

limit for carbon was 0.4 µg. Tissue samples of about 30 mg were used.

- ii. The Walkley-Black procedure of C analysis was based on the description of Nelson & Sommers (1996), with adaptation to the employment of external heat (Tedesco et al., 1995). The heating was provided by swirling the suspension over a Bunsen burner-flame after the addition of H₂SO₄ and was controlled so that the initial temperature of 120°C could rise to 150°C within one minute. Tissue samples of about 0.50 g were used.

$$R = \frac{Q_1(C_1 \times (100 - M_1)) + Q_2(C_2 \times (100 - M_2)) + Q_3(C_3 \times (100 - M_3)) + \dots + Q_n(C_n \times (100 - M_n))}{Q_1(N_1 \times (100 - M_1)) + Q_2(N_2 \times (100 - M_2)) + Q_3(N_3 \times (100 - M_3)) + \dots + Q_n(N_n \times (100 - M_n))}$$

where

R = Desired C:N ratio of the compost mixture

Q_n = Mass of material n

C_n = Carbon (%) of material n

N_n = Nitrogen (%) of material n

M_n = Moisture content (%) of material n

The above equation was used for a mixture of two or more materials, provided their; Carbon, Nitrogen, and C:N ratio set values are given or assumed, and specifying the mass of one ingredient. So the mass of the second and subsequent materials may be given by the following formula:-

$$Q_n = \frac{Q_1 \times N_1 \times (R - C_1) \times (100 - M_1)}{(N_1)}$$

$$N_2 \times \frac{(C_2 - R) \times (100 - M_1)}{(N_2)}$$

Calculations were cross checked using Evans's formula (Evans 2009) as follows:

Calculate the pile's total carbon value by multiplying the % carbon of each ingredient by the number of parts by weight of that ingredient and then adding up all the carbon totals for all ingredients. Do the same for nitrogen then divide the carbon value (% or weight) by that of nitrogen. Adjust the proportions of ingredients to bring it to the required ratio. In this project, Evans formula has been used

2.5 Formulating compost recipes from the agricultural wastes based on the desired C:N Ratios

Desired C:N ratio is the basis of making compost recipes. Using Evans formula the following substrates; rice husk, maize stalk, sorghum stalk, sugar cane bagasse, saw dust, soya meal and grass clippings were first subjected to chemical analysis, and then their carbon and nitrogen values used to calculate the ratios. Using set C:N ratios, recipes were developed by balancing the carbon based substrates and the nitrogen based substrates.

2.6 Testing the efficacy of the C:N Ratio based recipes on composting feedstock

Six Treatments in a Randomized Complete Block Design (RCBD) replicated three times was the design shown in Table 1 below:

The other elements (Ca %, Mg %, Na % Fe ppm, Mn ppm, Zn ppm, Cu ppm, B ppm.) were determined by the standard laboratory test methods

2.4 Determining C:N ratios of each of the agricultural substrates

2.4.1. Calculations of C:N ratios.

A desired C:N ratio was set, then using the formula of Richard *et al.* (1996); in a relationship given as:

Table 1: Design Arrangement of the Compost Piles

Trt 1	Trt 4	Trt 3
Trt 2	Trt 6	Trt 1
Trt 3	Trt 1	Trt 4
Trt 4	Trt 5	Trt 6
Trt 5	Trt 3	Trt 2
Trt 6	Trt 2	Trt 5

Where:-

Trt 1 = Rice husk composting recipe C:N ratio 30:1

Trt 2 = Rice husk recipe + EMI (500gms)

Trt 3 = Grass clippings recipe + EMI (500 gms)

Trt 4 = Mixed agricultural wastes with no known C:N ratio + EMI (500gms)

Trt 5 = Mixed agricultural wastes with no known C:N ratio with no EMI (1000gms)

Trt 6 = Mixed wastes of no known C: N ratio.

The unit measure was days to compost maturity, and the data was analyzed by Analysis of Variance (ANOVA)

2.7. Maturity Indicators for the Compost

The parameters used in this study were the following:

- No Temperature variations
- No odors
- pH of around 7.0
- Physical appearance
- Size of heap reduced to around 70% of the starting feedstock
- Germination test

3. Results

3.1 The Chemical composition of various substrates

Table 2: Chemical Components of Local Agricultural Wastes

Organic Wastes	C/N Ratio	C %	N %	P %	K %	Ca %	Mg %	Na %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Bagasse from Muhoroni	179.4	57.4	0.32	0.03	0.18	0.11	0.076	0.16	2438.6	117.7	43.7	32.4	0.0
Bagasse frm Chemelil	155.4	57.5	0.37	0.02	0.14	0.11	0.55	0.21	1158.5	55.4	14.5	8.9	0.0
Bagasse frm Kibos	230.8	57.7	0.21	0.02	0.11	0.069	0.039	0.089	787.7	45.3	11.2	7.4	0.0
Compost Day 1	91.5	42.1	0.46	0.01	0.36	0.27	0.19	0.16	1159.9	1344.5	49.4	6.1	0.0
Compost Day 4	85.7	51.4	0.60	0.01	0.47	1.13	0.23	0.15	1578.3	1469.8	70.9	6.9	0.0
Cattle Manure	33.8	40.2	1.19	0.02	0.64	1.49	0.36	0.18	1398.4	604.2	251.2	16.3	4.5
Chicken Manure	31.5	24.3	0.77	0.01	1.27	0.62	0.33	0.17	6228.6	4553.5	218.9	14.7	2.1
Rice Husk	220.8	55.2	0.25	0.01	0.36	0.086	0.065	0.012	371.1	390.9	19.3	2.6	0.0

3.2. Determining C:N ratios of each of the Agricultural Wastes

From the raw chemical components of the substrates shown in the above table, C:N ratios were calculated. A desired C:N ratio was then set using the formula of Richard *et al.* (1996). The various C:N ratios were calculated using a mixture of two or more materials. These calculations were cross checked using Evans's formula (Evans 2009), resulting in the following desired ratios: Sugar cane bagasse had a C:N ratio of 28.75, Rice husk 29.38, Maize stovers 25.06, Grass clippings 29.8, Soya bean meal 27.1, Rice straw 26.63 and Rice hull 29.1

3.3 Formulating Compost Recipes from the Agricultural Wastes

Evan's formula was used to develop the various recipes, one of which based on sugar cane bagasse is shown in Table 3 below. The same formula is used for other recipes based on rice hull, rice straw and saw dust.

Table 3: Recipe based on Sugar cane bagasse

Raw material	C (%)	N (%)	Amount in a pile (KG)	C (KG)	N (KG)	C:N Ratio
Bagasse	53	0.26	600	318	1.56	
Chicken manure	21.8	3.5	100	10	3.5	
Maize germ	52	1.76	90	26	1.76	
Cattle Manure	17.5	.8	200	11.4	1.3	
Urea	-	46	10	-	4.6	
Total amount			1000	365.4	12.72	28.73

Table 4: Results of compost maturity under natural conditions compared to project outputs:

Phase	Time in Days Natural condition	Measured Time in Days S/Cane Bagasse	Measured Time in Days Maize stovers	Measured Time in Days Grass clippings
1	30			
2	300			
3	480			
4	720	108.7	103.8	73.5

3.3 Germination Test

Germination test was done using tomato seeds. Immature compost would not allow germination due to changing temperatures and pH

Plate 1: Testing compost maturity



The compost piles were set up to test:

1. The effectiveness of using the correct C: N ratios, alone and in comparison with the addition of EMI.
2. The efficacy of EMI in relation to compost maturity speed using some three commonly available substrates.
3. Over a period of two years, data was collected and the results obtained were analyzed using Analysis of Variance. A mean of three replicates is given in Table 5 below:

Table 5: Mean of 3 Replicates of days to maturity

Trt	Carrier	Compost maturity in days			
		Maize stovers based pile	Sugar cane bagasse Based pile	Grass clippings Based pile	
1.	Peat	63.0	71.3	41.7	Sum =175.6 SS=30835.36 MS=58.53
2.	Filter mud	71.7	77.3	48.7	Sum =197.7 SS=39085.29 MS=65.9
3.	Ant hill core soil	85.0	97.3	60.7	Sum =243.0 SS=59049.0 MS= 81
4.	Rice husk	104.7	109.0	69.0	Sum=282.7 SS=79919.29 MS=94.23
5.	Recipe pile without inoculants	138.3	139.7	94.0	Sum=372.0 SS= 138384 MS=124.0
6.	Inoculants on non recipe pile	160.0	158.0	120.3	Sum=438.0 SS=191844.0 MS= 146.0
		Sum = 622.7 SS = 387755.3 MS = 103.8	Sum = 651.9 SS = 424973.6 MS = 108.7	Sum = 440.7 SS = 194216.5 MS = 73.5	

3.4 Analysis of Variance

3.4.1. Analysis of Variance across the Substrates

These scores are then subjected to Analysis of Variance to test the significance of the differences between the different treatments (if any) in accordance with the following computational relationships:

i) $SS_{total} = \frac{\sum X^2}{N} - \frac{G^2}{N}$

ii) $SS_{between} = \left[\frac{\sum T^2}{n} \right] - \frac{G^2}{N}$

iii) $SS_{within} = \sum X^2 - \frac{(\sum X)^2}{N}$

iv) $SS_{total} = SS_{between} + SS_{within}$

$SS_{total} = (387755.3 + 424973.6 + 194216.5) - \frac{(622.7 + 651.9 + 440.7)^2}{21} = 1,254593.4$

$SS_{between} = \left[\frac{387755.3}{6} + \frac{424973.6}{6} + \frac{194216.5}{6} - 1,846.3 \right] = 165977.9$

$SS_{within} = 1,254593.4 - 165977.9 = 1,088,615.5$

So that:

Source	SS	df	MS	F
Between	165977.9	2	82988.95	2.0
Within	1,088,615.5	15	72574.4	

and noting that, each df is associated with a specific SS,

Where;

X = Treatments

N = Total number of scores

G = Grad Mean

n = number of Treatments

T = Sum of b Treatments

SS = Sum of squares

Wherefore;

With df = (2, 15) F_O value of 2.0 and the corresponding F_C = 3.682 at P = ≤ 0.05, and is therefore statistically significant.

and

$SS_{total} = [30835.4 + 39085.3 + 59049 + 79919.3 + 138384.0 + 191844] - [175.6 + 197.7 + 243 + 282.7 + 372 + 438] = 537605.7$

$SS_{between} = \left[\frac{30835.4}{3} + \frac{39085.3}{3} + \frac{59049}{3} + \frac{79919.3}{3} + \frac{138384}{3} + \frac{191844}{3} \right] - 162260.1 = 174440.8$

$$SS_{\text{within}} = 537605.7 - 174440.8 = 363164.9$$

So that:

Source	SS	df	MS	F
Between	174440.8	2	87220.4	1.99998
Within	363164.9	15	24211	

With $df = (2, 15)$, F_0 value of 1.99998 against corresponding $F_C = 3.682$ at $P \leq 0.05$, and therefore is statistically significant.

The results show that sterilized carriers significantly reduced the cfu (colony forming units) counts, and also significant reduction in maturity of the composts. Similar results were demonstrated by *Kuster et al.*, 1966. Results also showed that better growth of soil microorganisms was found in sterilized carriers confirming results by *Hobben et al.*, 1982; and *Rhoughley et al.*, 1970.

4. Discussion on Challenges on Soil Health Management, Conclusions and Recommendations

4.1 Socio-cultural challenges on C:N ratio for Composting

In a related study, most of the smallholder farmers in the study area have land holdings under one hectare strewn about in scattered settlements. As it is now, these farmers are not able to generate sufficient compost feedstock to make more than two one-ton composting pile, which when matured will reduce to less than 700 kg of compost from each pile. Considering that the application dose for compost is some 15 mt per hectare or 6 mt per acre, composting as a means of maintaining or resuscitating soil health may not be an option for most of these farmers at this point in time. Considering that the population growth in this area is growing exponentially, the pressure on land is increasing at even a higher rate. Being able to feed the people in another 10 years will be such a challenge that the farmers will not be able to cope; and even the government will find it very difficult to feed people whose soil cannot produce any crop. Looked from that perspective, the concept of C:N ratio may be a useful technological tool, but will face serious constraints in its application.

4.2 Technological Challenges on C:N ratio for composting

The C:N ratios obtained from chemical analysis of various locally available substrates as shown in table 2 above; bagasse 203.8, maize stovers 68, sorghum stalks 73, rice straw 78, cattle manure 22, chicken manure 5.7, rice husks 87.5 and grass clippings 67.9 are way above the optimal 30 for carbonaceous source substrates and way below the 25 threshold for the nitrogenous source materials. Left on their own, they would not decompose and make composts. Organisms that decompose organic matter use carbon as a source of energy, and nitrogen for building cell structure.

When the energy source carbon is less than that required for converting available nitrogen into protein, organisms make full use of the available carbon and get rid of excess nitrogen

as ammonia to the atmosphere. C: N ratio is a critical factor in composting to avoid nitrogen robbing from the soil, and conserving maximum nitrogen in the soil.

To ensure a compost feedstock will be useful for making rich compost and in the shortest time available, correct calculations have to be made to create the perfect compost recipes.

This is what was observed where the non-recipe treatment ranged from 120 to 160 days to mature compared with the best recipe treatment (peat on grass clippings) which ranged from 41 to 63 days to mature. This finding compares favorably with the experiments reported by other researchers; (*Okalebo et al.* 2005, *Mucheru et al.* 2003, and *Lekani et al.* 2003). Being ready to calculate the ratios every time one wishes to make a compost is a big challenge as the composting substrates are rarely obtained in any one predictable form.

This finding confirms report by Richard et al that "many ingredients for composting do not have the ideal ratio of 25-30:1. As a result, most must be mixed to create 'the perfect compost recipe'" (*Richards et al.* 2009).

4.3 Conclusions

For successful composting, the selection of the most appropriate raw material is an important component (*Fourti et al.* 2011). Of the substrates tested, grass clippings, maize stovers and sugar cane bagasse were the most suitable material for large scale composting, but these are merely carbon sources and for proper composting nitrogen sources have to match the carbon sources in the prescribed ratios. However it is not easy to find matching cattle manure, chicken manure or leguminous plant remains, and considering that matured compost is dosed in tons per acre/hectare, composting under current circumstances is not a regular option for the smallholder farmers.

4.4 Recommendations

4.4.1 General

From the conclusion that composting is not viable in low potential areas because the quantity and quality of the biomass is limited, a design should be developed that would stimulate intensified agriculture. With intensified agriculture, it is then possible to generate high biomass within the small farm units, and composting to become a routine procedure because improvement of soil health is not a debatable intervention in the face of exponentially increasing population of the rural poor.

4.4.2 Socio-cultural considerations

The National and County governments should be persuaded to advice or even enforce cluster settlements for smallholder farmers so that agricultural land however small is lawfully protected. In the long run this option may need no debate if future livelihoods have to be self-supporting

4.4.3 Mixed farming

It is hereby highly recommended that the households in the project areas and their neighborhoods should be encouraged

to practice mixed farming, so that whatever crop residues from their farms may be fed to livestock and the remainder used to produce composts.

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