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The Nitrogen and Phosphorus Release Potential of Selected Organic Materials Applied to Three Contrasting Soils of Kilimanjaro Region

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Abstract The nutrient release potential of selected types of organic materials available in a coffee farming system was studied with three contrasting soils of Kilimanjaro Region, to broaden the ISFM options. An incubation experiment was conducted at TaCRI Lyamungu screenhouse between June and November 2019. The design was split plot RCD, three soil types Humi-Umbric Nitisols from Lyamungo, Eutric Cambisols from Kilacha and Humi-Rhodic Luvisols from Kikafu Chini as main factors, and different organic additives (cattle manure and leaves of *Tithonia diversifolia*, *Tephrosia vogelii*, *Vernonia subligera* and *Adhatoda engleriana)* as sub-factors. The organics were dried, crushed, sieved in a 6 mm sieve, mixed with the soils at 2% organic to soil ratio, moistened to field capacity and incubated in 10 litre plastic containers at room temperature. Duplicate soil samples were taken at day 0, 3, 8, 15, 26, 45, 74, 112 and 180 and analyzed for NH_4-N, NO_3-N, and available P. The total amounts of nutrients released during the incubation period were subjected to Analysis of Variance using COSTAT Statistical Software, with means separated by Tukey's HSD at $p \leq 0.05$. The nutrient release trends were more or less the same in all the three soil types. In terms of NH_4-N, NO_3-N and P, soil types, additives and their interactions were very highly significant ($p < 0.001$). In all the soil types, the four organics are fairly comparable to manure and can be used as its substitute. It was noted that soils differ in their responsiveness to organic treatments. Also unveiled was the potential of the wild plants such as Adhatoda, available in the wilderness around Mt. Kilimanjaro and Usambaras, which could be domesticated and planted at hedgerows for ISFM purposes. It also encourages the use of the semi-domesticated hedgerow plants like Tithonia and Vernonia; and Tephrosia as temporary shade plants.

Keywords: *organic materials, nutrient release, soil incubation, Kilimanjaro*

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1. Introduction

Coffee is one of the most traded commodities in the world. Its importance in the Tanzanian economy is well documented by [1,2,3], among others. Of the challenges facing the coffee industry for the time being, soil fertility degradation [4] was identified by the stakeholders as one of the most limiting factors. Tanzania Coffee Research Institute (TaCRI) aims at promoting integrated soil fertility management (ISFM), which includes use of organic materials in the coffee ecosystems, as complementary to industrial fertilizers, for improved and sustainable productivity. Gumbo [5] and Raab [6] describe ISFM as the key in raising productivity levels in agricultural systems while maintaining the natural resource base. It aims at replenishing soil nutrient pools, maximizing on-farm recycling of nutrients, reducing nutrient losses to the environment and improving the use efficiency of external inputs.

A number of efforts have been made in other countries to develop coffee ISFM by making use of organic residues around a coffee farm. Examples are [7] in India and [8] in Zimbabwe. In Tanzania, however, there has not been a clear ISFM strategy in the coffee areas [9]. The contribution of organic components of the coffee ecosystem has not been thoroughly studied. As a result, farmers apply such materials haphazardly, while others even destroy them by burning [10]. Maro and others [11] initiated such an effort, noting high potential of four green manure plants (Mucuna, Lupine, Canavalia and Crotalaria) in NPK nutrient release. During the study, some wild plant species were identified by farmers as potential for nutrient release. Some of them have been studied to a considerable extent; like *Tithonia diversifolia* [12,13,14,15] and *Tephrosia vogelii* [16]. There is limited literature about the other two, *Adhatoda engleriana* Lindau and *Vernonia subligera*, except that the former is known as a treatment for epilepsy [17]; and the latter known to enhance P availability in soils [18]. This follow-up study aimed to assess the nutrient (N and P) release potential of the four wild plants as they compare among themselves and against cattle manure in order to enrich the farmers' ISFM options. It also aimed to check if such potential differs significantly among different soils.

2. Materials and Methods

2.1. Experimental Materials

2.1.1. Soils

Soils were obtained from Lyamungo Primary Cooperative Farm, Hai district (-3^{o}2049; 37^{o}2438; 1280 metres above sea level - masl), representing Humi-Umbric Nitisols, Mwika South – Kilacha, Moshi District (-3^{o}3746; 37^{o}5662; 895 masl), representing Eutric Cambisols, and Kikafu Chini - Longoi, Hai district (-3^{o}4437; 37^{o}2914; 791 masl), representing Humi-Rhodic Luvisols. The soil classification is according to the SOTER database for Tanzania, described in [19]. In each site, a pit 1.5m x 1.5m was dug down 50cm and the experimental sample taken as a vertical slice representing the 50-cm profile. Enough soil was transported to the TaCRI Screenhouse, spread on canvas to dry for 2 days with coarse pebbles removed, then stored for the experiment.

2.1.2. Organic Materials

Fresh cattle manure was taken from an indoor kraal belonging to one TaCRI staff. It was dried in a well ventilated drying oven at 40°C for 48 hours, then ground, sieved at 6 mm mesh and stored [20]. Leaves from the experimental plants – Wild sunflower (*Tithonia diversifolia*), Fishbean (*Tephrosia vogelii*), Wild Tobacco (*Adhatoda engleriana*) and Tugutu (*Vernonia subligera*) were collected, spread in the open to dry for about 1 week in raised coffee drying beds, then ground in a tissue grinder and sieved through 6 mm mesh.

Figure 1. Plant leaves used: Tithonia (a), Tephrosia (b), Vernonia (c), Adhatoda (d)

2.2. Setting and Monitoring of the Experiment

The test materials were mixed with the soils at 2% organics to soil ratio, moistened to field capacity (FC) and incubated in 10 litre plastic containers arranged in split-plot RCD (5 treatments and 3 replications; on three tables each representing a different soil type) in the screenhouse at room temperature (24°C ± 2) [21]. Moisture level was maintained around FC by covering with poly-sheet during the day and uncovering at night [22]; together with spraying twice a week with a hand sprayer.

Duplicate soil samples were taken with a soil scoop at day 0, 3, 8, 15, 26, 45, 74, 112 and 180. Fresh soils were used for the determination of mineral nitrogen as suggested by [23,24]. 20g of moist soils in 200 mL of 2M KCl solution was shaken for 40 minutes and filtered through Whatman filter paper no 42. NH_4^+-N and NO_3-N from soil extracts were measured by steam distillation procedure using MgO and Devarda's alloy. Available phosphorus was determined by using the same samples, but after the routine drying, grinding and sieving. It was analyzed by using the Bray 1 method [20,25].

2.3. Data Processing and Analysis

Nutrient release trends were descriptively assessed. Total NH_4-N, NO_3-N and P were calculated and values for Day 0 subtracted from the totals to get the nutrients released only during the time of the experiment. These were exposed to ANOVA under COSTAT Software according to the split plot model suggested by [26] as follows:

$$Y_{ijk} = \mu + \alpha_i + P_k + D_{ik} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \quad (1)$$

Where μ stand for the general mean, α_i the effect of the main factor (soils), P_k the block effect, D_{ik} the main factor random error, β_j the effect of the sub-factor (organic additives), $(\alpha\beta)_{ij}$ the interaction effect between main factor and sub-factor, and ε_{ijk} the sub-factor random error. Then means were separated using the Tukay's HSD method at $p \leq 0.05$. Finally, the normalized difference between the means for each of the test organics and the means from cattle manure (the standard check) was computed using the formula suggested by [27]:

$$ND = \left(\frac{R_o}{R_m}\right) - 1 \quad (2)$$

whereby ND represents normalized difference; R_o is the mean release from the test entries, and R_m is the mean release from manure. This way, positive and negative variations could be visualized.

3. Results and Discussion

3.1. Nutrient Release Trends

Nutrient release trends are summarized in Table 1 for NH_4-N, NO_3-N and available P respectively. Peak release was generally between Day 3 and Day 45, accounting for 68-72% of the total NH_4-N released for the Luvisol of Kikafu; 66-74% for the Nitisol of Lyamungo; and 64-67% for the Cambisol of Kilacha. With NO_3-N the same time interval accounted 56-67%, 60-74% and 61-68% of the total NO_3-N released respectively, while with P, the interval accounted for 61-68%, 67-79% and 59-65% of the total P released respectively. This trend is partly in line with [11] who noted peak nutrient release between 8 and 45 days. Amounts initially present (Day 0) were 9-15% of the total NH_4-N for Kikafu and Lyamungo; and 11-14% for Kilacha. NO_3-N was 14-20%, 10-20% and 13-20% respectively, while that of P was 11-13%, 7-14% and 8-11% respectively.

Table 1. Summary of nutrient release trends

Soil	Nutrient released	Peak range (%)	Baseline amount (%)
Luvisol	NH4-N	68-72	9-15
	NO3-N	56-67	14-20
	P	61-68	11-13
Nitisol	NH4-N	66-78	9-15
	NO3-N	60-74	10-20
	P	67-79	7-14
Cambisol	NH4-N	64-67	11-14
	NO3-N	61-68	13-20
	P	59-65	8-11

3.2. Variation among Soils and Organic Additives

3.2.1. Ammonium N

Soils, additives and their interactions were very highly significant (p<0.001) but replications were not. Lack of significance with replications in a controlled experiment such as this is not abnormal because the set conditions are the same. This was also noted by [28] in their work on somatic embryogenesis. The model was also very highly significant with R^2 = 0.897 and CV = 4.08%. Mean rankings for soils (Figure 2) followed a decreasing order Cambisol > Nitisol > Luvisol; while the rankings for additives (Figure 3) followed the order Tephrosia > Tithonia > Adhatoda > Vernonia > manure.

3.2.2. Nitrate-N

As with the NH_4-N, soils, additives and their interactions were very highly significant (p<0.001) but replications were not. The model was also very highly significant with R^2 = 0.983 and CV = 3.01%. Mean rankings for soils (Figure 2) followed a decreasing order Nitisol > Luvisol > Cambisol; while the rankings for additives (Figure 3) followed the order manure > Adhatoda > Vernonia > Tithonia > Tephrosia.

3.2.3. Available P

Even in this case, soils, additives and their interactions were very highly significant (p<0.001) but replications were not. The model was also very highly significant with R^2 = 0.998 and CV = 2.86%. Mean rankings for soils (Figure 2) followed a decreasing order Luvisol > Cambisol >>> Nitisol; while the rankings for additives (Figure 3) followed the order Tephrosia > Adhatoda > Vernonia > Tithonia > manure. Kaloi and others [29] noted that P release increased with less clay and vice-versa. And the fact that Nitisols are known to have more clay than the other soils can partially explain its lower ranking.

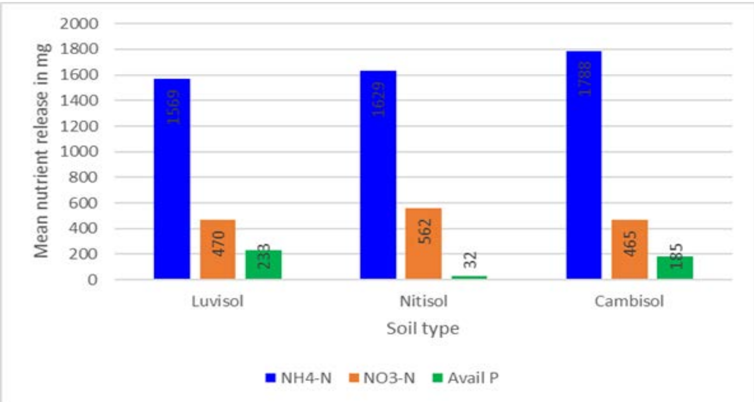

Figure 2. Response of different soils to the application of organic additives

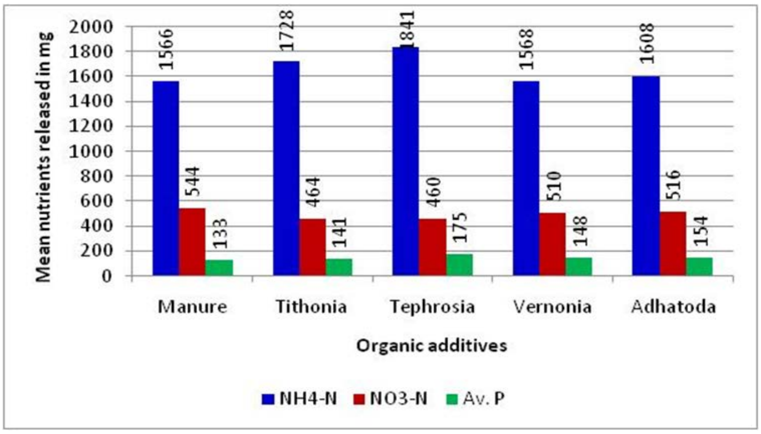

Figure 3. Mean amounts of nutrients released across soil types

3.3. Comparison of Organics with the Manure Check

The relative difference in nutrient release, between the tested organics and the manure check is given in Figure 4. There were positive variations in NH_4-N release from Tephrosia, Tithonia and Adhatoda. Vernonia did not record any variation. Positive variation was also noted in P release from all entries, with Tephrosia recording the widest difference of about 0.3, followed by Adhatoda (about 0.16). NO_3-N had negative variation in all cases, with Tephrosia and Tithonia recording a variation of -0.16 and -0.14 respectively. None of the variations reached 0.5 in any direction, implying that the organics are fairly comparable to manure and can be used as its substitute. Compared to [11], the organics used in this study fall into the lower category (which also included coffee leaves, pulp and husks).

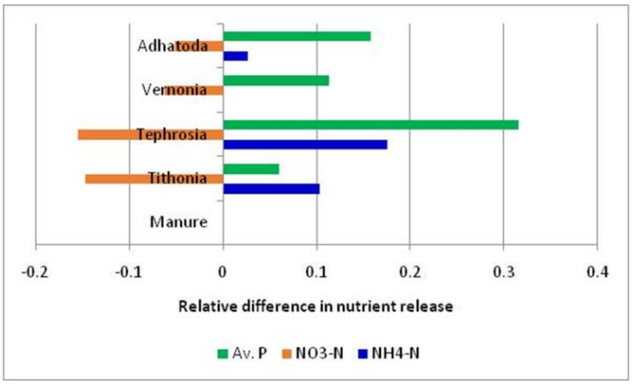

Figure 4. A comparison of organic additives to the manure check

3.4. General Discussion

Organic matter decomposition (and therefore, nutrient release) is controlled by many factors, including the quality of the litter itself and the conditions within the soil environment [30,31]. The influence of litter quality is emphasized by [32] who noted that plant (species) diversity influences many fundamental ecosystem functions including nutrient dynamics during litter breakdown. As such, the very highly significant difference among the tested species (Figure 3) is justified.

Other influential factors, as noted by [33] on decomposition of coarse wood, are location, soil texture (as also noted by [29]), clay mineralogy and temperature. Soils in this work differed in altitude of origin, with Lyamungo Nitisols substantially higher (1280 masl) than the Kilacha Cambisols (895 masl) and Kikafu Luvisol (791 masl). The former is in a denudation zone while the rest are typically in a deposition zone. In terms of soil texture, [19] described Nitisols as clayey soils with a nitic subsurface horizon of high aggregate stability. Cambisols are medium to fine textured soils without much illuviated clay or organic matter, while Luvisols have illuviated clays resulting from ages of deposition of materials from elsewhere. In this case however, no particular trend was noted that can be directly linked to soil texture or clay mineralogy. Temperature at origin is obviously lowest at Lyamungo, increasing with decreasing altitude. On the other hand, as opposed to field-based mesocosms [33] and litterbags [30], this work was a more controlled experiment in a screenhouse where room temperature (24°C ± 2) was maintained throughout.

Kwabiah and others [12] worked on *Tithonia diversifolia*, along with five similar species *Sesbania sesbani*, *Croton megalocarpus*, *Calliandra calothyrsus*, *Lantana camara* and *Senna spectabilis*; all branded as agroforestry plant species. In that study, Tithonia topped the list in N and P release. As regards *Vernonia subligera*, [18] noted its beneficial effects on beans when applied in combination with Minjingu rock phosphate or triple superphosphate. Both species have been domesticated as hedgerow plants. *Adhatoda engleriana* is a wilder species found in evergreen Tropical forests, but can be domesticated as hedgerow plant too. Only *Tephrosia vogelii* can be interplanted with coffee as temporary shade during young age (0-3 years). It compares fairly well with the best-bet temporary shade plant Sesbania [34], and was also one of the recommended temporary shade plants in the Climate-Smart Toolbox [35]. Its difference from the other three is that it does not regrow when cut, therefore not very suitable for hedgerows.

Of the three soil types involved in this study, only the Nitisol falls within the coffee belt. The other two are outside the coffee belt, but there are such soils growing coffee elsewhere. For Nitisols, Tithonia is the best bet hedgerow plant. The hedgerows can be periodically clipped and the clippings spread into the fields as mulch. We would not recommend immediate domestication of Adhatoda for hedgerows yet – we need to explore it further, in terms of compatibility with coffee. In the meantime, for those near the forests they may clip it right there and carry the clippings to their fields to spread as mulch. The hedgerow plant of choice in Cambisols (Bukoba, Muleba, parts of Kibondo, Uvinza and Mpanda) and Luvisols (parts of Longido, Mwanga, Same and Lushoto) could be Vernonia. The best in all soils was Tephrosia, which we can recommend as temporary shade for young coffee in its first 2-3 years.

4. Conclusion

In this work we explored the nitrogen and phosphorus release potential of different organic additives (cattle manure and leaves of *Tithonia diversifolia*, *Tephrosia vogelii*, *Vernonia subligera* and *Adhatoda engleriana)* when applied to three soil types Humi-Umbric Nitisols from Lyamungo, Eutric Cambisols from Kilacha and Humi-Rhodic Luvisols from Kikafu Chini, in order to broaden the ISFM options for coffee in Tanzania. The nutrient release trends were more or less the same in all the three soil types. Peak nutrient release was between Day 3 and Day 45, whereby over 50% of the available N and P were released in all cases. In terms of NH_4-N, NO_3-N and P, soil types, additives and their interactions were very highly significant. Cambisol was the best soil in NH_4-N release while Tephrosia was the best additive. Nitisol was the best soil in NO_3-N release while manure was the best additive. Luvisol was the best soil in P release while Tephrosia again was the best additive.

Comparing the relative difference in nutrient release between each entry and the manure check, there were positive variations in NH_4-N and P; and negative variations in NO_3-N. In any case, the variation did not exceed 0.5 in absolute terms. The implication here is that, in all the three soil types, all the four organics are fairly comparable to manure and can be used as its substitute. This study has shown that soils differ in their responsiveness to organic treatments. It has also shown the potential of the wild plants such as Adhatoda, available mostly in the wilderness around Mt. Kilimanjaro and the Usambaras, which could be domesticated and planted at hedgerows for ISFM purposes. It also encourages the use of the semi-domesticated hedgerow plants like Tithonia and Vernonia; and Tephrosia as temporary shade plants.

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Statement of Competing Interests

The authors wish to declare no competing interests in this work.

Abbreviations

Acronym	Long form/description
ANOVA	Analysis of variance
CV	Coefficient of variability
FC	Field capacity
GAPs	Good agricultural practices
ND	Normalized difference
NSS	National Soil Services centre
SOTER	Soils and terrain database of the world
TaCRI	Tanzania Coffee Research Institute

References

[1] Agrisystems (1998). The coffee sector strategy study for Tanzania. Report No. 3, Government of Tanzania, Dar es Salaam, Tanzania. 97pp.

[2] Baffes, J. (2003). Tanzania coffee sector: Constraints and challenges in Global environment. The World Bank 1818 H street, NW MC 2-339 Washington D.C: 56 pp.

[3] Hella, J.P., Mdoe, N.S. and Lugole, J.S. (2005). Coffee baseline report for Tanzania Coffee Research Institute. Bureau for Agricultural Consultancy and Advisory Service, Sokoine University of Agriculture, Morogoro, Tanzania. 40pp.

[4] Maro, G.P., Kitalyi, A., Nyabenge, M. and Teri, J.M. (2010). Assessing the impact of land degradation on coffee sustainability in Kilimanjaro region, Tanzania. In: Proceedings of the 23rd ASIC Conference, 3 -8 October, 2010, Nusa Dua, Bali, Indonesia: 607-614.

[5] Gumbo, D. (2006). Integrated soil fertility management. Technical Brief, Practical Action Southern Africa, Harare, Zimbabwe; 06 September, 2006. 5pp.

[6] Raab, R.T. (2002). Fundamentals of Integrated Soil Fertility Management. IFDC Training materials for the "Training Program on Integrated Soil Fertility Management (ISFM) in the Tropics", Lome, Togo, October 7-12, 2002. 10 pp.

[7] Korikanthmath, V.S. and Hosmani, M.M. (1998). Organic recycling of coffee pulp in coffee-based cropping systems. *Mysore Journal of Agricultural Sciences* 32: 127-130.

[8] Chemura, A., Mandhlazi, R. and Mahoya, C. (2008). Recycled coffee wastes as potential replacements of inorganic fertilizers for coffee production. In: Proceedings of the 22nd ASIC Conference, 14-19 Sept. 2008, Campinas, Brazil, 1197-1201.

[9] Semoka, J.M.R., Mrema, J.P. and Semu, E. (2005). A comprehensive literature review on integrated soil fertility management for coffee. Consultancy report submitted to TaCRI. Department of Soil Science, SUA. 142 pp.

[10] Maro, G.P. and Mbogoni, J.D.J. (2009). Soils of Kasulu, Kibondo, Tarime and Rorya districts and their suitability for coffee production. Technical report submitted to MAFSC (PADEP Project), May, 2009. 78 pp.

[11] Maro, G.P., Mrema, J.P., Msanya, B.M., Janssen, B.H. and Teri, J.M. (2014). Exploring the nutrient release potential of organic materials as integrated soil fertility management components using SAFERNAC. International Journal of Plant and Soil Science Vol 3 (4): 419-433.

[12] Kwabiah, A, B., Stoskopf, N.C., Voroney, R.P., and Palm, C.A. (2001). Nitrogen and Phosphorus release from decomposing leaves under subhumid Tropical conditions. Biotropica Vol. 33 (2): 229-240.

[13] Okalebo, J.R., Othieno, C.O., Woomer, P.L., Karanja, N.K., Semoka, J.M.R., Bekunda, M.A., Mugendi, D,N., Muasya, R.M., Bationo, A. And Mukhwana, E.J. (2007). Available technologies to replenish soil fertility in East Africa. In: A. Bationo (eds), Advances in ISFM in Sub-Saharan Africa: Challenges and opportunities: 45-62.

[14] Ikerra, S.T., Semu, E. and Mrema, J.P. (2007). Combining Tithonia diversifolia and Minjingu phosphate rock for improvement of P availability and maize grain yields on a Chromic Acrisol in Morogoro, Tanzania. In: A. Bationo (eds), Advances in ISFM in Sub-Saharan Africa: Challenges and opportunities: 333-344.

[15] Kimani, S.K., Esilaba, A.O., Odera, M.M., Kimenye, L., Vanlauwe, B. and Bationo, A. (2007). Effect of organic and mineral sources of nutrients on maize yields in three districts of Central Kenya. In: A. Bationo (eds), Advances in ISFM in Sub-Saharan Africa: Challenges and opportunities: 353-357.

[16] Tumuhairwe, J.B., Rwakaikara-Silver, M.C., Muwanga, S. and Natigo, S. (2007). Screening legume green manure for climatic adaptability and farmer acceptance in the semi-arid agroecological zone in Uganda. In: A. Bationo (eds), Advances in ISFM in Sub-Saharan Africa: Challenges and opportunities: 255-259.

[17] Moshi, M.J., Kagashe, G.A.B. and Mbwambo, Z.H. (2005). Plants used to treat epilepsy by Tanzanian traditional healers. Journal of Ethnopharmacology Vol. 97: 327-336.

[18] Ndakidemi, P. (2014). Dry bean response to fertilization using Minjingu Phosphate Rock and composted Tughutu (*Vernonia subligera* O. Hofn). Journal of Experimental Agriculture International Vol. 6 (1): 51-59.

[19] Mlingano Agricultural Research Institute (MARI). (2006). Soils of Tanzania and their potential for agriculture development. Report to the Ministry of Agriculture, November, 2006: 33 pp.

[20] Khalil, M.I., Hossain, M.B., and Schmidhalter, U. (2005). Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. Elsevier, Ltd. Soil Biology & Biochemistry 37 (2005): 1507-1518.

[21] Gunapala, N., Venette, R.C., Ferris, H. and Scow, K.M. (1998). Effects of soil management history on the rate of organic matter decomposition. Elsevier Ltd. Soil Biology & Biochemistry Vol. 30 (14), 1998: 1917-1927.

[22] Van Ranst, E., Verloo, M., Demeyer, A. and Pauwels, J.M. (1999). Manual for soil chemistry and fertility laboratory: Analytical methods for soil and plants, equipment and management of consumables. International Training Centre for Post-graduate Soil Scientists, Krijgslaan 281/S8, B-9000 Gent, Belgium. ISBN 90-76603-01-4, 243pp.

[23] Verloo, M. and Demeyer, A. (1997). Soil preparation and analysis – A practical guide. Department of Applied Analytical and

Physical Chemistry, Coupure Links 653, B-9000 Gent, Belgium; March, 1997. 107pp.

[24] National Soil Services (NSS), (1990). National Soil Services: Laboratory procedures for routine soil analysis (3rd Edition). NSS Miscellaneous Publication M13, Mlingano, Tanzania. 140 pp.

[25] Anderson, J.M and Ingram, J.S.I. (1993). The Tropical Soil Biology and Fertility: A handbook of methods. 2nd Edition. CAB International, Wallingford, Oxon OX108DE, UK. 92pp.

[26] Kuehl, R.O. (2000). Design of experiments: Statistical principles of research design and analysis. 2nd Edition, Brooks Cole, Duxbury. 665 pp.

[27] Maro, G.P. (2004). Yield gap analysis for selected sugarcane estates in Tanzania. M.Sc Thesis, Lab of Soil Science, Krijgslaan 281/S8, B-9000 Ghent, Belgium, September, 2004: 114pp.

[28] Monyo, G.K., Mtenga, D.J., Maro, G.P., Kilambo, D.L. and Urassa, J.M. (2020). Developmental variation among improved coffee hybrids propagated through somatic embryogenesis. World Journal of Agricultural Research Vol. 8 (3):70-74.

[29] Kaloi, G.M., Bhughio, N., Panhwar, R.N., Junejo, S., Mari, A.H. and Bhuto, M.A. (2011). Influence of incubation period on phosphate release in two soils of District Hyderabad. Journal of Animal and Plant Sciences 21 (4):665-670.

[30] Kwabiah, A, B., Voroney, R.P., Palm, C.A. and Stoskopf, N.C. (1999). Inorganic fertilizer enrichment in soils: Effect on decomposition of plant litter under subhumid Tropical conditions. Biology and Fertility of Soils 30: 224-231.

[31] Rodriguez, M.A. (2004). An in situ incubation technique to measure the contribution of organic nitrogen to potatoes. Agronomie 24: 249-256.

[32] Lecerf, A., Marie, G., Kominoski, J.S., Leroy, C.J., Bernadet, G. and Swan, C.M. (2011). Incubation time, functional litter diversity and habitat characteristics predict litter mixing effects on decomposition. Ecology 92 (1): 160-169.

[33] Fissore, C., Jurgensen, M.F., Pickens, J., Miller, C., Page-Dumroese, D. and Giardina, C.P. (2016). Role of soil texture, clay mineralogy, location and temperature in coarse wood decomposition – A mesocosm experiment. Ecosphere 7 (11):1-13.

[34] Tadesse, A., Taye, E. and Mesfin, T. (2018). Effect of temporary shade tree species on growth performance of newly transplanted Arabica coffee seedlings at Jimma, Ethiopia. American Journal of Medical Science Vol. 3: 93-100.

[35] Coffee and Climate Initiative (2015). Climate change adaptation in coffee production: A step-by-step guide to supporting coffee farmers in adapting to climate change. Version 2015, GIZ: 184pp.