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Nutrient release dynamics of an accelerated compost: A case study in an Alfisol and Ultisol

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Abstract

Acceleration of composting process could influence fertilizer-efficiency of the accelerated composts. This study therefore evaluated the nutrient release dynamics of different rates of a commercial accelerated compost (*OBD-plus*) in two soils described as Alfisol and Ultisol, under laboratory incubation study, in order to generate information for simulation under field conditions. Accelerated compost (AC) at the rates of 30, 60, 90, 120, 150 kg N ha^{-1}, mineral fertilizer (NPK 15-15-15) and conventional compost (CC) at 60 kg N ha^{-1}, were each mixed with 2 mm sieved soil (Alfisol and Ultisol) in cups, and arranged in a completely randomised design with three replications. Soils without amendment served as control. The treated soils were retrieved at 2, 4, 6, 8, 10 and 12 weeks of incubation (WOI), air dried and analysed for pH, organic C, N, P and K, and data analysed using regression test. The results revealed that the 60 kg N ha^{-1} AC improved the pH, OC, N. P, K by -2%, 11%, 3%, 141% and 4% respectively, across the WOI, on the average of performance in the two soils, comparable with mineral fertilizer (-5%, 8%, -1%, 76%, 4% respectively) and CC (11%, 40%, 3%, 773%, 10% respectively). The 60 kg N ha^{-1} AC significantly correlated ($p<0.05$) with time of incubation only with respect to P (0.934) and gave a similar nutrient release pattern compared with mineral fertilizer and CC, in terms of C, N, P and K in both soils. It therefore showed that the accelerated compost evaluated could mineralize in a way similar to conventional compost and mineral fertilizers, despite its shorter composting duration to maturity.

Keywords: Accelerated compost, Alfisol, incubation study, Ultisol.

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Introduction

Nutrient release from applied fertilizer is the process by which the plant nutrients from fertilizer materials become available in the soil for plants uptake. It has been widely reported that mineral fertilizers could release their nutrients in the soil almost immediately after application (Adediran et al., 2004), whereas, composts release their nutrients gradually. This is because compost would first go through decomposition (mineralization) before the release of the nutrients (Eghball et al., 2004; Tejada and Gonzalez, 2007). The soil organisms would first breakdown the fertilizer materials before nutrients are mineralized by eventual death of soil organisms (Abou El-Magd et al., 2005; Deenik, 2006). The rate of mineralization by compost could be affected by some factors such as climate, soil moisture, soil type, the composition, formulation and characteristics of the raw materials, maturity of the compost, as well as the composting technology (FAO, 2005; Gutser et al., 2005; Diacono and Montemurro, 2010).

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The potential of conventional (traditional) compost to mineralize nutrients for crop use has been widely reported (Molindo, 2008; Ipinmoroti, 2013). Although, there is a campaign for the use of compost all over the world due to its benefits over the mineral fertilizers (Koning and Smaling, 2005; Pender et al., 2006), the duration of composting is a limiting factor to its adoption. The conventional composting procedures take as long as two – eight months to produce matured compost, depending on the nature of the materials involved and methodology in use (Cooperband, 2002). This led to the development of the new technologies aiming at reducing the composting duration. There are now rapid composting methods, which offer the possibilities of reducing the composting period to three weeks and such are referred to as rapid (accelerated) compost (FAO, 2003). However, there is a need to evaluate accelerated compost (AC) in respect of mineralization of its constituent nutrients, considering its shortness in the time to maturity. There is a dearth of information on the pattern of release of nutrients by accelerated compost in Alfisols and Ultisols, which are major agricultural soil types in the world. Alfisols and Ultisols constitute 9.7% and 8.5%, respectively of the global soil, based on soil order (Blum and Eswaran, 2004).

The two soil types are highly weathered, leached and inherently low in soil nutrients, hence, they usually require soil amendments to improve their productivity (FFD, 2012). Laboratory soil incubation studies give opportunities to properly understudy soil properties or amendments with less environmental interference, which then generate results that could be highly useful in simulation of the performance of the understudied factor or soil amendment. Meanwhile, different crops have different nutrient requirement ranging from low to very high (FAO, 2006), hence, the need to consider fertilizer amendment at different rates in incubation study. This study therefore evaluated the nutrient release dynamics of different rates of an accelerated compost in a typical Alfisol and Ultisol of Southwest Nigeria.

Material and Methods

The experiment was carried out at the Federal College of Agriculture, Moor Plantation, Ibadan. The two soils used for this study were described as Alfisol (Smyth and Montgomery, 1962) and Ultisol (Periaswamy and Ashaye, 1982). The Alfisol was collected from the experimental site of the Federal College of Agriculture, Moor Plantation, Ibadan, Nigeria (Lat. 7^0 22' 27.95'' and Long. 3^0 50' 20.62''). The Ultisol was collected from the Institute of Agricultural Research and Training sub-Station, Ikenne, Nigeria (Lat. $6^0$51' 21.11'' and Long. 3^0 42' 20.23"). The soils were air-dried and sieved with 2 mm mesh. The accelerated compost; *OBD-plus* evaluated in this study was a commercial product, obtained from Gateway Fertilizer Company, Abeokuta, Ogun State, Nigeria. The method of composting involves the artificial introduction of some microorganisms, which speed up the rate of decomposition of organic materials. The compost matures in three weeks instead of the two to eight months period in conventional composting. The particle size was ≤2 mm. The conventional compost used as a check was also a commercial product, obtained from Alesinloye Compost Company, Alesinloye market, Ibadan, Nigeria.

The accelerated compost (AC) at the rates of 30, 60, 90, 120, 150 kg N ha^{-1}, mineral fertilizer (NPK 15-15-15) and conventional compost (CC) at 60 kg N ha^{-1} each, were thoroughly mixed with 80 g of the sieved Alfisol or Ultisol in cups, and arranged in a completely randomised design with three replications. Cups without amendment served as control. A total of 144 (8 treatments x 3 replicates x 6 weeks) filled incubation cups were involved for each of the two soils and each of the cups served as an experimental unit. The surface diameter and depth of each cup were 8 cm and 4 cm, respectively. The treated soils were moistened with deionized water to field capacity and each cup was covered and made air-tight. The cups were set up in the laboratory at temperature of 26 ± 2 ^{0}C.

Chemical analysis of the composts were carried out using standard procedures (Olsen and Dean, 1965; Okalebo et al., 1993; Bremner, 1996; Thomas, 1996). The physical and chemical analysis of the pre- and post-incubated soils were also carried out using standard procedures (Bray and Kurtz, 1945; Murphy and Riley, 1962; Hendershot et al., 1993; Bremner, 1996; Nelson and Sommers, 1996; Thomas, 1996). The chemical analysis of the accelerated and conventional composts is shown in the Table 1. The soil analysis before incubation showed that the Alfisol was low in N (0.4 g kg^{-1}), but marginal in K (0.4 cmol kg^{-1}) and P (8 mg kg^{-1}). The pH was 6.2, soil organic carbon (SOC) of 7.2 g kg^{-1} was low and the textural class was loamy sand. The Ultisol was low in N (0.7 g kg^{-1}), P (7 mg kg^{-1}) and K (0.2 cmol kg^{-1}), pH was 5.9, SOC (10.2 g kg^{-1}) was medium and the textural class was loamy sand (FFD, 2012). The treated soils were retrieved at 2, 4, 6, 8, 10 and 12 weeks of incubation (WOI), air dried and analysed for pH, SOC, N, P and K, and data analysed using regression test.

Table 1. Chemical analysis of the accelerated and conventional composts

Parameter	pH (H_2O)	Total C	N	P	K	Ca	Mg	Na	C:N	Fe	Cu	Mn	Zn
		---------- (g kg^{-1}) ----------								---------- mg kg^{-1} ----------			
AC	6.2	170	12.3	46	5	3.1	1.1	2	140	2860	71	495	464
CC	9.7	170	12.0	8	17	3.2	1.0	4	140	1670	78	393	186

AC; Accelerated compost, CC; Conventional compost

Results

The effects of the different rates of AC on soil pH across 12 WOI (Figure 1) showed that the change of pH per week was similar for all the fertilizer treatments in each of the two soil types. However, 60 kg N ha^{-1} CC led to the highest pH (Alfisol; 7.3 – 7.6, Ultisol; 6.5 – 8.0) across the WO1, followed by the various rates of AC and control treatment. The 60 kg N ha^{-1} NPK gave the lowest pH value (Alfisol; 6.2 – 6.6, Ultisol; 5.5 – 6.5). The result also showed that coefficient of determination (CD) (R^2) for each treatment was low in both soil types.

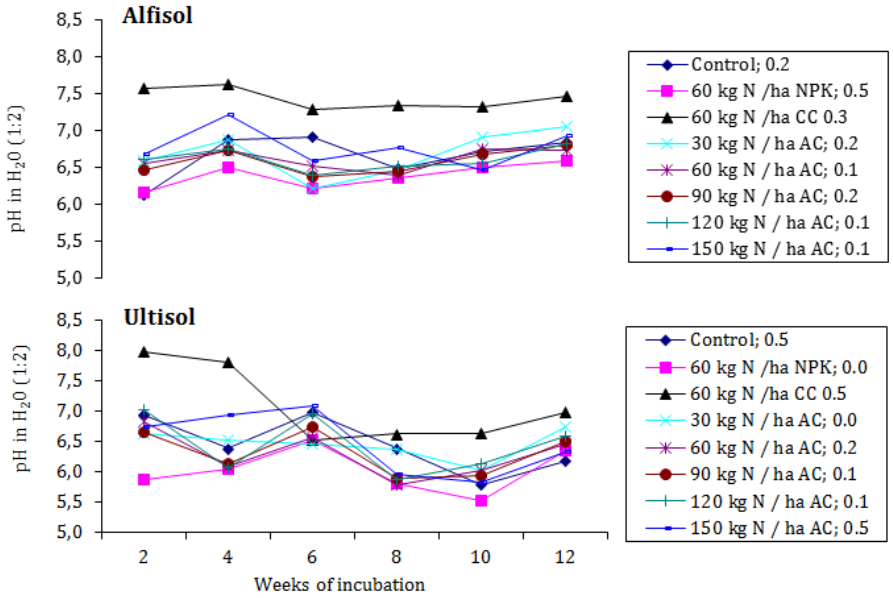

Figure 1. Comparative effects of the fertilizer treatments on soil pH across weeks of incubation
AC; Accelerated Compost, CC; Conventional Compost; the values in front of treatments legends are R^2.

The result of the values of the SOC recovery in Alfisol (Figure 2) showed that all the different rates of AC gave irregular pattern across WOI, which was similar with that of the control (3.0 – 13.6 g kg^{-1}), NPK (4.2 – 11.5 g kg^{-1}) and CC (6.3 – 11.0 g kg^{-1}) treatments. A similar trend was also observed in Ultisol. The CD for each treatment was low in both soil types, except with respect to 60 kg N ha^{-1} NPK (0.7) and 60 kg N ha^{-1} CC (0.7) treatments in Ultisol.

The result of the nitrogen release is shown in Figure 3. In Alfisol, all compost treatments resulted into less N values from 2 – 6 WOI (average of 0.6 g kg^{-1}), but higher values from 8 – 12 WOI (average of 0.7 g kg^{-1}), when compared with NPK, which had average of 0.7 and 0.5 g kg^{-1} values for 2 – 6 and 8 – 12 WOI, respectively. Also, CC released more N (0.7 g kg^{-1}) compared to various rates of AC at 2 - 6 WOI, but less compared to 90 and 150 kg N ha^{-1} AC at 8 – 12 WOI. In the Ultisol, all the various rates of AC and the CC resulted into similar pattern of release of N across the WOI, though in a trend different to what was obtained in Alfisol. On the average across the WOI, 60 kgN/ha AC gave highest value of N (1.6 g kg^{-1}), followed by 60 kg N ha^{-1} CC (1.5 g kg^{-1}), both higher than 60 kg N ha^{-1} NPK (1.1 g kg^{-1}). However, the AC and CC had similar N release pattern across the WOI. The CD for each treatment was low in both soil types, except for 60 kg N ha^{-1} CC (0.7) and 150 kg N ha^{-1} AC (0.9) treatments in Alfisol.

The result of available phosphorus release (Figure 4) showed that all various rates of AC (except 30 kg N ha^{-1}) followed a similar pattern, with a higher value of available P (average of 42 mg kg^{-1} over WOI) compared to NPK (average of 17 mg kg^{-1}). Although the different rates of AC had a similar pattern of release with CC (average of 48 mg kg^{-1}), the values were less across the WOI. A similar pattern was obtained in Ultisol. The CD were high for 60 kg N ha^{-1} AC (0.88) and 120 kg N ha^{-1} AC (0.70), but low for other treatments in Alfisol. The CD were also high for 60 kg N ha^{-1} CC (0.79), 120 kg N ha^{-1} AC (0.80) and 150 kg N ha^{-1} AC (0.68), but low for others in Ultisol.

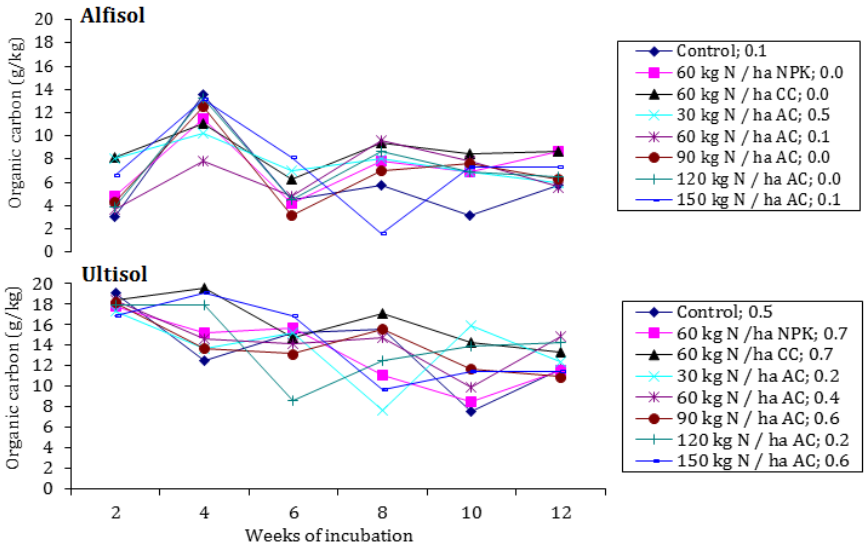

Figure 2. Effects of the fertilizer treatments on soil organic carbon across weeks of incubation
AC; Accelerated Compost, CC; Conventional Compost; the values in front of treatments legends are R^2.

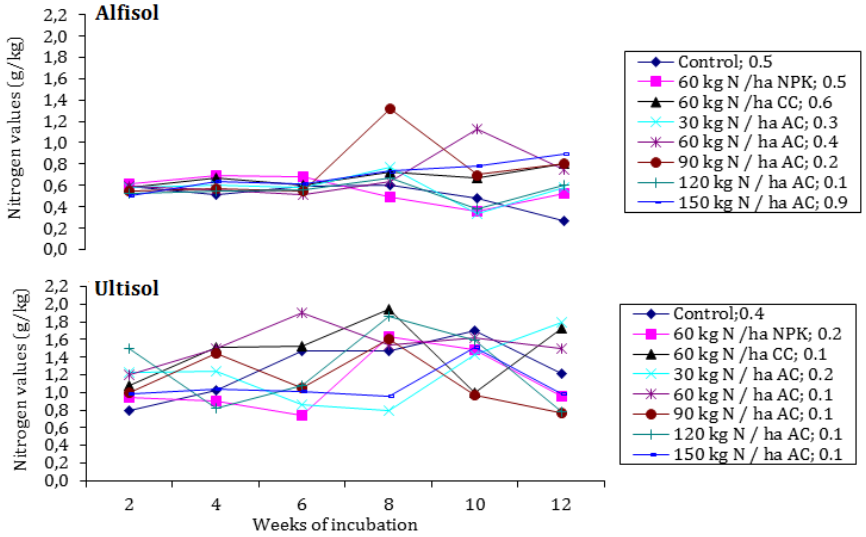

Figure 3. Comparative N release pattern by the various treatments across weeks of incubation
AC; Accelerated Compost, CC; Conventional Compost; the values in front of treatments legends are R^2.

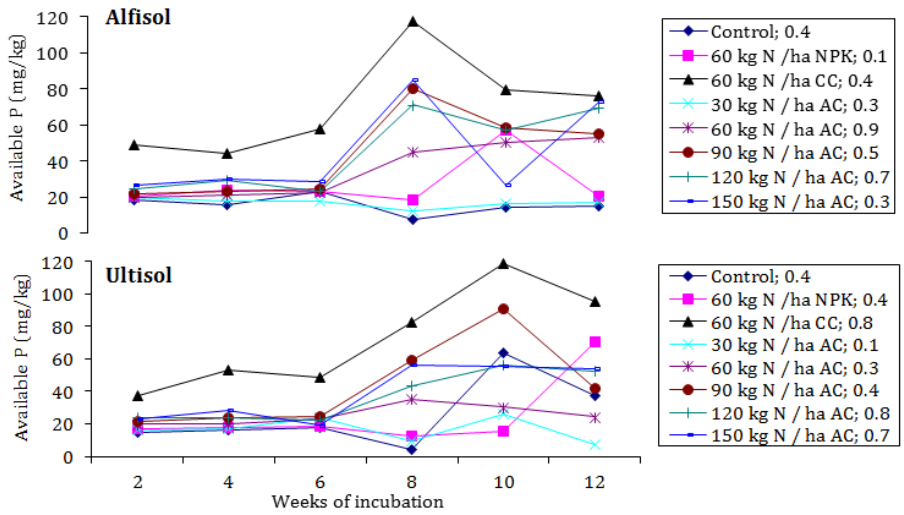

Figure 4. Comparative effects of the fertilizer treatments on available P across weeks of incubation
AC; Accelerated Compost, CC; Conventional Compost; the values in front of treatments legends are R^2.

The result of potassium release (Figure 5) showed that all the various rates of AC gave a similar pattern across WOI compared with CC and NPK in Alfisol. However, the result showed that CC gave the highest potassium release (average of 2 cmol kg^{-1}), except at 12 WOI. In Ultisol, all the various rates of AC, the CC and NPK treatments gave a similar pattern of potassium release across WOI, except that NPK dropped at 8 WOI (0.1 cmol kg^{-1}), while CC (2 cmol kg^{-1}) gave the highest value across the WOI. The CD were high for the control (0.74) and 150 kg N ha^{-1} AC (0.84), but low for others in Alfisol. The CD were also high for the control (0.68), 30 kg N ha^{-1} AC (0.86), 90 kg N ha^{-1} AC (0.76) and 120 kg N ha^{-1} AC (0.92), but low for others in Ultisol.

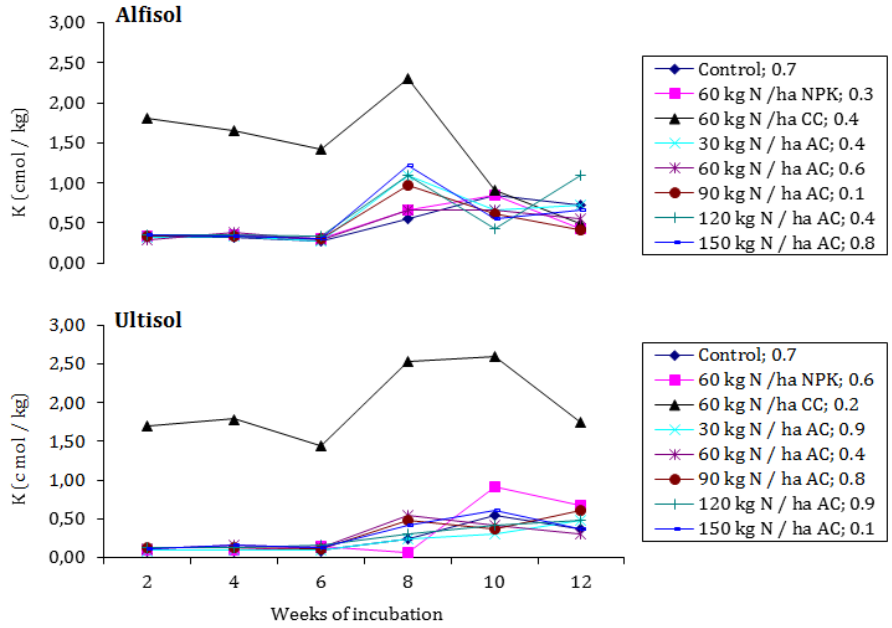

Figure 5. Comparative effect of the fertilizer treatments on K across weeks of incubation
AC; Accelerated Compost, CC; Conventional Compost; the values in front of treatments legends are R^2.

Discussion

The soil pH values obtained across the WOI of the fertilizer treatments are in the order of CC > AC > NPK (NPK 15-15-15 mineral fertilizer) in both Alfisol and Ultisol. This showed that the AC used for this study resulted into low soil pH compared with CC, but higher than that of NPK in both soils. This could be alluded to the fact that the pH 6.2 of the AC at application was much less than that of the CC (9.7). The Coefficient of determination (R^2) values for each treatment being low for all the treatments in both soil types showed that the effect of each fertilizer treatment on the soil pH was not time dependent.

The organic carbon (OC) recovery pattern of the various rates of AC was similar to that of the control, NPK and CC treatments in each of the two soil types. While it generally increased at 12 weeks relative to 2 WOI in Alfisol, it decreased with Ultisol. This suggested the influence of soil types on mineralization of the soil amendments (Diacono and Montemurro, 2010). The OC been highest at 2 WOI with Ultisol and lowest at 12 WOI suggested that mineralization of organic matter was at lag phase initially, while material could have been transformed in the soil at later period. This result confirmed the findings of Abbasi et al. (2015), where the applied organic amendments endured immobilization with little mineralization during the early period of incubation. The application of AC lowered OC relative to CC across the WOI, suggesting that the OC might have formed chelate and organic complexes with Fe and Mn (Voss, 1998). The AC used in this study had higher Fe and Mn than CC, as revealed by the results of chemical analysis of the two composts.

The N release pattern of the different rates of AC was similar and within the same range compared with CC and NPK across the WOI, in both Alfisol and Ultisol. This showed that AC compared favourably with NPK and CC in terms of N release. All compost treated soils had less N values from 2 – 6 WOI, but higher values from 8 – 12 WOI, when compared with NPK in Alfisol. This confirmed the reports of Tejada and Gonzalez (2007) and AyanfeOluwa et al. (2015) that composts release their nutrients gradually, compared to mineral fertilizers. This is because soil organisms will first act on the composts, before the release of the nutrients, while the nutrients from mineral fertilizer could be readily available to the plant almost immediately after application (Adediran et al., 2004). This, therefore confirmed the need for composts to be applied before

planting so as to allow for mineralization and aid plant uptake of the nutrients (Paulin and O'Malley, 2008; Nwaogu et al., 2013). The rate of release of nitrogen by the 60 kg N ha^{-1} CC and 150 kg N ha^{-1} AC increased with the time of incubation in Alfisol. Also, in Ultisol, the AC and CC at 60 kg N/ha resulted into more nitrogen (across the WOI) than 60 kgN/ha NPK. This result showed that the shortness in the duration of composting of AC did not affect its rate of nitrogen release. The result of the available P release of the different rates of AC showed that all the various fertilizer rates (except 30 kg N ha^{-1}) gave a similar P release pattern comparable with the CC and NPK in both Alfisol and Ultisol. However, while CC gave the highest value, AC at various rates (except 30 kg N ha^{-1} which is a lower rate compared to that of NPK) gave higher values across the WOI compared with the control and NPK in both Alfisol and Ultisol. The high value of P obtained from compost treatments relative to NPK could be due to the ability of organic materials to reduce the P adsorption capacity of soils, and the potential of chemical fertilizers to reduce soil pH, thus increasing P fixation (von Wandruszka, 2006; Hepperly et al., 2009; Yu et al., 2013). This is in line with the findings of Ipinmoroti (2013) that compost released higher amount of available P than the control. This result showing that AC had similar pattern of release of P compared with CC and NPK when applied at the same rate of 60 kg N ha^{-1}, indicate that AC could be a suitable fertilizer for crop production.

The K release of the various rates of AC also gave a pattern comparable with CC and NPK treatments in both Alfisol and Ultisol, with the same range of K values observed in AC and NPK, but higher values in CC. The high K recorded in the soil treated with CC is traceable to the high K present in the CC, compared with AC. The higher K value recorded in Alfisol compared with Ultisol could also be linked to the difference in the amount of initial K present in the two soil types, however, the pattern of release was similar. It therefore showed that AC compared favourably with NPK and CC as it gave a similar pattern of release of K.

Conclusion

The focus of this study was to investigate the nutrient release dynamics of an accelerated compost, in relation to that of the conventional compost and commonly used NPK fertilizers, as possibility of simulating the performance of the commercial compost in Alfisols and Ultisols. The result showed that the accelerated compost used for this study gave a similar nutrient release pattern, compared with mineral fertilizer NPK 15-15-15 and conventional compost as revealed by the result of organic C, N, P and K. As much as the accelerated compost seemed better than the mineral NPK, application of conventional compost still seemed to be preferred in release of N, P and K.

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