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Exploring the Nutrient Release Potential of Organic Materials as Integrated Soil Fertility Management Components Using SAFERNAC

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Authors' contributions

This work was carried out in collaboration between all authors. Author GPM designed this study, managed the experimental part of the study, wrote the protocol and wrote the first draft of the manuscript. Authors JPM, BMM, BHJ and JMT managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The aim of this study was to establish the nutrient release potential of different organic materials and assess their role in integrated soil fertility management for coffee using the new coffee yield model SAFERNAC. It involved an incubation experiment conducted at TaCRI Lyamungu Screenhouse for 180 days between April and September 2011. Cattle manure, coffee leaves, pulp and husks, *Albizzia* leaves and four green manure plants – *Mucuna pruriens*, *Lupinus albus*, Canavalia ensiformis and *Crotalaria ochroleuca* were mixed with two soil types – Eutric Nitisols from Lyamungu, Hai district and Humi-Umbric Acrisols from Yoghoi, Lushoto district. The mixing ratio was 5% organic to soil, the mixture was moistened to FC and incubated in 10 litre plastic containers arranged in RCBD (10 treatments and 3 replications) 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, available P and exchangeable K. The cumulative N_{min}, P and K values resulting from the treatments were used to estimate their relative contribution to the soil nutrient pool and

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later exposed to the new model SAFERNAC for yield estimation under different nutrient management options (1 to 10 tons organics per ha alone on one hand and supplemented with 160 kg N, 60 kg P and 160 kg K). The tested organics differed significantly (P<0.001) in their $N_{min,}$ P and K release in the two soil types. They also differed in their substitution values and therefore the amounts of nutrients each one can contribute to the soil nutrient pools. Green manures showed about ten times higher potential as compared to cattle manure. Four of them (*Crotalaria*, *Mucuna*, *Canavalia* and *Lupine*) were picked as best bets for inclusion in the coffee ISFM programme. SAFERNAC recommended a number of nutrient management options involving the test organics and the two soil types under organic and conventional coffee farming.

Keywords: Arabica coffee; model; nutrient release; organic materials; soil types; Tanzania.

ABBREVIATIONS

Acronym	***Description / Long form***
AAS	*Atomic absorption spectrometer*
ANOVA	*Analysis of variance*
CBD	*Coffee berry disease*
CEC	*Cation exchange capacity (of a soil)*
FC	*Field capacity*
FMO	*Fraction of mineralized nutrients from organic sources*
FYM	*Farmyard manure (in the context of this work, cattle manure)*
HSD	*Highest significant difference*
IPM	*Integrated pest management*
ISFM	*Integrated soil fertility management*
K	*Potassium (or potash fertilizer)*
Nmin	*Mineralizable Nitrogen (NH4-N and NO3-N)*
OC	*Organic carbon*
P	*Phosphorus*
RCBD	*Randomized complete block design*
RE	*Relative effectiveness of nutrients in organic sources*
SAFERNAC	*Soil analysis for fertility evaluation and recommendation on nutrient application to coffee*
SV	*Substitution value (same as RE)*
TaCRI	*Tanzania Coffee Research Institute*
TSBF	*Tropical soil biology and fertility (a subsidiary of IITA)*
TY	*Target yield*

1. INTRODUCTION

Tanzania's annual coffee production is variably pegged between 45,000 and 55,000 metric tons [1] which is lower than its potential of over 100,000 tons. The Northern Zone (Arusha, Kilimanjaro, Manyara and Tanga) has been experiencing a decline in annual coffee production over years [2]. Kilimanjaro, once a giant coffee producer, appears to have suffered most, with annual production decreasing from about 20,000 tons in 1981/82 to less than 5000 tons by 2005/06 [3]. Several constraints have been suggested as the cause of this decline. In the past, farmers complained of improper marketing and low prices [1,4] and production costs, especially fungicides for CBD and rust control [5]. These have been addressed through quality improvement by putting emphasis on central pulpers, new disease-resistant varieties and IPM [6,7]. Currently, as reflected during the coffee stakeholders' forum [8], soil fertility degradation has emerged as one of the most limiting factors.

In a bid to address this farmers' concern, Tanzania Coffee Research Institute (TaCRI) aims at promoting integrated soil fertility management (ISFM), which includes use of organic materials in the coffee ecosystems, for improved and sustainable productivity. This is clearly stated in its Strategic Action Plans, 2003-2008 [9] and 2008-2013 [10]. From a practical agricultural standpoint, organic matter is important for two main reasons: first as a nutrient reserve (by itself releasing nutrients and by improving CEC) and second, as an agent to improve soil structure, maintain tilth and minimize erosion [11]. ISFM is described [12,13] 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. In India for instance, [14] established the amount of various nutrients in coffee and its processing by-products (pulp and husks) in a bid to plough back some of the by-products in coffee monocrop and coffee-cardamom systems. They rated coffee pulp higher than FYM in terms of nutritive value, having 2.38, 0.53 and 4.21% of N, P and K respectively, compared to respective figures in FYM of 0.3-0.4, 0.1-0.2 and 0.1-0.3%. In Zimbabwe, [15] worked on composted coffee pulp, husks, flocculent, pruned materials and live mulch, in various combinations. It was noted that composted pulp alone or in combination with husks, flocculent and pruned material gave higher coffee yields and financial returns when applied together with fertilizer levels (NPK 20:10:20) lower than the recommended rates.

In Tanzania, however, there has not been a clear ISFM strategy in the coffee areas [16]. 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 [17]. This underscores the need for a thorough study to establish the amounts and types of nutrient they release to develop proper preparation and application packages and the most optimum combination of organic and inorganic sources for use in coffee, which will be socially acceptable, economically profitable and environmentally sustainable.

An experiment was therefore done to investigate the nutrient release potential of selected types of organic materials available in a coffee farming system applied to two contrasting coffee soils of Hai and Lushoto districts, Northern Tanzania and to demonstrate how the new model SAFERNAC can be used in devising and implementing appropriate coffee ISFM programmes. The focus was the release of primary macronutrients Nitrogen, Phosphorus and Potassium.

2. MATERIALS AND METHODS

2.1 The Experimental Materials

Soils were obtained from Lyamungu, Hai district (Field 46), representing Eutric Nitisols of volcanic origin and Yoghoi Prisons Farm, Lushoto district, representing Humi-Umbric

Acrisols of gneiss origin. 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 Lyamungu Screenhouse, spread on canvas to dry for 2 days with non-soil material removed, then stored for the experiment. Fresh cow dung was dried in a well-ventilated drying oven at 40ºC for 48 hours, then ground, sieved at 6 mm mesh and stored [18]. Coffee leaves were prunings from coffee fields, separated from branches and spread to dry in the open. Fresh coffee pulp was hung overnight for water to drain, spread for 4 days in the open to reduce moisture further, then oven-dried at 70°C for 48 hours [19]. Husks (a mixture of pulp and husks from hard Arabica hulling) were collected from an open heap and spread to dry for one day. Dry *Albizzia* leaves were shaken off branches of the recently uprooted *Albizzia maranguensis* trees and spread to dry further in the open. Dry materials were ground in a tissue grinder and sieved through 6 mm mesh. The green manure plants–Velvet bean (*Mucuna pruriens*), Lupine (*Lupinus albus*), Jackbean (*Canavalia ensiformis*) and Sunhemp (*Crotalaria ochroleuca*) had been grown in augmentation blocks. They were harvested at 3 months of age, (onset of blossoming) chopped and spread in the open to dry for about 1 week, then ground in a tissue grinder and sieved through 6 mm mesh (see picture below – right).

Before the experiment, the two test soils were analyzed for routine soil fertility parameters as suggested by [20,21]. Organic substrates were analyzed for total and mineralizable N, P and K by following procedures of [19].


The bulking up plot showing Crotalaria and Canavalia (left), processed test organics (right)

2.2 Setting and Monitoring of the Experiment

The test materials were mixed with the soils at 5% organics to soil ratio to reflect, as much as possible, the average organic matter content of mineral soil, moistened to field capacity (FC) and incubated in 10 litre plastic containers arranged in RCBD (10 treatments and 3 replications) as shown below in the screenhouse at room temperature (24ºC±2) [22]. Moisture level was maintained around FC by covering with poly-sheet during the day and uncovering at night [23]; together with spraying twice a week with a hand sprayer.

2.3 Sampling and Analysis

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 [20]; [24]. 20g of moist soils in 200 mL of 2M KCl solution were 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 and exchangeable potassium were determined by using the same samples, but after the routine drying, grinding and sieving. The former was analyzed by using the Bray 1 method and the latter was first extracted with NH4OAc at pH 7and quantified by flame AAS [18,21].

Nutrient release trends were descriptively assessed. N_{min} (NH_4-N + NO_3-N), P and K were calculated and values for Day 0 were subtracted from the totals to get the nutrients released only during the time of the experiment. The values for the untreated control were also subtracted to remain with the nutrients released from the treatments. These were exposed to ANOVA and means separation (Tukay's HSD) under COSTAT Software.

The set-up of experiment for Yoghoi (left) and Lyamungu (right)

2.4 Application of the SAFERNAC Model

The mineralization model developed by Yang [25,26] was adopted for describing the substitution values of various organics. The basic equations are:

$$Y_t = Y_0 * e^{-K * t} \quad (1)$$

$$K_9 = R_9 * f * t^{-S} \quad (2)$$

Hence,

$$Y_t = Y_0 * \exp(-R_9 * (f * t)^{1-S}) \quad (3)$$

Where:

Y_t = quantity (mass) of organic matter at time t, *e.g.* in kg per ha
Y_0 = quantity (mass) of organic matter at time 0, *e.g.* in kg per ha
K_9 = average relative decomposition rate (between t = 0 and t), expressed in $year^{-1}$, after application of the organic material, at an average annual temperature of 9°C
R_9 = average relative decomposition rate, expressed in $year^{S-1}$, during the first year after application (so between t = 0 and 1) at an average annual temperature of 9ºC
S = 'rate of aging', dimensionless; values between 0 and 1.
f = temperature correction factor, between 9 and 27ºC, f = $2^{(T-9)/9}$ and at 22- 27ºC, f is set at 3.

From Eq. 2 it follows that K decreases over time. Values of parameters R_9 and S are presented in Appendix 1. Using the R9 and S parameters where f = 3, the remaining fractions (Y_t/Y_0), calculated with Eq. 3 are given in Appendix 2. After half a year, which is about 180 days, Y_t/Y_0 of cattle manure is 0.44, while those for green manure and compost are 0.25 and 0.69. So, the fraction that is mineralized of the nutrient in organic form (FMO) is $1-(Y_t/Y_0) = 0.56$, 0.75 and 0.31 respectively. Then SV is calculated according to Equation 4.

$$SV_e = FMO * F_o + F_i \tag{4}$$

For cattle manure, F_o for N and P were set at 0.9 and 0.3 according to [27,28] and the SVs were set at 0.6 for N and 0.87 for P. The F_o suggested here have been assumed to apply to all organics in the apparent absence of better alternatives.

It had been noted earlier that the input available nutrients from organic sources are exposed to substitution values also called Relative Effectiveness RE – [29] related to their rate of mineralization. From Appendix 3, it is clear that green manures excel in the rate of decomposition and therefore nutrient release, followed by manure and compost. The study materials were therefore subdivided into the three categories: *Albizzia, Mucuna, Lupine, Canavalia* and *Crotalaria* as green manures, coffee leaves, pulp and husks as composts, and cattle manure in its own category as in Appendix 3.

The other organics were compared to cattle manure (which is common in the study areas and whose substitution value and recovery fraction are known [26] in order to know how many times as much of the other organics are needed to match with a standard amount of manure. These were entered as input into SAFERNAC whereby total N, available P, exchangeable K, OC and pH had been adjusted to the local condition where the bulk soils were collected. With the tree density maintained at 1330 per ha, two scenarios were assessed where only the organics were applied at 1, 5 and 10 ton per ha each and same treatments plus a blanket application of inorganic fertilizer (160 kg N, 60 kg P and 160 kg K).

3. RESULTS AND DISCUSSION

3.1 Properties of the Test Soils and Organics

Lyamungu soil is a sandy loam with high percent of silt (20.8%) typical of a Nitisol. It has pH 5.02, CEC 16 cmol kg^{-1}, OC 1.58%, total N 0.06%, N_{min} 18.1 mg kg^{-1}, available P 0.62 mg kg^{-1} and exchangeable K 1.2 cmol kg^{-1}. Yoghoi soil is a clay with 40.8% clay and 8.8% silt. It has pH 4.94, CEC 8.5 (low, typical of an Acrisol), OC 0.76%, total N 0.02%, N_{min} 20.4 mg kg^{-1}, virtually no available P and exchangeable K 0.1 cmol kg^{-1}. There is no significant difference in soil pH between the two soils – they are both below the low threshold of 5.2 for Arabica coffee. All other parameters showed significant difference, with CEC for Lyamungu about twice that for Yoghoi, same for OC, while total N was about 3 times and K about 10 times. The only parameter whereby Yoghoi was slightly better than Lyamungu is N_{min}.

Initial N_{min}, P and K for the organics before treatment indicated that *Canavalia* had highest N_{min}, followed by *Mucuna* and manure, while the rest were not significantly different. Lupine was highest in initial P, while *Albizzia* was lowest, with virtually no P. As for K, pulp was highest, followed by *Crotalaria* and *Mucuna*.

3.2 Trends of N, P and K Release

Peak NH_4^+-N release was attained between Day 8 and Day 45 for both Yoghoi and Lyamungu, accounting for 62-89% and 58-90% respectively of the total NH_4^+-N released.

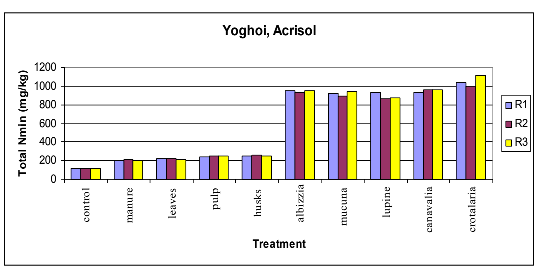
With NO_3-N, the two soil types differed in the time of peak release. Lyamungu attained peak release between Day 15 and Day 74, which accounted for 41-92%, while Yoghoi attained peak realease between Day 26 and Day 102, accounting for 34-87%. A stagger was observed in peak release time between NH_4^+-N and NO_3-N, which can be explained from the nitrogen cycle [11,30]. Nitrogen mineralization from organic materials starts with NH_4^+-N formation and a further transformation is needed through NO_2-N to NO_3-N, hence the delay in NO_3-N accumulation. Similar trends were observed by [31] in their study on domestic sludge.

Peak P release was attained at Day 3 for Yoghoi and between Day 3 and 8 for Lyamungu. Initial P content differed more markedly among treatments at Yoghoi than at Lyamungu. The trend for cattle manure was the smoothest in both sites. These results are in conformity to those of [32] who noted a progressive decrease in P release with increasing incubation period. They are also in conformity with the principle of [33] who described the kinetics of P release as an initial rapid rate followed by a progressively slower rate. Other authors who had similar trends are [34,35].

In both soils, K appeared to be present in appreciable levels initially (Day 0), experiencing a readjustment which included sharp decease or increase, to Day 3; before steadying off throughout the remaining period. Crotalaria, Canavalia and Lupine had highest initial levels at Yoghoi, while manure gave highest level at Lyamungu. Not much seems to have been documented on the release of K from organic matter, though it is known [36,37] that K is required by most crops in equal or slightly higher amounts than N. [38] observed similar trend but in a slightly different experiment (artificial extraction of K from plant residues). It seems as if the change between Day 1 and 3, common to both soils, is related to the process of soil stabilization during which most of the organics reach their optimum K release and maintain it.

3.3 Cumulative Release of N, P and K

Cumulative N_{min} (NH_4- and NO_3- N) over the entire incubation period showed clear distinction between high-releasing materials in the order *Crotalaria* > *Albizzia* > *Canavalia* > *Mucuna* > *Lupine* for Yoghoi and *Mucuna* > *Crotalaria* > *Canavalia* > *Lupine* > *Albizzia* for Lyamungu and the rest of the organics. Results are summarized in Fig. 1.



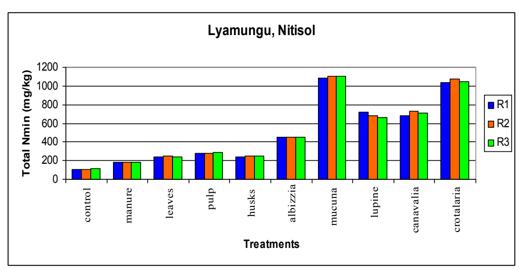


Fig. 1. Cumulative N_{min} released

The N_{min} release from the tested organics showed highly significant variations (P<0.001) among the organics and between the two soil types. As expected, replicates were not significant (P>0.05) as they belonged to the same formulations. These results are in line with those of [39] in their work on decomposing leaves. Slight replicate variation was noted, which could be attributed to possible variations in moisture conditions [40]. The model was also highly significant with R^2 of 0.9976, RMSE of 21.3794 and CV of 4.6%. From Tukey's HSD, the four green manure plants emerged top of the list, in the order *Crotalaria* > *Mucuna* > *Canavalia* > *Lupine*. *Albizzia* leaves came next in the list, performing better with the Acrisols than the Nitisols. There was a clear distinction between these and the last four (Pulp > Husks > Leaves > Manure), whereby *Albizzia*, the last in the upper list, was about 5 times coffee pulp, the first in the lower list. The Acrisols of Yoghoi gave average N_{min} of 488.56 $mg.kg^{-1}$, which was higher than the average N_{min} of 440.29 $mg.kg^{-1}$ from the Nitisols of Lyamungu.

Cumulative available P behaved quite differently between the sites of Yoghoi and Lyamungu. Mean released P for Yoghoi was around 70 ppm (manure), followed by 40 ppm (coffee leaves) and 20-30 ppm (*Crotalaria, Canavalia, Mucuna* and *Albizzia*). Lyamungu soil released mean available P around 152, 148, 110 and 85 ppm for *Lupine, Canavalia, Albizzia*, *Crotalaria* and *Mucuna* respectively. The green manure plants have proved to be a dependable source of P in the soils of Lyamungu, though somewhat less so in the Yoghoi soil. Results are summarized in Fig. 2.

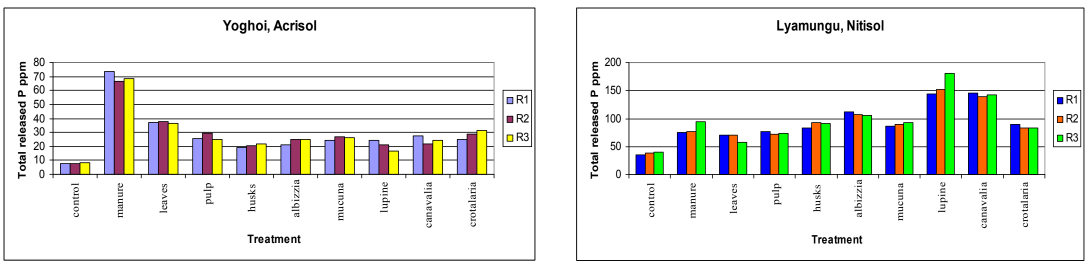


Fig. 2. Cumulative available P released by the two soils

The P statistics distinguished two significantly different groups of organics, with the upper group in the order *Lupine*>*Canavalia*> Manure (averages of 58.5, 49.99 and 47.75 ppm respectively). The rest of the organics, ranging between 23 and 33 ppm, were in the order *Albizzia*>*Mucuna*> Husks > *Crotalaria* > Pulp > Leaves. Average P release for Lyamungu Nitisols was 46.83 ppm, while that for Yoghoi was much lower (16.58 ppm).

Cumulative total K release followed the same trend for Yoghoi and Lyamungu Fig. 3. Highest mean release of 22 cmol kg-1 was noted in *Canavalia* and manure respectively. In both cases, coffee pulp was lowest in the list.

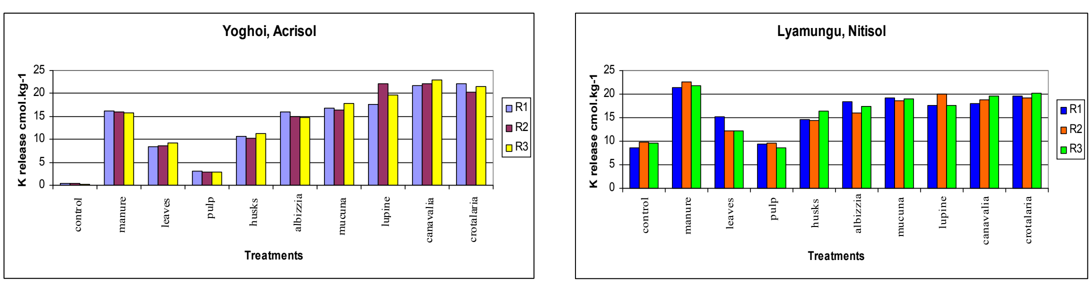


Fig. 3. Cumulative exchangeable K released by the two soils

The K statistics showed the first five organics in the order *Canavalia* > *Crotalaria* > *Lupine* > Manure > *Mucuna* (averages of 12.86, 12.53, 11.59, 11.43 and 11.39 cmol kg^{-1} respectively). The rest of the organics, ranging between 1.5 and 10 cmol kg-1, were in the order *Albizzia* > Husks > Leaves > Pulp. Average K release for Yoghoi was 10.97 cmol kg^{-1}; while that for Lyamungu was much lower (5.86 cmol kg^{-1}).

3.4 Results of SAFERNAC Model Application

The results of comparing cattle manure with other organics are shown in Table 1, which implies that leaves, pulp and husks can release 1.92, 2.51 and 1.98 times as much N_{min} as cattle manure respectively with the Lyamungu Nitisol and 1.22, 1.62 and 1.59 times with the Yoghoi Acrisol. As for P and K, the three organics can release 0.69-1.06, 0.08-0.54 times as much as manure for Lyamungu and 0.29-0.53, 0.17-0.68 times for Yoghoi. Using the figures of kg N, P and K per ton dry matter for cattle manure (13, 6 and 14 kg), the comparative nutritive potential of the test organics and the two soil types were represented as in Appendix 4.

Table 1. Comparison of organics in terms of nutrient (N, P and K) release in 180 days

Organics	Lyamungu nitisol			Yoghoi acrisol		
	N_{min}	P	K	N_{min}	P	K
Manure	1.00	1.00	1.00	1.00	1.00	1.00
Leaves	1.92	0.69	0.44	1.22	0.52	0.54
Pulp	2.51	0.81	0.08	1.62	0.53	0.17
Husks	1.98	1.06	0.54	1.59	0.29	0.68
Albizzia	4.93	1.32	0.74	11.44	0.39	0.96
Mucuna	14.29	1.07	0.85	11.17	0.64	1.09
Lupine	8.33	2.67	0.88	10.73	0.53	1.10
Canavalia	8.61	2.13	0.96	11.63	0.58	1.23
Crotalaria	13.63	0.82	0.94	12.77	0.68	1.20

The yield estimated with SAFERNAC are given in Figs. 4a and b

Fig. 4a (Lyamungu) indicates that with organics alone, there is no significant difference in yield between manure, leaves, pulp and husks, whether at 1 ton, 5 tons or 10 tons, though there is a linear increase as the application rate increases. This implies some benefit in increasing the rate, at least up to 10 tons. With *Albizzia*, *Mucuna, Lupine, Canavalia* and *Crotalaria,* there is a more significant yield difference as rate is increased from 1 to 5 tons than from 5 to 10 tons. This suggests an optimum application of 5 tons organics per ha. With a combination of organic and inorganic nutrient sources, a significant leap in yield with manure, leaves, pulp and husks is noted, which also narrows the difference between 1, 5 and 10 tons organic per ha throughout the treatments. Because raising enough organics for supplying 10 ton dry matter per ha may be rather tedious, we recommend the ISFM or combined approach, in which case the rate of organics to apply can go as low as 1 ton per ha.

Fig. 4b (Yoghoi) shows that the estimated yields are much lower than those for Lyamungu. Even with the addition of 10 tons of organics alone, the maximum estimated yield was around 700 kg ha^{-1}. With fertilizers, the maximum yield was raised to slightly over 1 ton ha^{-1}. This implies that coffee investment in Yoghoi requires a substantial effort in ISFM. With organics alone, manure competed well with the high nutrient releasing green manure plants at 1, 5 and 10 ton ha^{-1}, while the coffee by-products were relatively lower. The same trend was seen with the addition of inorganic fertilizers (160/60/160), except that both the gaps between the coffee by-products and the rest of the organics on one hand, and between the rates of organics applied on the other, have been significantly narrowed.

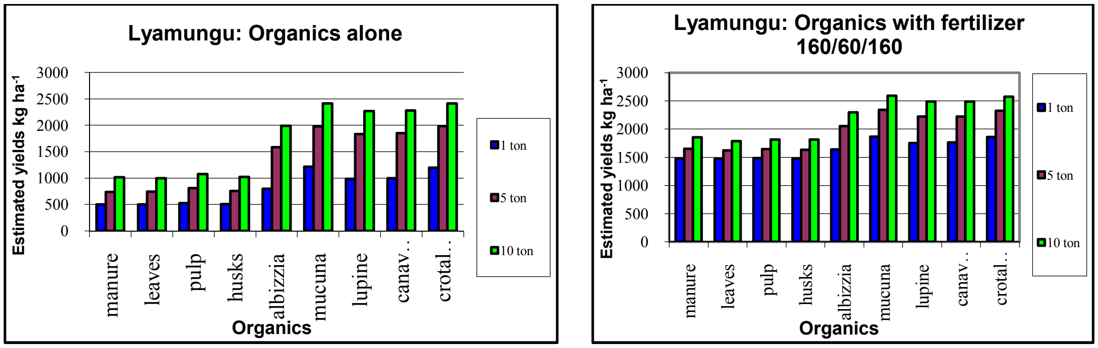


Fig. 4a. SAFERNAC estimated yields Lyamungu, with and without added inorganic fertilizer

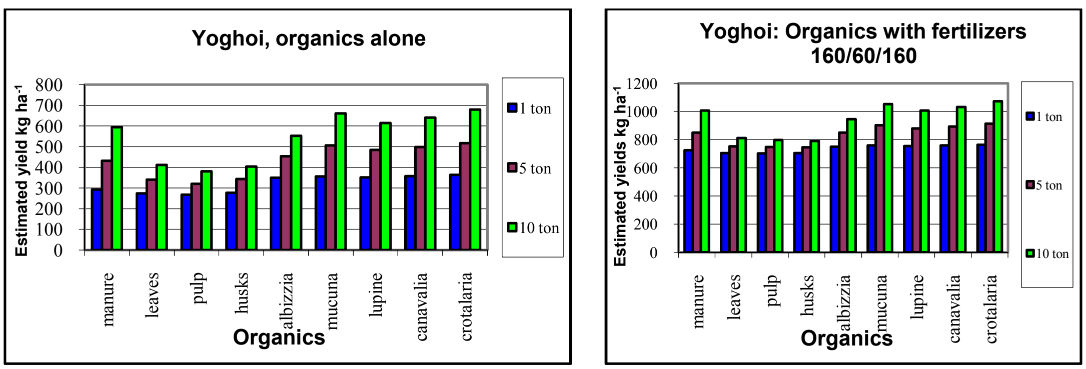


Fig. 4b. SAFERNAC estimated yields Yoghoi, with and without added inorganic fertilizer

Organic farmers around Lyamungu can set target yield at 1.5 tons ha^{-1} with the application of 5 tons ha^{-1} of either *Albizzia, Mucuna, Lupine, Canavalia* or *Crotalaria*. The conventional ones can set their target yield at 2 tons ha^{-1} with same applications and rates, combined with inorganic fertilizers. Organic farmers around Yoghoi are advised to set their target yield at 500 kg ha^{-1} and use either 10 tons manure or *Albizzia*; or alternatively 5 tons of *Mucuna, Lupine, Canavalia* or *Crotalaria*. The conventional ones can either pick a pessimistic or optimistic option. The former sets the target yield at 800 kg ha^{-1} with the application of 5 tons manure, *Albizzia, Mucuna, Lupine*, *Canavalia* or *Crotalaria* plus inorganic fertilizer. The latter option sets the target yield at 1 ton ha^{-1} with the application of 10 tons manure, *Mucuna, Lupine, Canavalia* or *Crotalaria* plus inorganic fertilizer.

3.5 Experience of Selected Organics in Different Crops

An appreciable amount of literature is available on *Mucuna*, *Canavalia* and *Crotalaria*; less so for *Lupine*. Most of the TSBF efforts in ISFM were based on the first three. *Mucuna* and *Canavalia* were evaluated by [41] under maize and competed fairly well with other common organics *Leucaena, Tithonia* and *Calliandra*. In a participatory demonstration plot with maize in Uganda, [42] noted good farmers' ranking in the order *Canavalia* > *Crotalaria* > *Mucuna*. The choice of the four green manure plants in this work, for inclusion into the coffee ISFM programme, is therefore justified.

4. CONCLUSION

The nutrient release potential of nine types of organic materials available in a coffee farming system was studied in this work, as applied to two contrasting coffee soils of Northern Tanzania. It was noted that the Yoghoi Acrisols are slightly more efficient in N_{min} release than the Lyamungu Nitisols, but the reverse is true with P. There was no significant difference in K release potential in the two soil types. $N_{min,}$ P and K release varied significantly ($P<0.001$) among the organics and between the two soil types. SAFERNAC has demonstrated its potential in suggesting appropriate nutrient management options for both organic and conventional farmers, and has also confirmed the test results, that green manure plants have great potential in coffee ISFM. Four of them (*Crotalaria*, *Mucuna*, *Canavalia* and *Lupine*) were picked as best bets for inclusion in the coffee ISFM programme. The challenge remains the appropriate application techniques in coffee farms, which will be pursued in future research work.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Baffes J. Tanzania coffee sector: Constraints and challenges in Global environment. The World Bank 1818 H street, NW MC 2-339 Washington D.C. 2003;56.
2. Maro GP, Kitalyi A, Nyabenge M, Teri JM. 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. 2010;607-614.
3. Tanzania Coffee Board (TCB). Tanzania coffee industry development strategy 2011 to 2021. A TCB Publication, amended version. 2012;53.
4. Envirocare. A study on the importance of coffee industry in Kilimanjaro region. A NORAD Project, Moshi, Tanzania. 2004;33.
5. Teri JM, Kilambo DL, Mtenga D, Nyange NE, Nzallawahe TS, Chipungahelo GS, Kipokola TP, Kullaya IK. Improved Arabica varieties for the benefit of Tanzanian coffee producers.In: Proceedings of the 20th ASIC Conference, 15-19 October, 2004, Bangalore, India. 2004;622-629.
6. Kilambo DL, Ng'homa NM, Mohamed RA, Teri JM, Poole, Flor A, Pinard F. Coffee Disease Survey in Tanzania. In: Proceedings of the 20th ASIC Conference, 15-19 October, 2004, Bangalore, India. 2004;774-781.

7. Magina FL. A review of coffee pest management in Tanzania. A TaCRI publication, (2nd Edition). 2011;78.
8. Tanzania Coffee Board (TCB). Way forward in the Tanzanian coffee sector. Proceedings of the first Coffee Stakeholders' Conference, Arusha, Tanzania. 2009;39.
9. Carr MKV, Stephens W, Van Der Vossen HAM, Nyanga A. Tanzania Coffee Research Institute: Strategic Action Plan 2003 to 2008, contributing towards a profitable and sustainable coffee industry in Tanzania. ICPS, Cranfield University, Silsoe, UK. 2003;142.
10. Smith C, Ndunguru B. The second Strategic Action Plan (SAP II) and business plan for Tanzania Coffee Research Institute, 2008 – 2013. Consultancy report submitted to TaCRI, Cardno Agrisystems Inc. 2007;178.
11. Brady NC, Weil RR. The Nature and Properties of Soils, 13th Edition. Prentice Hall London. 2002;960.
12. Gumbo D. Integrated soil fertility management. Technical Brief, Practical Action Southern Africa, Harare, Zimbabwe; 06 September. 2006;5.
13. Raab RT. Fundamentals of Integrated Soil Fertility Management. IFDC Training materials for the Training Program on Integrated Soil Fertility Management (ISFM) in the Tropics, Lome, Togo. 2002;10.
14. Korikanthmath VS, Hosmani MM. Organic recycling of coffee pulp in coffee-based cropping systems. Mysore Journal of Agricultural Sciences. 1998;32:127-130.
15. Chemura A, Mandhlazi R, Mahoya C. Recycled coffee wastes as potential replacements of inorganic fertilizers for coffee production. In: Proceedings of the 22nd ASIC Conference, Campinas, Brazil. 2008;1197-1201.
16. Semoka JMR, Mrema JP, Semu E. A comprehensive literature review on integrated soil fertility management for coffee. Consultancy report submitted to TaCRI. Department of Soil Science, SUA. 2005;142.
17. Maro GP, Mbogoni JDJ. Soils of Kasulu, Kibondo, Tarime and Rorya districts and their suitability for coffee production. Technical report submitted to MAFSC (PADEP Project). 2009;78.
18. Anderson JM, Ingram JSI. The Tropical Soil Biology and Fertility: A handbook of methods. 2nd Edition. CAB International, Wallingford, Oxon OX108DE, UK. 1993;92.
19. Temminghoff EEJM, Houba VJG. Plant analysis procedure 2nd Edition. Kluwer Academic Publishers, Dordrecht, the Netherlands; 2004. ISBN 1-4020-2769-9,179.
20. Van Ranst E, Verloo M, Demeyer A, Pauwels JM. 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 281/58, B-9000 Gent, Belgium; 1999. ISBN 90-76603-01-4,243.
21. National Soil Services (NSS). National Soil Services: Laboratory procedures for routine soil analysis (3rd Edition). NSS Miscellaneous Publication M13, Mlingano, Tanzania. 1990;140.
22. Khalil MI, Hossain MB, Schmidhalter U. Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. Elsevier, Ltd. Soil Biology & Biochemistry 37. 2005;1507-1518.
23. Gunapala N, Venette RC, Ferris H, Scow KM. Effects of soil management history on the rate of organic matter decomposition. Elsevier Ltd. Soil Biology & Biochemistry. 1998;30(14):1917-1927.
24. Verloo M, Demeyer A. Soil preparation and analysis – A practical guide. Department of Applied Analytical and Physical Chemistry, Coupure Links 653, B-9000 Gent, Belgium. 1997;107.
25. Yang HS. Modelling organic matter mineralization and exploring options for organic matter management in arable farming in northern China. Ph.D thesis Wageningen University, The Netherlands. 1996;159.
26. Yang HS, Janssen BH. A mono-component model of carbon mineralization with a dynamic rate constant. European Journal of Soil Science. 2000;51:517-529.

27. Sluysmans CMJ, Kolenbrander GJ. The significance of animal manure as a source of nitrogen in soils. Proc. Int. Sem Soil Environment and Fert. Management in Intensive Agric Tokyo. 1977;403-411.
28. Gerritse RG, Zugec I. The phosphorus cycle in pig slurry measured from ^{32} PO4 distribution rates. J Agric Sci Camb. 1977;88:101-109.
29. Velthof GL, Van Beusichem ML, Raijmakers WMF, Janssen BH. Relationship between availability indices and plant uptake of nitrogen and phosphorus from organic products. Plant and Soil. 1998;200:215-226.
30. Pidwirny M. The Nitrogen Cycle 2006. Fundamentals of Physical Geography, 2nd Edition. Viewed 07July, 2012.
Available: http://www.physicalgeography.net/fundamentals/9s.html
31. Vimlesh K, Giri AK. 2009. Nitrogen Mineralization in Soil Amendedwith Crop Residue: An Incubation ExperimentUnder Flooding Conditions. E-Journal of Chemistry. 2011;8(1):25-28. Available: http://www.e-journals.net
32. Kaloi GM, Bhughio N, Panhwar RN, Junejo S, Mari AH, Bhutto MA. Influence of incubation period on phosphate release in two soils of District Hyderabad. Journal of Animal & Plant Sciences. 2011;21(4):665-670. ISSN: 1018-7081.
33. Jalali M, Zinli NM. Kinetics of phosphorus release from calcareous soils under different land use in Iran. Journal of Plant Nutrition and Soil Science. 2011;174:38-46.
34. Horta MD, Torrent J. Phosphorus desorption kinetics in relation to phosphorus forms and sorption properties of Portuguese acid soils. Soil Science. 2007;172:631-638.
35. Nafiu A. Effects of soil properties on the kinetics of desorption of phosphate from Alfisols by anion-exchange resins. Journal of Plant Nutrition and Soil Science. 2009;172:101-107.
36. Kaur N, Benipal DS. Effects of crop residue and farmyard manure on potassium forms on soils of long term fertility experiment. Indian Journal of Crop Science. 2006;1(1-2):161-162.
37. Potash Development Association (PDA), Principles of Potash Use. Brochure No. 8/2006, PDA, York YO32-5WP, UK. 2006;12.
38. Ako PAE, Adebanjo AS, Fadipe AL, Ndamitso AM. Extractability of potassium from some organic manures in aqueous medium and the effects of pH, time and concentration. Journal of Applied Sciences & Environmental Management. 2003;7(1):51-56.
39. Kwabiah AB, Stoskopf NC, Voroney RP, Palm CA. Nitrogen and phosphorus release from decomposing leaves under sub-humid tropical conditions. Biotropica. 2001;33(2):229-240.
40. Moyano F, Chenu C. An integrated analysis of soil incubation data: deriving soil type dependent moisture-respiration relations. Geophysical Research Abstracts Vol. 13, EGU2011-14017, 2011, EGU General Assembly; 2011.
41. Okalebo JR, Otieno CO, Woomer PL, Karanja NK, Semoka JMR, Bekunda MA, Mugendi DN, Muasya RM, Bationo A, Mukhwana EJ. Available technologies to replenish soil fertility in East Africa. In: Bationo A. (eds), Advances in ISFM in sub-saharan Africa: challenges and opportunities. Springer. 2007;45-62.
42. Tumuhairwe JB; Rwakaikara-Silver MC, Muwanga S, Natigo S. Screening legume green manure for climatic adaptability and farmer acceptance in the semi-arid agro-ecological zone of Uganda. In: Bationo, A. (eds), Advances in ISFM in sub-saharan Africa: challenges and opportunities. Springer. 2007;255-259.

APPENDIX

1. Parameters R_9 and S in the model for some organic materials and soil organic matter (SOM)

	Green manure	Straw	Cattle manure	Compost	SOM
R_9, (Y^{-1})	1.204	1.117	0.0706	0.276	0.046
S	0.6260	0.6201	0.6023	0.3125	0.3150

2. Remaining fractions (Y_t/Y_0), calculated with Eq. 3, of some organic materials and SOM

Time, year	Green manure	Straw	Cattle manure	Compost	SOM
0	1	1	1	1	1
0.25	0.34	0.37	0.53	0.80	0.96
0.5	*0.25*	0.27	*0.44*	*0.69*	0.94
0.75	0.20	0.22	0.38	0.62	0.92
1.0	0.16	0.18	0.34	0.56	0.91

3. Substitution values for organic materials according to categories

Type of organic	Category	YT/Y0 AT 180 days	FMO	SVN	SVP
Cattle manure	FYM	0.44	0.56	0.6	0.87
Leaves	CP	0.69	0.31	0.33	0.48
Pulp	CP	0.69	0.31	0.33	0.48
Husks	CP	0.69	0.31	0.33	0.48
Albizzia	GM	0.25	0.75	0.8	1.16
Mucuna	GM	0.25	0.75	0.8	1.16
Lupine	GM	0.25	0.75	0.8	1.16
Canavalia	GM	0.25	0.75	0.8	1.16
Crotalaria	GM	0.25	0.75	0.8	1.16

4. Calculated availability of N, P and K for the test soils and organics

		LYAMUNGU				YOGHOI			
		Kg/TDM	SV	MRF	IA	Kg/TDM	SV	MRF	IA
Nitrogen	Manure	13.00	0.60	0.7	5.46	13.00	0.6	0.7	5.46
	Leaves	24.96	0.33	0.7	5.77	15.86	0.33	0.7	3.66
	Pulp	32.63	0.33	0.7	7.54	21.06	0.33	0.7	4.86
	Husks	25.74	0.33	0.7	5.95	20.67	0.33	0.7	4.77
	Albizia	64.09	0.80	0.7	35.89	148.72	0.8	0.7	83.28
	Mucuna	185.77	0.80	0.7	104.03	145.21	0.8	0.7	81.32
	Lupine	108.29	0.80	0.7	60.64	139.49	0.8	0.7	78.11
	Canavalia	111.93	0.80	0.7	62.68	151.19	0.8	0.7	84.67
	Crotalaria	177.19	0.80	0.7	99.23	166.01	0.8	0.7	92.97
Phosphorus	Manure	6	0.87	0.1	0.52	6	0.87	0.1	0.52
	Leaves	4.14	0.48	0.1	0.20	3.12	0.48	0.1	0.15
	Pulp	4.86	0.48	0.1	0.23	3.18	0.48	0.1	0.15
	Husks	6.36	0.48	0.1	0.31	1.74	0.48	0.1	0.08
	Albizia	7.92	1.16	0.1	0.92	2.34	1.16	0.1	0.27
	Mucuna	6.42	1.16	0.1	0.74	3.84	1.16	0.1	0.45
	Lupine	16.02	1.16	0.1	1.86	3.18	1.16	0.1	0.37

Table 4 continued…………….

	Canavalia	12.78	1.16	0.1	1.48	3.48	1.16	0.1	0.40
	Crotalaria	4.92	1.16	0.1	0.57	4.08	1.16	0.1	0.47
Potassium	Manure	14	1	0.7	9.80	14	1	0.7	9.80
	Leaves	6.16	1	0.7	4.31	7.56	1	0.7	5.29
	Pulp	1.12	1	0.7	0.78	2.38	1	0.7	1.67
	Husks	7.56	1	0.7	5.29	9.52	1	0.7	6.66
	Albizia	10.36	1	0.7	7.25	13.44	1	0.7	9.41
	Mucuna	11.9	1	0.7	8.33	15.26	1	0.7	10.68
	Lupine	12.32	1	0.7	8.62	15.4	1	0.7	10.78
	Canavalia	13.44	1	0.7	9.41	17.22	1	0.7	12.05
	Crotalaria	13.16	1	0.7	9.21	16.8	1	0.7	11.76

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