the soil of all the treatments increased upto the 120th day of incubation and thereafter it decreased at a slow rate till the end of the incubation period (Figure 1). The NH_4^+-N content on 60th day of incubation was in the range of 37.33-61.60 mg kg^{-1}. The highest NH_4^+-N content was recorded for T_3 (61.60 mg kg^{-1}) which was followed by T_1 (59.73 mg kg^{-1}) and T_7 (57.87 mg kg^{-1}). The lowest was recorded for T_8 (37.33 mg kg^{-1}) which was on par with T_4 (39.20 mg kg^{-1}). The NH_4^+-N content for all the treatments increased till 120th day of incubation. On 120th day, the highest concentration of NH_4^+-N was recorded for T_3 (85.87 mg kg^{-1}) which was on par with T_1 (84.00 mg kg^{-1}) and the lowest was recorded for T_8 (52.27 mg kg^{-1}) which was on par with T_4 (54.13 mg kg^{-1}). The NH_4^+-N content in soil for different treatments showed a gradual decline after 120th day. The same trend of results was observed on 180th and 240th days of incubation. On 300th day the highest NH_4^+-N content was recorded for T_3 (78.40 mg kg^{-1}) which was on par with T_1 (76.53 mg kg^{-1}) and the lowest was recorded for T_8 (44.80 mg kg^{-1}) which was on par with T_4 (46.67 mg kg^{-1}).

The NO_3^--N content in soil was influenced significantly by different treatments throughout the incubation period (Table 4). A similar trend of result as NH_4^+-N content was observed in NO_3^--N content for all treatments where NO_3^--N content increased upto the 120th day of incubation and thereafter it decreased at a slow rate (Figure 2). During the initial days of incubation (60th day) the NO_3^--N content ranged from 16.80-39.20 mg kg^{-1}. The NO_3^--N content increased till 120th day. On 120th day the highest NO_3^--N content was recorded for T_3 (48.53 mg kg^{-1}) which was on par with T_1 (46.67 mg kg^{-1}) and T_7 (44.80 mg kg^{-1}). The lowest NO_3^--N content was recorded for T_8 (20.53 mg kg^{-1}) which was on par with T_4 (22.40 mg kg^{-1}). The NO_3^--N content of all the different treatments decreased on 180th, 240th and 300th day. At the end of the incubation period (300th day) the highest NO_3^--N content was recorded for T_3 (39.20 mg kg^{-1}) which was on par with T_1 (35.47 mg kg^{-1}) and the lowest was recorded for T_8 (14.93 mg kg^{-1}) which was on par with T_4 (16.80 mg kg^{-1}). In all the different treatments NH_4^+-N content in soil was predominant than NO_3^--N content throughout the incubation period.

Table 3: Effect of multi-nutrient powder and pellet formulations on NH_4^+-N of soil, mg kg^{-1}

Treatments	Days of incubation				
	60	120	180	240	300
T_1	59.73^{ab}	84.00^{ab}	82.13^{ab}	80.27^{ab}	76.53^{ab}
T_2	50.40^{c}	65.33^{d}	63.47^{d}	59.73^{d}	57.87^{d}
T_3	61.60^{a}	85.87^{a}	84.00^{a}	82.13^{a}	78.40^{a}
T_4	39.20^{d}	54.13^{e}	52.27^{e}	48.53^{e}	46.67^{e}
T_5	56.00^{b}	78.40^{c}	76.53^{c}	74.67^{c}	70.93^{c}
T_6	48.53^{c}	63.47^{d}	61.60^{d}	57.87^{d}	56.00^{d}
T_7	57.87^{ab}	80.27^{bc}	78.40^{bc}	76.53^{bc}	72.80^{bc}
T_8	37.33^{d}	52.27^{e}	50.40^{e}	46.67^{e}	44.80^{e}
SE (m)	1.32	1.62	1.32	1.87	1.75
CD (0.05)	3.96	4.85	3.96	5.60	5.24

Table 4: Effect of multi-nutrient powder and pellet formulations on NO_3^--N of soil, mg kg^{-1}

Treatments	Days of incubation				
	60	120	180	240	300
T_1	37.33^{a}	46.67^{a}	44.80^{ab}	41.07^{ab}	35.47^{ab}
T_2	26.13^{b}	33.60^{c}	31.73^{c}	28.00^{d}	24.27^{c}
T_3	39.20^{a}	48.53^{a}	46.67^{a}	44.80^{a}	39.20^{a}
T_4	18.67^{cd}	22.40^{d}	20.53^{d}	18.67^{e}	16.80^{d}
T_5	33.60^{a}	41.07^{b}	39.20^{b}	35.47^{c}	31.73^{b}
T_6	24.27^{bc}	31.73^{c}	29.87^{c}	26.13^{d}	24.27^{c}
T_7	35.47^{a}	44.80^{ab}	42.93^{ab}	39.20^{bc}	33.60^{b}
T_8	16.80^{d}	20.53^{d}	18.67^{d}	16.80^{e}	14.93^{d}
SE(m)	2.19	1.48	1.98	1.32	1.48
CD(0.05)	6.56	4.42	5.94	3.96	4.42

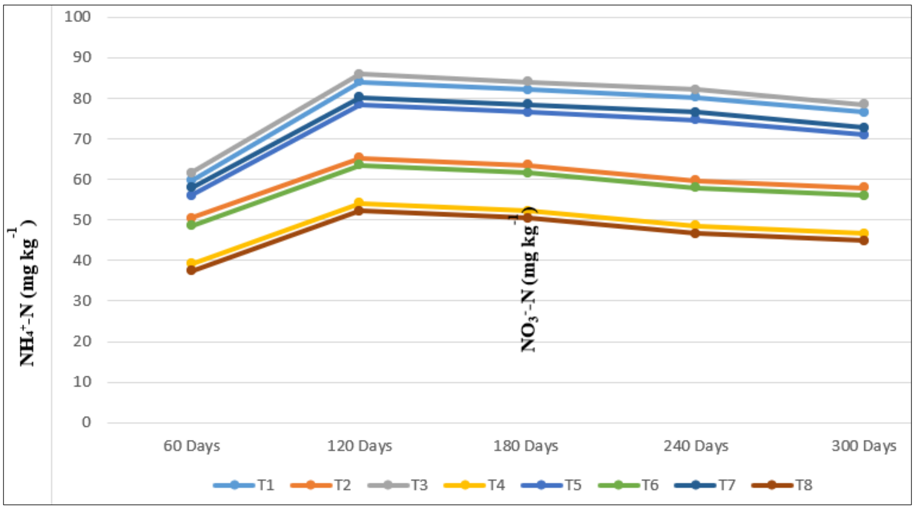

Fig 1: Effect of multi-nutrient powder and pellet formulations on NH_4^+-N content in soil

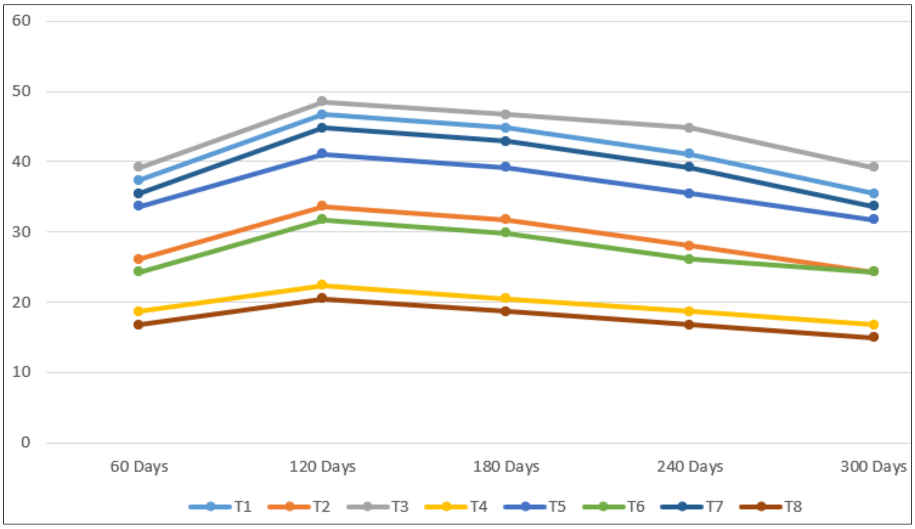

Fig 2: Effect of multi-nutrient powder and pellet formulations on NO_3^--N content in soil

3.2 Organic nitrogen

The treatments significantly influenced the organic N content in the soil throughout the incubation period (Table 5). The highest organic N in soil was recorded on the 60th day of incubation which decreased rapidly till the 180th day and further decreased gradually till the end of the incubation period (Figure 3). On the 60th day, the highest organic N was recorded for T_3 (309.87 mg kg^{-1}) which was on par with T_1 (304.27 mg kg^{-1}). The lowest was recorded for T_4 (268.80 mg kg^{-1}) followed by T_8 (272.53 mg kg^{-1}), T_6 (272.53 mg kg^{-1}) and T_5 (274.40 mg kg^{-1}) which were on par. A similar trend was observed at 120 days of incubation. On 180th day the highest organic N content in the soil was recorded for T_3 (270.67 mg kg^{-1}) and the lowest was recorded for T_8 (229.60 mg kg^{-1}). On the 240th and 300th day of incubation, the organic N in the soil decreased gradually following the same trend between the treatments. The highest organic N content on 300th day was recorded for T_3 (274.40 mg kg^{-1}) followed by T_6 (255.73 mg kg^{-1}) and T_1 (252.00 mg kg^{-1}) which were on par and the lowest was recorded for T_8 (201.60 mg kg^{-1}).

Table 5: Effect of multi-nutrient powder and pellet formulations on organic N content in soil, mg kg^{-1}

Treatments	Days of incubation				
	60	120	180	240	300
T_1 (BM+RP+SOP)	304.27^{ab}	280.00^{ab}	265.07^{ab}	261.33^{ab}	252.00^{ab}
T_2 (BM+RP+L)	278.13^{bc}	265.07^{abc}	250.13^{abc}	248.27^{bc}	244.53^{bc}
T_3 (BM+SBM+SOP)	309.87^{a}	285.60^{a}	270.67^{a}	274.40^{a}	274.40^{a}
T_4 (SM+RP+L)	268.80^{c}	259.47^{bc}	235.20^{c}	222.13^{de}	216.53^{de}
T_5 (BM+RP+SOP +4% B)	274.40^{c}	253.87^{c}	238.93^{c}	235.20^{cde}	224.00^{cde}
T_6 (BM+RP+L+4% S)	272.53^{c}	259.47^{bc}	244.53^{bc}	242.67^{bcd}	255.73^{ab}
T_7 (BM+SBM+SOP+4%B)	280.00^{bc}	257.60^{c}	252.00^{abc}	238.93^{bcde}	238.93^{bcd}
T_8 (SM+RP+L+4%B)	272.53^{c}	244.53^{c}	229.60^{c}	216.53^{e}	201.60^{e}
SE(m)	9.19	7.11	8.53	8.40	8.03
CD(0.05)	27.56	21.31	25.57	25.18	24.07

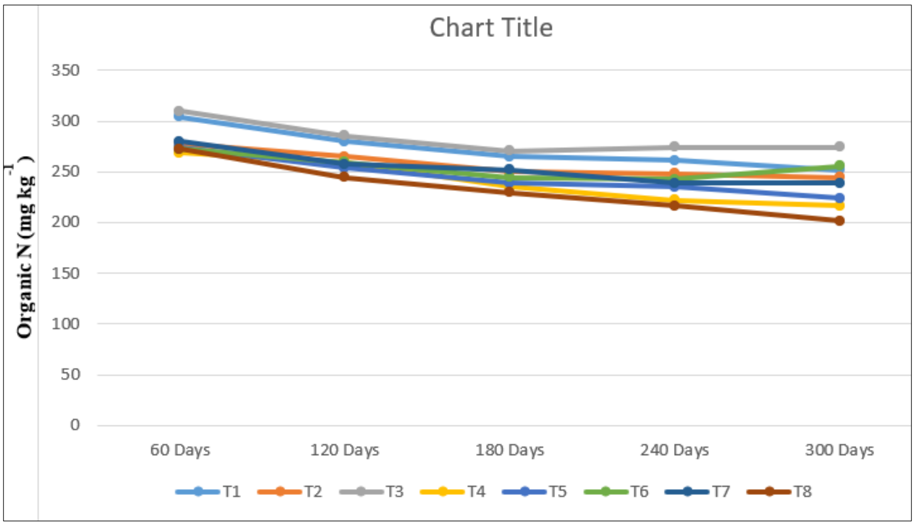

Fig 3: Effect of multi-nutrient powder and pellet formulations on organic-N of soil, mg kg^{-1}

4. Discussion

The difference in the N mineralization pattern of different treatments can be explained by the difference in their chemical composition. Treatment T_3, T_1, T_7, T_5, T_2 and T_6 had lower C/N ratios compared to T_4 and T_8 because blood meal was the N source in T_3, T_1, T_7, T_5, T_2 and T_6 while soybean meal was the N source in T_4 and T_8 which affected the mineralization rate. Also, soybean meal has high lignin content which is hard to mineralize (Bonanomi *et al.*, 2019, Cassity-Duffey *et al.*, 2020) [3, 6]. The maximum N mineralization was observed till the 120th day of the incubation period. The slower rate of mineralization of multi-nutrient powder and pellet formulations after the 120th day suggests the microbial mediated degradation of more complex organic N forms (Hartz and Johnstone, 2006; Mondini *et al.*, 2008) [9, 12] and loss of N in the form of N_2O, N_2 (denitrification) and NH_3 (volatilization) gas (Agehara and Warncke, 2005; Calderon *et al.*, 2005) [1, 5]. The powder formulation treatments (T_1-T_4) had a higher N mineralization rate than pellet formulations (T_5-T_8) because the powdered form gives more surface area for microbial activity. Whereas, pellets have slow nutrient release characteristics as they are compacted and have less surface area (Agehara and Warncke, 2005; Cayuela *et al.*, 2009) [1, 7].

The organic nitrogen content rapidly decreased till the 180th day and then decreased gradually till the end of the incubation period which may be signs of the stabilization of organic matter. It shows that nitrogen in organic matter is composed of unstable N form and stable N form. Unstable N rapidly mineralizes during initial incubation days and stable N is more resistant to mineralization (Kaleem Abbasi *et al.*, 2007) [11].

5. Conclusion

Results of the study revealed that NH_4^+-N and NO_3^--N content in soil for all treatments increased upto the 120th day of incubation and thereafter it decreased at a slow rate till the end of the incubation period. T_3 recorded the maximum NH_4^+ and NO_3^--N content. Mineralization of organic N to mineral N (NH_4^+-N and NO_3^-- N) was maximum for multi-nutrient powder formulation containing blood meal + steamed bone meal + potassium sulphate+ epsom salt + borax (T_3) and the least for multi-nutrient pellet formulation containing soyabean meal + rock phosphate + langbeinite+ epsom salt + borax + 4% bentonite (T_8). The organic nitrogen content showed a rapid declining trend till 180th day and further decreased gradually till the end of the incubation period. Nitrogen mineralization was rapid upto 60th day and reached a maximum on 120th day and further declined till the end of the incubation period.

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7. Competing Interests

The authors report there are no competing interests to declare.

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