

Uptake and Use Efficiencies of Nutrients by Sesame and Bambara Nut Alley Crops as Influenced by Manuring in a Cashew-Based Intercropping System in the Guinea Savanna Agroecology of Nigeria

Samuel Agele^{1*}, Nduka Beatrice², Famuwagun Babadele¹, Adejoro Solomon¹

¹Department of Crop, Soil & Pest Management, Federal University of Technology, Akure, Nigeria

²Cocoa Research Institute of Nigeria, Ibadan, Nigeria

Email: *ohiagele@yahoo.com, soagele@futa.edu.ng

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Abstract

Field experiments were conducted at the experimental farm Cocoa Research Institute of Nigeria (CRIN) Sub-Station, Ochaja, in the Southern Guinea Savanna agro ecological zone of Nigeria to examine uptake and use efficiencies of nutrients by Sesame and Bambara nut alley crops as influenced by manuring in a Cashew-based intercropping system. Experimental treatments were based on responses of sole and intercrop mixtures of Sesame and Bambara nut alley crops to Cocoa Pod Husk (CPH), pelletized organic fertilizer and NPK fertilizer in a cashew-based intercropping system. Data were collected on the growth and yield variables of the alley crops. Highest nitrogen harvest index (NHI) for seed and leaf of alley crops were obtained from un-manure treated plants. Cocoa pod husk (CPH) significantly enhanced P uptake compared with other fertilizers applied. CPH improved Na, Ca, Mg Zn, Cu, P, K and carbohydrate in the leaves and Ca, Mg, Zn, Fe, Cu, crude fibre and carbohydrate contents of seeds of sole crops while Sesame + Bambara had enhanced contents of N, Ca, Mg, Zn, Cu, P, N, K, moisture, protein, and crude fibre, crude protein, moisture content in leaves. The effects of NPK were significant for N, K Ca, Zn, Fe, Cu, P, moisture and crude fibre, while in the un-manure (control) plots influenced N, fat and protein and nitrogen harvest index (NHI) of leaf and seeds. CPH and NPK fertilizers enhanced nutrient uptake and nitrogen harvest index of alley crops. Nutrient uptake was similar for the varieties of Sesame and Bambara nut as affected by the application of 4.84 and 9.68 Kg pelletized organic fertilizer. Sole Bambara had higher N and

K concentration in leaves compared with Bambara + Sesame. In addition, sole Bambara had higher values of Physiology efficiency (PE), and fertilizer use efficiency (FAE) compared to the mixed crops of Bambara + sesame. However, physiology efficiency (PE), and fertilizer use efficiency (FAE) were significantly lower for Bambara + Sesame. The un-manure plants had enhanced N, P and K uptake. Varietal effects were pronounced for most of the resource use efficiency variables measured. The alley crop varieties responded differently to 4.84 and 9.68 kg pelletized fertilizer treatments (Agronomy Efficiency (AE), N-removed at harvest and Internal Utilization Efficiency (IE) and partial factor productivity (PFP)). Sesame variety NCRIBen04E had enhanced AE, N-remove at harvest, IE and PFP while variety E8 had significantly higher apparent Recovery Efficiency (RE), apparent Recovery Efficiency by difference (RE%), Physiology Efficiency (PE), Utilization Efficiency (UE), and internal Utilization Efficient (IE). Bambara variety TVSu999 had higher IUE, Agronomy Efficiency (AE), Apparent Recovery Efficiency (RE), Physiology Efficiency (PE) and Fertilizer Agronomy using Efficiency respectively (FAE) compared to variety TVSu1166. The fertilizers affected most of the indicators of nutrient use efficiency (NUE) measured. The effects were significant on AE, agronomic N-use efficiency (ANUE), RE, UE and PFP. NPK fertilizer enhanced Physiology efficiency (PE) and Partial factor production. NPK fertilizer significantly enhanced NUE parameters compared to CPH and un-manure. CPH manure significantly influenced RE%, PE and IE. The Internal Utilization Efficiency and N-remove at harvest were compared with the un-manure plants (control). The effects of 9.68 kg/plot pelletized fertilizer, were pronounced on Agronomy Efficiency (AE), Apparent Recovery Efficiency by difference (RE%), Physiology Efficiency (PE), Utilization Efficiency (UE), N-removed at harvest and Internal Utilization Efficiency (IE). Similar trends were observed in the responses NUE of Sesame and Bambara manuring. The responses sole crops in terms of RE, PE UE PFP were similar while their inter-crop combinations had significantly higher AE, RE, UE, PFP and N removed at harvest. Sole Sesame significantly influence Agronomy Efficiency (AE), Utilization Efficiency (UE), Internal Efficiency (IE) and Partial Fertilizer Production (PFP) and sole Bambara under NPK fertilizer had enhanced N-removed at harvest and apparent recovery by difference (RE%). Bambara + Sesame under cocoa pod husk (CPH) manure had enhanced apparent recovery efficiency by difference (RE%), fertilizer use efficiency (FAE) and internal utilization efficiency (IE). Sesame variety NCRIBen04E had enhanced Agronomy Efficiency (AE), N-removed at harvest and Internal Utilization Efficiency (IE) under 9.68 kg treatment while variety E8 had higher partial factor productivity (PFP) at 4.84 kg/plot pelletized organic fertilizer.

Keywords

Tropics, Fruit Tree-Based Agroforestry, Resources Use, Mixture Productivity, Agriculture, Food Security

1. Introduction

In recent years, the increased tendency for intensive vegetable production in the tropics has increased the demand for high application rates of fertilizers to maximize yields. High costs and accessibility of fertilizer constitute huge constraints to the success of intensive vegetable production [1] [2]. The continuous cropping systems of the tropics reduce soil fertility. Rapid degradation of soil quality and accelerated erosion in sub-Saharan Africa has become a huge problem where annual N depletion rate is about 26 kg year⁻¹ [3] [4]. Increase in N uptake and utilization efficiency by crops without deleterious effect on yield and ecosystem are required [2] [5].

Worldwide, the interest in the use of organic materials as sources of nutrients (fertilizers) for the production of organically grown vegetables had increased [5]. A balanced use of organic and mineral fertilizer could enhance stable soil chemical, physical and biological properties in addition to a large and rapid rate of nutrient turn over and high soil fertility status within the soil-plant system. Bair [6] opined that proper soil fertility management and sustainable agriculture can be achieved with the use of both mineral fertilizer and organic manure. Paul and Mannan [7] suggested that integrated nutrient management through combined use of organic wastes and chemical fertilizers can be an effective approach to combat nutrient depletion and promote sustainable crop productivity. Increases in soil organic matter pool have the potential to increase crop yield and N uptake. Replenishing the nutrients removed by crops by recycling back of agricultural wastes into the soil can sustain soil and crop productivity [7]. There is ample opportunity for nutrient recycling in the tropics where huge amounts of agricultural wastes are generated yearly. It would be necessary to develop economically and environmentally suitable integrated nutrient management packages for sustaining the changing needs of intensive vegetable production in the tropics. Integrated use of organic wastes and mineral fertilizer is reported to reduce the cost and amount of fertilizer required by crops. This practice is also known to improve nutrient use efficiency and chemical and nutritional quality of crops [8]. Renewable management of organic sources of N through use of agricultural waste materials would improve the quality of the environment and soil health.

The growth and yield performance of a crop are a function of the status of soil nutrients (especially N) [9]. Yield increase may respond to additional N supply and increased N utilisation efficiency for yield production. Physical and chemical availability of nutrients and plant physiological factors affect the rate of nutrient absorption in plants [5]. Potential availability of nutrients for plant uptake is a function of its solubility in the growing media and its physical location in the root zone. Physiological factors affect diffusion transport and rates of nutrient transfer across root boundaries and nutrient uptake through differentiation between the absorption of water and nitrates [8]. The level of N supply to the growing tissues, flowering and fruit set and N accumulation/concentration in

plant tissues (fruits) are affected by the time of N application and root absorption efficiency. Although a high level of N supply to the growing tissues will be maintained when the time of N application coincides with maximum root absorption efficiency, maximum partitioning of N between the reproductive and vegetative organs may not be attained [5] [8].

Most crops are capable of accumulating huge amounts of nitrates (NO_3) in their tissues [10]. Although nitrate nitrogen ($\text{NO}_3\text{-N}$) contents in plant parts are important to its quality, a high nitrate concentration in edible plant parts is detrimental to human health [2]. Causal relations between nitrate intake and methaemoglobinaemia and carcinogenic nitrosamines have been established. Variability in the efficiency of N translocation and nitrogen harvest index (NHI) by nitrogen availability were confirmed for lettuce leaf [11] and tomato [2]. Soil mal-nutrition is becoming widespread and increasing problems especially in the tropics hence the need to increase through management practices, the N uptake and utilisation efficiencies of crops. Accumulation and partitioning of biomass and N between vegetative and reproductive components (NHI) are commonly used in addition to other criteria in the selection for yield in crops [5] and to create cultivars adapted to low input management systems. Although these attributes vary in diverse ecologies, there are however, scanty information on uptake and use of soil N in crop species common to the cropping systems of the humid tropics [5] [12].

Our working hypotheses were based on literature reports. Rather *et al.* [9] and Graham [13] postulated that N efficiency in terms of high yield production is affected by the status of soil N, and crop varieties may differ in performance under varying soil N status. Rather *et al.* [9] and Agele *et al.* [8] opined that crop yield responses may increase under fertilizer treatments possibly due to improved efficiency of nutrient utilization for yield production. The nutrient release characteristics of organic materials depends on the material, particle size, soil temperature and moisture content [8]. In addition to this, the availability of soil N, the efficiency of its uptake and use in biomass and fruit production are also affected by crop types, soil and climatological characteristics of a region [8] [14] [15]. Based on these reports, some hypotheses were formulated as follows: That externally applied nutrients from different sources (organic and inorganic) would results in partitioning of large amounts of nutrients for growth. The efficiencies of nitrogen uptake and utilization for yield production and hence NHI are strongly affected by nutrient availability from fertilizer sources. The objectives of this study were to provide information which would improve understanding of the nutrient cycling of incorporated agricultural wastes used alone, and in combination with reduced rates of chemical fertilizer and to develop an integrated nutrient management package for vegetable production in the tropics.

2. Materials and Methods

Experiments were conducted between 2013 and 2015 cropping seasons at the experimental farm Cocoa research institute of Nigeria Sub-Station located in

Ochaja, Kogi State in the Southern Guinea Savanna agroecological zone of Nigeria. The objective was to address the constraints of declining soil fertility via manuring to enhance uptake and use efficiencies of nutrients and hence optimizing the benefits of resource availability within cashew alley. Experimental treatments were based on responses of sole and intercrop mixtures of Sesame and Bambara nut alley crops to Cocoa Pod Husk (CPH), pelletized organic fertilizer and NPK fertilizer in a cashew-based intercropping system. Treatments were a factorial scheme consisting of crop types (sole and intercrop mixtures of Sesame and Bambara nut) and fertilizers (Cocoa Pod Husk (CPH)), pelletized organic manure and NPK fertilizer arranged using RCBD at three replications. There was an unmanured control. The fertilizers were applied two weeks after planting (WAP). Data were collected on the growth and yield variables of the alley crops. Bambara nut and Sesame seeds were planted in the Cashew alley and separated by unplanted cashew boarder plant. Fertilizers were applied two weeks after planting (WAP) using Cocoa Pod Husk (CPH: 6.17 kg/plot) and N.P.K (1.44 kg/plot) in a twelve treatments layout comprised of sole and intercrop combination of Sesame and Bambara nut as alley crops in cashew. In addition, the responses of varieties of Bambara nut (TVSu1166 and TVSu999) and Sesame (E-8 and NCRIBen04E (Ex-Sudan)) to varying rates (0, 4.84 and 9.68 kg/plot) of organic pelletized manure in cashew alley was examined.

Data were collected on nutrient uptake and use efficiencies using indicators such as Agronomic Efficiency (AE), Physiological Efficiency (PE), Apparent Recovery (RE), Apparent Recovery Efficiency by difference (RE%), Utilization Efficiency (UE), Internal Utilization Efficiency (IE), Partial Factor Production (PFP). Agronomic Efficiency (AE): AE is calculated in units of yield increase per unit of nutrient applied. Its more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. The calculation of AE requires knowledge of yield without nutrient input, so is only known when research plots with zero nutrient input have been implemented on the farm [16]:

$$\text{Agronomy efficiency (AE)} = \frac{Y - Y_0}{F}$$

where Y = Crop yield with fertilizer, Y₀ = Crop yield without fertilizer, F = Amount of fertilizer applied. Agronomic Nutrient use efficiency (ANUE): This is defined as the ratio of grain yield with N application minus grain yield without N application. This was used to describe the capability of yield increase per kilogram pure N (kg of crop yield increase per kg of nutrient applied):

$$\text{Agronomic Nutrient Use Efficiency (ANUE)} = \frac{Y_n - Y_0}{F_n}$$

where AE is agronomic efficiency, Y_n and Y₀ are crop yields (kg·ha⁻¹) with and without the nutrient being tested, F_n is the amount of nutrient applied (kg·ha⁻¹).

Physiological efficiency was calculated as yield increased per kg increased in Nutrient taken up and express as:

$$\text{Competitive Ratio (CRb)} = \frac{Y_{ab}}{Y_{aa}} \div \frac{Y_{ba}}{Y_{bb}} \times \frac{Z_{ab}}{Z_{ba}}$$

CRb: Competative ratio of Bambara nut with respect to sesame, Yab: Nutrient uptake by Bambara nut in intercropping, Yaa: Nutrient uptake by Bambara nut in sole crop, Yba: Nutrient uptake by Sesame in intercropping, Ybb: Nutrient uptake by Sesame in sole crop, Zab: Nutrient uptake by Bambara nut in intercropping, Zba: Nutrient uptake by Bambara nut in intercropping.

Physiological N use efficiency (PNUE): PNUE is defined as the yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant. Like AE and RE, it needs a plot without application of the nutrient of interest to be implemented on the site. It also requires measurement of nutrient concentrations in the crop and is mainly measured and used in research. Or defined as the ratio of yield increased with N application and it reflected the use efficiency of N absorbed (kg yield increase per kg of increase in nutrient taken up):

Physiological N use efficiency (PNUE) = (kg yield increase)/(kg fertilizer nutrient uptake) :

$$\text{PNUE} = \frac{Y - Y_0}{U - U_0}$$

where PE: Physiological efficiency, Y: Crop yield with applied nutrient, Y₀: Crop yield with no applied nutrient, U: Plant nutrient uptake of above ground biomass at maturity, U₀: Plant uptake with zero fertilizer.

Apparent recovery or apparent efficiency (RE): RE (kg of nutrient uptake by the c kg of nutrient applied); is one of the more complex forms of NUE expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. It is often the preferred NUE expression by scientists studying the nutrient response of the crop. Like AE, it can only be measured when a plot without nutrient has been implemented on the site, but in addition requires measurement of nutrient concentrations in the crop.

$$\text{Apparent Recovery Efficiency (ARE)} = \frac{N_n - N_0}{F_n} \times 100$$

where: RE is apparent recovery efficiency, N_n and N₀ (kg·ha⁻¹) are nutrient uptake by the crop with and without the applied nutrient respectively, and F_n (kg·ha⁻¹) is the amount of nutrient applied. Apparent recovery efficiency by difference was computed according to [17].

$$\text{Apparent recovery efficiency by difference RE} = \frac{U - U_0}{F}$$

where: U is Total nutrient uptake in above ground crop biomass with nutrient applied, U₀ is Nutrient uptake in above ground crop biomass with no nutrient applied, F = Amount of fertilizer applied.

Utilization efficiency (UE): Nutrient Utilization efficiency is a product of physiological and apparent recovery efficiency. It can be calculated according to [18] (Dobermann (2007)).

$$\text{Utilization Efficiency } UE (\text{mg} \cdot \text{mg}^{-1}) = PE \times ARE$$

Internal Utilization efficiency (IE): IE is defined as the yield in relation to total nutrient uptake. It varies with genotype, environment and management. A very high IE suggests deficiency of that nutrient. Low IE suggests poor internal nutrient conversion due to other stresses (deficiencies of other nutrients, drought stress, heat stress, mineral toxicities, pests etc.).

$$\text{Internal Utilization efficiency } IE = \frac{Y}{U}$$

where: Y = Yield of harvested portion of crop with nutrient applied, U = Total nutrient uptake in above ground crop biomass with nutrient applied.

Partial Factor Productivity (PFP): PFP is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied using the method of [19].

$$\text{Partial Factor Productivity } PFP = \frac{Y}{F}$$

where: Y = Yield of harvested portion of crop with nutrient applied, F = Amount of nutrient applied.

Data on determination of crop mixture productivity between Bambara and Sesame

System productivity index (SPI) was calculated according to [19]:

$$SPI = (S_a/S_b) Y_b + Y_a$$

where S is the mean yield of each plant in sole culture and Y is the mean yield of each plant in mixed crop.

Relative yield was computed using the formula as described by [20]:

$$RY = \frac{YA}{SA} = \frac{\text{Individual component crop yield in mixture (YA)}}{\text{Individual component crop yield in sole crop (SA)}}$$

Relative yield total (RYT): Relative yield total is defined as the sum of relative yields of the species in mixture expressed as a ratio of its yield in monoculture. Mathematically, as described by [21], it is expressed as:

$$RYT = ry_a + ry_b + \dots + r + y_n$$

where: ry_a and ry_b are the relative yields of species a and b respectively.

Nutrient use efficiency (NUE) is expressed in several ways as reported in literature as follows.

The efficiency of conversion of nutrient taken up by the plant into crop biomass was calculated as follows;

$$\text{Conversion efficiency of nutrient } X = \frac{\text{Total above ground biomass}}{\text{Total uptake of nutrient}}$$

where: Total aboveground biomass is the sum of seed + leaves biomass expressed on a dry weight basis. Uptake efficiency refers to the ability of crop to extract or absorb nutrients from the soil. The uptake of nutrients was calculated from the measurement of N, P and K content in the seeds and leaves biomass (Root were not considered). Nutrient accumulated (Uptake). Total plant uptake = N concentration in the sample biomass multiply by weight of the biomass.

The uptake of nutrients was calculated from the measurements of N, P, and K contains in seed and leaves biomass (root were not considered in this experiment).

$$\begin{aligned} & \text{Uptake efficiency} \\ & = \frac{\text{Total above – ground nutrient in the plant at maturity (Nt)}}{\text{Nutrient supplied (Ns)}} \end{aligned}$$

The conversion efficiencies for N, P, and K have the unit of Kg DM Kg N⁻¹, Kg DM Kg P⁻¹, Kg DM Kg K⁻¹.

Nitrogen Harvest index (NHI): N harvest index was defined as the percent of grain N uptake to total plant N uptake. The proportion of total plant N partitioned to the seed is called the N harvest index (NHI) according to [22]:

$$\text{N harvest index (NHI)} = \frac{\text{Seed N uptake}}{\text{total plant N uptake}}$$

$$\text{NUPE} = (\text{kg nutrient taken up})/(\text{kg nutrient available})$$

$$\text{NUPE} = \frac{U}{F + S}$$

where: N: Nutrient, U: Plant nutrient uptake of above ground biomass at maturity, F: Fertilizer applied, S: Nutrient in the soil.

Nitrogen Use Efficiency (NUE): This is a term used to indicate the ratio between the amount of fertilizer N removed from the field by the crop and the amount of fertilizer N applied. This ratio describes the efficiency of N fertilizer utilization in crop production express in % according to the methods of [23]:

$$\begin{aligned} & \text{N remove with harvest} \\ & = \frac{\text{N crop uptake fertilized} - \text{N crop uptake unfertilized}}{\text{Nfertilizer (Minerial N)}} \times 100 \end{aligned}$$

Fertilizer use efficiency reflects the recovery of applied fertilizer by the crop, however from the crop perspective, N (or other nutrient) use efficiency is a measure of biomass produced as a function of the N (or other nutrient) available to that crop.

Fertilizer agronomic efficiency refers to the quantity of yields obtained from the application of 1 Kg of fertilizer. It can be calculated as Kg of fertilizer or an element of interest (For example N, P, K etc.) and calculated using the procedure as outlined as follows:

$$(\text{AEF; kg}\cdot\text{kg}^{-1}) = (\text{yield at Fx} - \text{yield at F0}) \text{ to } (\text{applied F at Fx}).$$

where F is fertilizer, Yields at Fx is the yield obtained from the amount of fertilizer applied, and Yield at Fo is the yield from the control.

3. Results and Discussion

The results of the pre-cropping soil properties are presented in **Table 1**. The applied fertilizers (CPH, NPK and Pelletized organic fertilizer) improved soil physical and chemical properties (**Table 2(a)** and **Table 2(b)**). Soil pH under the

Table 1. Pre-cropping physical and chemical properties of soil of site of study.

Soil properties	Experiment 1 (2013)	Experiment 2 (2014)
Chemical properties		
pH (H ₂ O) 1:1	6.70	6.35
Organic carbon (g/kg)	0.54	0.92
Organic matter (g/kg)	0.92	1.59
Nitrogen (g/kg)	0.94	0.37
Available Phosphorus (g/kg)	0.50	1.82
Exchangeable bases (cmol·kg ⁻¹)		
K	0.54	0.01
Na	0.33	0.01
Ca	1.47	1.44
Mg	0.72	0.74
Exchangeable acidity (cmol·kg ⁻¹)		
Aluminum (Al ³⁺)	0.14	0.13
H ⁺	0.72	0.56
Effective cat ion exchange capacity (ECEC)	2.77	2.81
Physical properties (%)		
Sand	84.14	73.12
Silt	5.26	5.94
Clay	10.61	15.63
Water holding capacity (WHC)%	48.27	41.21
Textural class	Sandy loam	

Table 2. (a) Manuring effect on physical and chemical properties of soil in cashew-based Intercropping system; (b) Effects of organic fertilizer (Fert Plus) on physical and chemical properties of soil in cashew-based Intercropping system.

(a)

Treatments	pH	Chemical properties											Physical properties		
		N (g/kg)	P (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	OC (g/kg)	OM (g/kg)	Mg (cmol/kg)	Ca (cmol/kg)	H ⁺ (cmol/kg)	Al (cmol/kg)	CEC (cmol/kg)	Sand %	Silt %	Clay %
2013															
Cw – Un	6.50c	0.72a	2.48d	0.32a	0.26a	0.48a	0.82a	0.52c	1.07c	0.55b	0.14b	19.09a	84.63a	5.51b	9.85b
Cw + S + CPH	6.89b	0.96a	3.06a	0.31a	0.25a	0.66a	1.14a	0.92a	1.84b	0.58b	0.15b	3.35a	83.63a	6.26ab	10.11b
Cw + S + NPK	6.59b	0.14a	1.61c	0.35a	0.30a	0.44c	0.76c	0.83b	0.83b	0.63a	0.15b	1.80a	82.87a	6.47a	10.65b
Cw + B + CPH	7.05a	0.70a	2.65c	0.33a	0.27a	0.69a	1.19a	0.65b	1.29b	0.55b	0.15b	2.50a	82.12b	6.93a	10.95a
Cw + B + NPK	6.78a	0.75a	2.00b	0.32a	0.33a	0.75a	1.30a	0.73c	0.74c	0.60a	0.19ab	2.16a	82.00c	6.47a	11.53a

Continued

Cw + S + B + CPH	7.05ab	0.67a	2.84b	0.31a	0.26a	0.60a	1.03a	0.50c	0.91b	0.74a	0.31a	1.88a	83.13b	6.60a	10.27b
Cw + S + B + NPK	6.54b	0.91a	2.22a	0.35a	0.28	0.56b	0.96b	0.99a	1.03a	0.66a	0.20a	2.57a	83.01a	5.74b	11.25a
2014															
Cw – Un	6.43ab	0.92c	1.17ab	0.40a	0.35ab	0.70b	1.20b	1.27b	0.64a	0.69b	0.15b	2.65b	81.79c	6.94a	11.27c
Cw + S + CPH	6.41ab	1.04b	1.22a	0.37b	0.29b	0.35d	0.60d	1.41a	0.60a	0.83a	0.16b	2.86a	83.13a	4.18d	11.45b
Cw + S + NPK	6.38ab	1.07a	1.36a	0.36b	0.34ab	0.64b	1.11b	1.10b	0.52b	0.64b	0.16b	2.25b	82.62a	5.93b	11.45b
Cw + B + CPH	6.66a	0.79d	1.18a	0.30d	0.32b	0.76a	1.31a	0.86c	0.44b	0.65c	0.19b	1.98c	82.79a	5.81c	11.40b
Cw + B + NPK	6.24b	0.80c	0.98c	0.32c	0.33ab	0.41c	0.70c	1.22b	0.59a	0.73a	0.22a	2.78a	82.63a	5.94b	11.44b
Cw + S + B + CPH	6.12b	1.06a	1.11b	0.35c	0.40a	0.50c	0.87c	0.77d	0.40b	0.48d	0.23a	1.84d	79.46d	6.60b	13.94a
Cw + S + B + NPK	6.60a	0.99b	1.18b	0.38a	0.36ab	0.68a	1.18b	0.91c	0.45c	0.62c	0.15b	1.96c	80.13b	6.71a	13.16a

(b)

Treatments	Chemical properties											Physical properties			
	pH	N (g/kg)	P (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	OC (g/kg)	OM (g/kg)	Mg (cmol/kg)	Ca (cmol/kg)	H ⁺ (cmol/kg)	Al (cmol/kg)	CEC (cmol/kg)	Sand %	Silt %	Clay %
2014															
Fertilizer Types															
Control	6.59c	0.63a	1.24a	0.03b	0.02a	0.40c	0.68c	0.67c	0.34c	0.46c	0.13a	1.68c	68.13c	11.78b	20.10a
Pf (4.84 kg/plot)	6.79a	0.57b	0.99b	0.05a	0.02a	0.89a	1.53a	0.97a	0.49a	0.76a	0.23a	2.66a	74.11a	10.59c	15.30b
Pf (9.68 kg/plot)	6.63b	0.54c	0.62c	0.03b	0.03a	0.50b	0.86b	0.80b	0.41b	0.60b	0.16a	1.89b	71.65b	12.27a	16.08b
Crop Types															
E8	6.78a	0.62a	1.12a	0.02b	0.02a	0.51b	0.89b	0.80a	0.42a	0.61a	0.15a	1.85b	71.45a	11.54a	17.01b
NCRIBen04E	6.57b	0.54b	0.78b	0.04a	0.03a	0.67a	1.16a	0.82a	0.41a	0.60a	0.20a	2.30a	71.14b	11.55a	17.31a
2015															
Control	6.45b	0.60a	5.33a	2.31a	1.28c	1.03b	1.78b	3.25a	1.65a	0.16b	0.13c	8.60a	81.20c	6.48a	12.32a
Pf (4.84 kg/plot)	6.15c	0.57b	2.92c	1.88b	1.44b	1.03b	1.78b	3.15a	1.54b	0.18b	0.14b	8.61a	84.13a	5.23b	10.64b
Pf (9.68 kg/plot)	6.48a	0.53c	5.00b	1.79c	1.53a	1.26a	2.17a	2.84b	1.43c	0.24a	0.15a	7.77b	83.83b	5.47b	10.70b
E8	6.24b	0.60a	4.43a	2.01a	1.37b	0.76b	1.31b	3.11a	1.53a	0.19a	0.15a	8.49a	82.84b	5.71a	11.45a
NCRIBen04E	6.48a	0.52b	4.39b	1.98b	1.46a	1.46a	2.51a	3.05a	1.55a	0.20a	0.14b	8.16b	83.27a	5.74a	10.99a

fertilizers was within the satisfactory range for Sesame and Bambara production (5.5 - 7.0). Pelletized fertilizer (4.84 and 9.68 kg/plot) significantly influenced soil pH, OM, K, Ca, Mg and CEC, soil texture and water holding capacity (WHC) silt and clay properties and both rates influenced OM and N. Soil pH ranged from 5.5 - 7.0 and NPK fertilizer, CPH and Pelletized organic fertilizer significantly increased the soil organic matter content. Pelletized fertilizer at 4.84 and 9.68 kg/plot significantly influenced soil pH, OM, K, Ca, Mg and CEC. The applied fertilizers (CPH, NPK and pelletized organic fertilizer) improved physical and chemical properties of the soil. The un-manure (Control) differed significantly from fertilizer treatments for soil pH and clay contents. Organic carbon obtained increased slightly in the Cocoa pod husk (CPH) and NPK fertilizer treated soils than the un-manure. Soil organic carbon (SOC) can be increased by mixed cropping, or with the use of cover crops. The treatment involving pelletized organic fertilizer had enhanced N, OM content. Organic manures improved the soil properties, thus the use of a leguminous plant (Bambara) not only influenced the nitrogen (N), Potassium (K) and phosphate (P), but also the exchangeable cations and the soil organic carbon (SOC) content.

Uptake of N and K for sole sesame was significant under NPK application compared to the organic fertilizers, P uptake was significantly influenced by application of CPH manure and enhanced uptake of N and P for Sesame (**Table 3** and **Table 4**). Un-manured (control) plants had a significantly higher N compared to the fertilizer treated plants. Sole Sesame leaves had significantly higher chemical constituents for NPK, while N harvest index for Sesame + Bambara was significant CPH manure influenced Nitrogen Harvest index (NHI) compared to NPK and un-manure (**Table 2(a)** and **Table 2(b)**). Sesame + Bambara had higher Nitrogen harvest index (NHI) for NPK treatment NPK significantly influenced all the parameters measured except NHI which was significant for un-manure control. Sole Sesame under NPK fertilizer influenced NHI compared with Sesame + Bambara Sole Bambara leaves had higher N and K concentration compared to the Bambara + Sesame (**Table 3**). The Sesame nutrient uptake was similar in both cropping year for both varieties (E8 and NCRIBen04E) under application of 9.68 Kg pelletized fertilizer compared with 4.84 Kg pelletized fertilizer were enhanced for Sesame variety E8. Pelletized fertilizer (4.84 kg/plot) promoted uptake of N significantly compared to un-manure (**Table 4**). While 9.68 kg enhanced contents of P, K, N and K. The Sesame variety E8 was better in terms of N uptake ($P > 0.05$) compared with NCRIBen04E. Sesame variety E8 had enhanced N under application of 4.84 kg pelletized fertilizer compare to 9.68 kg in both years. The plots for which organic fertilizer at 9.68 kg was applied had higher uptake of P and K compared with un-manure (control) and 4.86 kg pelletized fertilizer.

Bambara plants had higher leaf N content in both cropping years, while the NPK fertilizer influenced P and K (**Table 5** and **Table 6**). The un-manure had higher N and P contents in leaves compared to fertilizers treatment for Sole Bambara. Bambara + Sesame had high P and K except for N contents which was

Table 3. Manuring effects on chemical and proximate composition of Sesame.

Treatments		Chemical Properties									Proximate properties					
		Na	Ca	Mg	Zn	Fe	Cu	P	N	K	Moisture (%)	Fat	Ash	Protein	Crude fiber	Carbohydrate
Fertilizer Types	Crop Types															
Unmanure	Sole Sesame	3.24b	12.17b	1.83c	0.06b	0.27a	0.05a	2.71c	3.71a	23 ^b	12.08b	9.76a	13.86a	23.1a	21.9a	19.2c
		4.25a	11.23c	1.92a	0.06b	0.23b	0.05a	4.51a	2.52c	23a	12.08b	9.27c	13.87a	21.0b	21.1c	27.9a
	NPK	3.20b	13.10a	1.88b	0.07a	0.28a	0.03b	3.45b	3.38b	23a	12.18a	9.64b	13.89a	15.6c	21.8b	21.3b
Lsd (0.05)		0.11	0.19	0.01	0.00	0.03	0.02	0.02	0.03	0.08	0.02	0.01	0.03	0.09	0.02	0.02
Unmanure	Sesame + Bambara	3.35c	12.17c	1.88b	0.07b	0.18a	0.04b	6.15a	4.71a	22a	12.17b	9.18a	13.77a	23.1a	21.9c	19.2c
Cocoa pod husk (CPH)		3.44b	24.13a	1.93a	0.14a	0.43a	0.07a	6.15a	3.26c	22a	12.18b	8.67c	13.04b	20.3c	22.4a	22.4a
	NPK	3.74a	14.20b	1.92a	0.14a	0.32a	0.06a	5.55b	3.52b	22a	12.22a	8.95b	13.77a	21.8b	22.2b	20.9b
Lsd (0.05)		0.02	0.13	0.03	0.03	0.33	0.02	0.01	0.02	0.11	0.04	0.02	0.04	0.03	0.03	0.04a
Fertilizer Types																
Unmanure		3.30c	12.17c	1.86c	0.07b	0.22a	0.05b	3.32c	4.21a	4c	12.13b	9.47a	13.81a	23.1a	21.9b	19.2c
Cocoa pod husk (CPH)		3.85a	17.68a	1.93a	0.10a	0.33a	0.06a	6.52a	2.89c	5a	12.13b	8.97c	13.46b	17.9c	21.8c	25.2a
	NPK	3.47b	13.65b	1.90b	0.11a	0.30a	0.05b	4.48b	3.45b	4b	12.20a	9.29b	13.83a	21.4b	22.0a	21.1b
Crop Types																
Cashew + Sole Sesame		3.56a	12.17b	1.88b	0.06b	0.26a	0.04b	4.09b	3.20b	3b	12.11b	9.56a	13.87a	19.9b	21.6b	22.8a
Cashew + Sesame + Bambara		3.51b	16.83a	1.91a	0.12a	0.31a	0.06a	5.46a	3.83a	5a	12.19a	8.93b	13.53b	21.7a	22.2a	20.9b

Table 4. Effect of organic fertilizer (Fert Plus) on Sesame leaf nutrient composition.

Treatments		Chemical properties									Proximate properties					
		N	P	K	Na	Ca	Mg	Zn	Fe	Cu	Moisture	Fat	Ash	Protein	Crude fiber	Carbohydrate
Fertilizer Types	Varieties															
Unmanure (Control)	E8	2.49c	14.64b	19.55b	2.33c	22.56a	2.69a	0.13b	0.92b	0.02b	12.59b	23.88b	7.87b	15.54c	11.97c	28.16a
POF (4.84 kg/plot)		4.45a	33.46a	19.86a	3.93a	22.89a	2.53b	0.18a	0.62c	0.08a	12.37c	24.75a	8.47a	27.79a	12.50b	14.12c
POF (9.68 kg/plot)		3.46b	12.37c	14.15c	2.88b	17.82b	2.47c	0.09c	1.27a	0.07a	12.96a	22.83c	8.33a	21.59b	13.08a	21.20b
Lsd (0.05)		0.05	0.05	0.05	0.05	0.59	0.04	0.02	0.04	0.04	0.04	0.04	0.16	0.30	0.03	0.41

Continued

Unmanure (Control)	NCRIBen04E	3.68b	15.10b	16.63b	2.71b	22.46a	2.94a	0.15b	0.65c	0.05b	12.77b	22.78c	9.06a	22.96b	11.77c	20.66a
POF (4.84 kg/plot)		3.48c	13.65c	15.35c	2.38c	18.72c	2.58b	0.06c	1.15a	0.06a	12.23c	23.85a	8.28c	21.70c	13.58a	20.35b
POF (9.68 kg/plot)		4.45a	18.85a	18.64a	3.40a	19.62b	2.56b	0.18a	0.85b	0.05b	12.93a	22.82b	8.48b	22.75a	12.48b	15.55c
Lsd (0.05)		0.02	0.03	0.03	0.12	0.02	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.11	0.02	0.09
Fertilizer Types																
Unmanure (Control)		3.09c	14.87c	18.09a	2.52b	22.51a	2.82a	0.14a	0.77c	0.04c	12.68b	23.33b	8.47a	19.25c	11.87c	24.41a
POF (4.84 kg/plot)		3.97a	23.56a	17.60b	3.16a	20.81b	2.56b	0.12b	0.89b	0.07a	12.30c	24.30a	8.38b	24.74a	13.04a	17.24c
POF (9.68 kg/plot)		3.95b	15.61b	16.40c	3.14a	18.72c	2.52c	0.13a	1.06a	0.06b	12.95a	22.82c	8.41ab	24.67b	12.78b	18.38b
Crop Types																
E8		3.47b	20.16a	17.85a	3.05a	21.09a	2.57b	0.13a	0.94a	0.06a	12.64a	23.82a	8.22b	21.64b	12.52b	21.16a
NCRIBen04E (Ex-Sudan)		3.87a	15.87b	16.8b	2.83b	20.27b	2.69a	0.13a	0.88b	0.05a	12.64a	23.15b	8.618a	24.14a	12.61a	18.85b

Table 5. Manuring effect on Bambara Leaf nutrient composition.

Treatments		Chemical properties									Proximate properties					
		Na	Ca	Mg	Zn	Fe	Cu	P	N	K	Moisture	Fat	Ash	protein	Crude fiber	Carbohydrate
Fertilizer Types	Crop Types															
Unmanure	Sole Bambara	3.85a	35.33b	1.94a	0.08a	0.24b	0.03b	2.82c	3.19a	39.09c	9.44b	8.88a	15.98b	19.88a	31.08b	14.73c
Cocoa pod husk (CPH)		3.63a	23.70c	1.92b	0.09a	0.24b	0.07a	3.38b	2.25c	48.30a	9.95a	8.58b	15.87b	14.02c	29.87c	21.71a
N.P.K		3.67	64.50a	1.87c	0.07a	0.28a	0.06a	4.62a	2.58b	40.57b	9.04c	8.57b	16.16a	16.10b	31.54a	18.59b
Lsd (0.05)		0.31	0.18	0.02	0.03	0.02	0.03	0.02	0.04	0.35	0.03	0.03	0.05	0.25	0.03	0.26
Unmanure	Bambara + Sesame	4.40a	20.42c	1.89a	0.07a	0.35a	0.03b	2.18c	2.86c	36.47a	8.87b	8.83b	15.67b	17.85c	30.78b	17.99a
Cocoa pod husks (CPH)		3.92b	40.14b	1.88b	0.09a	0.28b	0.05ab	5.28a	3.28c	30.57b	8.75c	8.75b	16.30a	20.45b	31.18a	14.57b
N.P.K		4.50a	83.50a	1.88b	0.09a	0.27b	0.07a	4.38b	3.39a	22.56c	9.74a	8.88a	15.89b	21.13a	30.07c	14.28b
Lsd (0.05)		0.22	0.10	0.01	0.02	0.03	0.02	0.01	0.08	0.38	0.03	0.05	0.25	0.51	0.01	0.78
Fertilizer Types																

Continued

Unmanure	4.13a	27.88c	1.92a	0.08a	0.29a	0.03b	2.78c	3.02a	37.77b	9.16c	8.86a	15.83b	18.87a	30.93a	16.36b
Cocoa pod husk (CPH)	3.78b	31.92b	1.90b	0.09a	0.26c	0.06a	4.95a	2.76c	39.43a	9.35b	8.67c	16.09a	17.23c	30.53c	18.14a
N.P.K	4.09a	74.00a	1.88c	0.08a	0.28b	0.06a	3.60b	2.98b	31.56c	9.39a	8.73b	16.02a	18.62b	30.81b	16.44b
Crop Types															
Cashew + Sole Bambara	3.44b	40.84b	1.90a	0.08a	0.23b	0.03a	3.56b	2.66b	42.44a	8.97b	7.52a	15.15b	17.98b	35.40a	14.99a
Cashew + Bambara + Sesame	4.01a	47.83a	1.86 b	0.09a	0.27a	0.04a	3.93a	3.14a	29.61b	9.29a	7.43b	15.18a	19.22a	34.00a	14.88a

Means with the same letters along each column are not significantly different using Lsd at 0.05 level of probability.

Table 6. Effects of organic fertilizer on Bambara Leaf nutrient composition.

Treatments		Chemical properties (%)									Proximate properties (%)					
		N	P	K	Na	Ca	Mg	Zn	Fe	Cu	Moisture	Fat	Ash	Protein	Crude fiber	Carbohydrate
Fertilizer Types	Crop Types															
Unmanure	TVSu1166	2.24c	9.44c	64.20b	4.41c	30.91a	3.38c	0.061b	0.21c	0.02b	8.72a	5.58c	3.62c	14.00c	10.73a	57.52a
	Pf (4.84 kg/plot)	2.74b	10.36b	61.50c	4.92b	28.52c	3.44b	0.62b	0.33b	0.05a	8.33b	5.73b	3.92a	17.10b	10.63b	54.35b
	Pf (9.68 kg/plot)	3.12a	11.10a	73.51a	6.08a	30.07b	3.65a	0.66a	0.36a	0.05a	8.31b	5.78a	3.83b	19.47a	8.98c	53.67c
Unmanure	TVSu999	1.52c	8.86c	65.27c	4.40c	29.52c	3.39b	0.67a	0.44b	0.07a	9.56a	5.33b	3.76a	9.49c	9.85a	61.63a
	Pf (4.84 kg/plot)	2.67b	21.81a	104.10a	5.51b	53.81a	4.20a	0.38b	0.45a	0.04b	8.55c	5.77a	3.57b	16.66b	8.83c	54.75b
	Pf (9.68 kg/plot)	3.37a	11.73b	80.67b	6.13a	31.61b	3.38b	0.37b	0.45a	0.08a	8.97b	5.65a	3.56b	21.05a	9.75b	51.06c
Fertilizer Types																
Unmanure		1.88c	9.15c	64.73c	4.41c	30.22c	3.39c	0.64a	0.33c	0.04b	9.14a	5.45b	3.69b	11.74c	10.29a	59.58a
	Pf (4.84 kg/plot)	2.71b	16.09a	82.80a	5.21b	41.17a	3.82a	0.50b	0.39b	0.05b	8.44c	5.75a	3.75a	16.88b	9.74b	54.55b
	Pf (9.68 kg/plot)	3.25a	11.42b	77.09b	6.11c	30.84b	3.52b	0.52b	0.41a	0.07a	8.64b	5.72a	3.70b	20.26a	9.36c	52.37c
Crop Types																
TVSu1166		2.70a	10.30b	66.40b	5.14b	29.84b	3.49b	0.63a	0.30b	0.04b	8.46b	5.69a	3.79a	16.85a	10.11a	55.18b
TVSu999		2.52b	14.13a	83.34a	5.35a	38.31a	3.66a	0.47b	0.45a	0.06a	9.03a	5.59b	3.63b	15.73b	9.480b	55.82a

Means with the same letters along each column are not significantly different using Lsd at 0.05 level of probability.

significant for the un-manure (control) and CPH treatment P and K uptake were enhanced NPK fertilizer. Sole Bambara leaves had higher N and K contents compare to the Bambara planted with Sesame. The Bambara variety TVSu1166 had significantly higher contents of P, fat, crude fiber and carbohydrate and was significant in the un-manure plot. Application of 4.84 kg pelletized fertilizer enhanced N, Na, Ca, Fe, Cu, Ash and protein content, while 9.68 kg pelletized fertilizer significantly influence K, Mg, Zn and moisture content in the Bambara nut. Bambara variety TVSu1166 had higher K up-take and Nitrogen harvest index (NHI), which were significantly different from 9.68 kg pelletized fertilizer. Bambara variety Tvsu999 was significant in Nitrogen (N), Phosphorus (P), and Potassium (K) with 4.84 Kg pelletized fertilizer treatment apart from the NHI (Table 6).

Application of NPK fertilizer significantly influenced most of the nutrient use efficiency parameters measured. Agronomy Efficiency (AE), Apparent recovery Efficiency (RE), Apparent recovery Efficiency by difference (RE%), Physiological Efficiency (PE), Utilization Efficiency (UE), Internal utilization Efficiency (IE) and Partial Fertilizer productivity (PFP) were significantly high in the intercrops, apart from the N removed during harvest in Sole Sesame (Table 7 and Table 8). Similar trends were observed in the Sesame + Bambara plots, apart for Internal Utilization Efficiency which was higher in the un-manure (control)

Table 7. Manuring effects on agronomic and physiological efficiencies of N use by Sesame.

Treatments		Agronomy Efficiency—(AE) Kg	Apparent Recovery Efficiency (RE)	Apparent Recovery Efficiency By Difference	Physiological Efficiency (PE)	Utilization Efficiency (UE)	N removed @harvest	Internal Utilization Efficiency (IE)	Partial-Fertilizer Productivity of Fertilizer N (PFP _N)
Fertilizer Types	Crop Types								
Unmanure		0.00b	0.00b	0.00b	0.00c	0.00b	0.00a	0.01c	0.00c
Cocoa pod husk	Sole Sesame	0.00b	0.07b	0.07b	0.01b	0.00b	0.01a	0.01b	0.01b
NPK		0.01a	0.53a	1.09a	0.02a	0.01a	0.01a	0.01a	0.021a
Unmanure		0.00b	0.00c	0.00b	0.00b	0.00b	0.00c	0.01a	0.00c
Cocoa pod husk	Sesame + Bambara	0.00b	0.04b	0.03b	0.01a	0.00	0.01b	0.01ab	0.01b
NPK		0.01a	0.29a	0.19a	0.01a	0.01a	0.02a	0.01b	0.02a
Fertilizer Types									
Unmanure		0.00c	0.00c	0.00c	0.00c	0.00c	0.00c	35.43b	0.00c
Cocoa pod husk		4.35b	0.05b	20.59b	0.01b	4.54b	-47.33b	50.84a	23.02b
NPK		53.44a	0.64a	52.89a	0.01a	53.44a	-55.50a	50.92a	140.44a
Crop Types									
Sole Sesame		10.48b	0.38a	13.55b	0.01a	10.48b	16.78b	49.90a	53.61b
Sesame + Bambara		28.04a	0.07b	35.44a	0.01b	28.17a	22.22a	41.57b	55.361a
Fertilizer Types		1.19	0.05	0.26	0.01	1.19	0.83	1.74	0.78
Crop Types		1.59	0.02	0.25	0.01	1.59	0.36	1.26	0.74

Table 8. Effects of organic fertilizer on agronomic and physiological efficiencies of N use by Sesame.

Treatments		Agronomy Efficiency (AE)	Recovery Efficiency (RE)	Recovery Efficiency by Difference (RE)	Physiology Efficiency (PE)	Utilization Efficiency (UE)	N Remove with Harvest	Internal Utilization Efficiency (IE)	Partial Factor Productivity (PFP)		
Fertilizer Types	Crop Types										
Unmanure		0.00c	0.00c	0.00c	0.00c	0.00c	0.00b	1.22c	0.00c		
Pf (4.84 kg/plot)	E8	11.84a	3.91a	391.07a	19.78a	234.19a	0.78a	2.86a	1.27b		
Pf (9.68 kg/plot)		7.41b	3.58b	357.94b	6.24b	46.40b	1.32a	1.93b	1.73a		
Unmanure		0.00c	0.00b	0.00b	0.00a	0.00a	0.00c	1.28c	0.00c		
Pf (4.84 kg/plot)	NCRIBen04E (Ex-Sudan)	7.44b	3.35a	334.80a	22.88a	170.1a	0.75b	2.03b	1.74a		
Pf (9.68 kg/plot)		15.52a	3.39a	339.30a	14.93a	236.1a	1.18a	4.25a	1.65b		
Fertilizer Types											
Un manure		0.00c	0.00c	0.00c	0.00a	0.0a	0.00b	1.25c	0.00c		
Pf (4.84 kg/plot)		7.42b	3.46b	346.37b	14.56a	108.2a	1.03a	1.98b	1.73a		
Pf (9.68 kg/plot)		13.67a	3.65a	365.19a	17.36a	235.1a	0.98a	3.56a	1.46b		
Crop Types											
E8		6.43b	2.42a	241.96a	14.22a	134.8a	0.51b	2.03b	1.00b		
NCRIBen04E		7.64a	2.32a	232.42a	7.06a	94.2a	0.83a	2.49a	1.12a		
Treatments		Agronomic Efficiency (AE)	Agronomic N use Efficiency (ANUE)	Apparent Recovery Efficiency (RE)	Apparent Recovery Efficiency by Difference%	Physiology Efficiency (PE)	Fertilizer Use Efficiency (FAE)	N Removed @ harvest	Internal Utilization Efficiency (IE)	Utilization Efficiency (EU)	Partial Factor Production (PFP)
Fertilizer Types	Crop Types										
Unmanure	Sole Bambara	0.00b	0.00b	0.00c	0.00c	0.00b	0.00b	0.00a	304.80b	0.00b	0.00c
Cocoa pod husk		3.19b	3.19b	318.7b	19.40a	0.02b	0.71b	-1.68b	535.73a	318.7b	9.33b
NPK		12.55a	12.55a	1254.5a	11.10b	1.06a	3.01a	-2.07c	540.23a	1254.5a	38.84a
Unmanure	Bambara + Sesame	0.00a	0.00a	0.00a	0.00c	0.00b	0.00b	0.00a	105.48b	0.00a	0.00c
Cocoa pod husk		4.52a	4.52a	451.6a	14.64a	0.09b	1.42a	-2.76c	218.38a	90.32a	13.32b
NPK		0.79a	0.79a	78.7a	4.02b	0.29a	0.30b	-0.49b	113.30b	15.75a	38.52a
Fertilizer Types											
Unmanure		0.00b	0.00b	0.00b	0.00c	0.00b	0.00c	0.00a	205.14c	0.00b	0.00c
Cocoa pod husk		3.85ab	3.85ab	385.1ab	17.03a	0.056b	1.06a	-2.22c	377.06a	204.5b	11.324b
NPK		6.67a	6.67a	666.6a	7.56b	0.24b	1.66a	-1.28b	326.76b	635.1a	38.68a
Crop Types											
Sole Bambara		5.24a	5.24a	524.4a	10.17	0.36a	1.24a	-1.25b	460.25a	524.4a	16.06a
Bambara + Sesame		1.77b	1.77a	176.8a	6.22	0.13b	1.24b	-1.08a	145.72b	35.4b	17.28a
Fertilizer Types		2.37	2.37	236.70	0.53	0.03	0.38	0.05	12.16	130.18	0.19
Crop Types		2.15	2.15	215.10	0.57	0.07	0.43	0.07	35.99	172.49	0.58

plants. Fertilizer type affected nutrient use efficiency parameters measured. NPK fertilizer promoted these parameters compared to CPH and un-manure plots. Sole Sesame plants had significantly higher RE, PE, UE PFP while Sesame + Bambara significant improved AE, RE, UE, N-removed at harvest PFP comparable to the sole Sesame plants. However, in 2014 no significant differences amongst the parameter measured, apart from PFP for sole Sesame plants. The combination of Sesame + Bambara with NPK fertilizer had significantly higher AE, RE, UE, N-removed at harvest and PFP. NPK fertilizer treatment plants had a significantly higher value of compared to CPH manure and the un-manure plants. Sole Sesame significantly influence agronomy efficiency (AE), utilization efficiency (UE), internal efficiency (IE) and partial factor productivity (PFP). Sole Bambara under N.P.K fertilizer had higher N-removed at harvest and apparent recovery by difference (RE%). Bambara + Sesame under cocoa pod husk (CPH) manure had enhanced apparent recovery efficiency by difference (RE%), fertilizer use efficiency (FAE) and internal utilization efficiency (IE). NPK fertilizer enhanced Physiology efficiency (PE) and Partial factor productivity. Fertilizer type affected significantly AE, agronomic N-use efficiency (ANUE), RE, UE and PFP for 2013. CPH manure treatment significantly influence RE%, PE and IE. The N-remove at harvest was significantly higher in the un-manure plants (control). Sole Bambara significantly influenced AE, RE%, PE, FAE, IE and UE. Bambara + Sesame had significantly enhanced N (removed at harvest). Application of fertilizers for 2014 experimental year, significantly improved AE and RE, however CPH manure treatment influenced ANUE, RE%, FAE, UE and PEP significantly. Crop type affected AE, ANUE, RE, RE%, UE, sole Bambara had higher values of most of the parameters measured compared to mixtures of Bambara + sesame. Physiology efficiency (PE), and fertilizer use efficiency (FAE) was significantly different to Bambara + Sesame plants (**Table 7** and **Table 8**). Bambara variety TVSu1166, that was treated with 9.68 kg/plot pelletized fertilizer had significantly higher Apparent Recovery Efficiency by difference (RE%) and Partial Factor Productive (PFP), while 4.84 kg pelletized fertilizer affected Physiology Efficiency (PE). Bambara variety TVSu999 under 4.84 kg pelletized fertilizer had higher Agronomy Efficiency (AE), Apparent Recovery Efficiency (RE), Physiology Efficiency (PE) and Fertilizer Agronomy use Efficiency respectively (FAE). Application of 9.68 kg pelletized fertilizer significantly enhanced RE%, IE and PFP AE, RE%, FAE and EU experiment (**Table 9** and **Table 10**). Application of 4.84 kg pelletized fertilizer influenced AE, RE%, PE, FAE, EU, and PFP for 2014 experiment. Bambara variety TVSu1166 had significantly higher AE, RE%, PE, FAE and EU, while TVSu999 variety influenced RE. Bambara variety TVSu1166 under application of 4.84 kg pelletized fertilizer enhanced IE, while 9.68 kg improved AE, RE, PE, FAE and EU respectively. Fertilizer effect type shows that 4.84 kg pelletized fertilizer influenced PFP, while 9.68 kg AE, RE%, FAE and EU respectively. Bambara variety TVSu999 compared to TVSu1166 had higher IUE (**Table 9**). Application of 4.84 kg organic fertilizer had higher values of most of the parameters measured expect for partial factor

Table 9. Effects of organic fertilizer on agronomic and physiological efficiencies of N use by Bambara nut.

Treatments		Agronomic Efficiency (AE)	Apparent Recovery Efficiency (RE)	Apparent Recovery Efficiency by Difference	Physiology Efficiency (PE)	Fertilizer Use Efficiency (FAE)	Internal Utilization Efficiency (IE)	Utilization Efficiency (EU)	Partial Factor Production (PFP)
Fertilizer Types	Crop Types								
Unmanure	TVSu1166	0.00a	0.00a	0.00c	0.00b	0.00a	0.64a	0.00b	0.00c
Pf (4.84 kg/plot)		0.10a	9.70a	0.09b	1.06a	0.10a	0.68a	10.37a	0.72b
Pf (9.68 kg/plot)		0.07a	6.93a	0.50a	0.14b	0.01a	0.67a	1.92b	1.54a
Un manure	TVSu999	0.00b	0.00b	0.00c	0.00b	0.00b	0.46c	0.00a	0.00c
Pf (4.84 kg/plot)		0.25a	25.25a	0.27b	0.92a	0.25a	0.68b	0.67a	0.81b
Pf (9.68 kg/plot)		0.07b	7.36b	0.86a	0.09b	0.07b	0.83a	25.63a	1.51a
Fertilizer Types									
Un manure		0.00c	0.00c	0.00c	0.00b	0.00c	0.57c	0.00b	0.00c
Pf (4.84 kg/plot)		0.16a	0.39b	16.09a	0.53a	0.16a	0.67b	13.77a	1.52a
Pf (9.68 kg/plot)		0.09b	0.48a	8.53b	0.57a	0.09b	0.74a	5.52ab	0.77b
Crop Types									
TVSu1166		0.12a	0.12b	11.65a	0.66a	0.12a	0.67a	11.99a	0.74a
TVSu999		0.05b	0.45a	4.76b	0.08b	0.05b	0.65a	0.86b	0.78a

Table 10. Manuring effect on Bambara agronomic and physiological efficiency of N use.

Treatments		Agronomic Efficiency (AE)	Agronomic N Use Efficiency (ANUE)	Apparent Recovery Efficiency (RE)	Apparent Recovery Efficiency by Difference %	Physiology Efficiency (PE)	Fertilizer Use Efficiency (FAE)	N Removed @ harvest	Internal Utilization Efficiency (IE)	Utilization Efficiency (EU)	Partial Factor Production (PFP)
Fertilizer Types	Crop Types										
Un-manure	Sole Bambara	0.00b	0.00b	0.00c	0.00c	0.00b	0.00b	0.00a	304.80b	0.00b	0.00c
Cocoa pod husk (CPH)		3.19b	3.19b	318.7b	19.40a	0.02b	0.71b	-1.68b	535.73a	318.7b	9.33b
N.P.K		12.55a	12.55a	1254.5a	11.10b	1.06a	3.01a	-2.07c	540.23a	1254.5a	38.84a
Lsd (0.05)		6.67	6.67	6.67	2.01	0.36	1.01	0.19	123.29	666.64	3.25
Un-manure	Bambara + Sesame	0.00a	0.00a	0.00a	0.00c	0.00b	0.00b	0.00a	105.48b	0.00a	0.00c
Cocoa pod husk (CPH)		4.52a	4.52a	451.6a	14.64a	0.09b	1.42a	-2.76c	218.38a	90.32a	13.32b
N.P.K		0.79a	0.79a	78.7a	4.02b	0.29a	0.30b	-0.49b	113.30b	15.75a	38.52a
Lsd (0.05)		13.67	13.67	1367.2	2.17	0.15	1.08	0.16	40.80	273.43	6.19
Fertilizer Types											
Un-manure		0.00b	0.00b	0.00b	0.00c	0.00b	0.00c	0.00a	205.14c	0.00b	0.00c

Continued

Cocoa pod husk (CPH)	3.85ab	3.85ab	385.1ab	17.03a	0.056b	1.06a	-2.22c	377.06a	204.5b	11.324b
N.P.K	6.67a	6.67a	666.6a	7.56b	0.24b	1.66a	-1.28b	326.76b	635.1a	38.68a
Crop Types										
Sole Bambara	5.24a	5.24a	524.4a	10.17	0.36a	1.24a	-1.25b	460.25a	524.4a	16.06a
Bambara + Sesame	1.77b	1.77a	176.8a	6.22	0.13b	1.24b	-1.08a	145.72b	35.4b	17.28a
Fertilizer Types	2.37	2.37	236.70	0.53	0.03	0.38	0.05	12.16	130.18	0.19
Crop Types	2.15	2.15	215.10	0.57	0.07	0.43	0.07	35.99	172.49	0.58

productivity (PFP) which were significant with 9.68 kg fertilizer treatments. Sesame variety (NCRIBen04E) and Bambara nut variety (TVSu1166) had enhanced Agronomy Efficiency (AE), N-removed at harvest and Internal Utilization Efficiency (IE) which was significantly enhanced by 9.68 kg pelletized fertilizer treatment. The influence of fertilizer type pronounced on the resource use efficiencies parameters measured in this study. The 4.84 kg treatment had higher partial factor productivity (PFP). Sesame variety E8 and Bambara nut variety (TVS U399) had higher N-removed at harvest at 9.68 kg/plot organic fertilizer. For both Sesame and Bambara nut varieties, 9.68 kg/plot enhanced most of the indicators of N use efficiency compared to the un-manure (control) and 4.84 kg fertilizer. Agronomy Efficiency (AE), Apparent Recovery Efficiency by difference (RE%), Physiology Efficiency (PE), Utilization Efficiency (UE), N-removed at harvest and Internal Utilization Efficiency (IE) had significantly higher values for 9.68 kg/plot compared to 4.84 kg/plot (**Table 10**). Sesame variety NCRIBen04E and Bambara nut (TVS U1166) were significantly different from E8 and TVS U399 varieties for AE, N-remove at harvest, IE and PFP. The earlier varieties had enhanced apparent Recovery Efficiency (RE), Apparent Recovery Efficiency by difference (RE%), Physiology Efficiency (PE), Utilization Efficiency (UE), and Internal Utilization Efficient (IE) when compared to NCRIBen 048.

The measured parameters of agronomic and physiological efficiencies, nutrient up-take and use for sole and intercrops of Sesame and Bambara were affected by manure application. NPK fertilizer significantly improved Sesame and Bambara nuts both as sole and intercrop in terms of Agronomic efficiency (AE), Agronomic N use efficiency (ANUE), apparent recovery efficiency (RE), Physiology efficiency (PE), fertilizer use efficiency (FUE), internal efficiency (IE), utilization efficiency (UE) and partial factor productivity (PFP). Alizadeh *et al.* [22] attributed high yield performance to improvements in efficient of resource use of bean monoculture compared to intercropping treatments. Nutrient P is reported to decrease species competition place on nutrient resources [8] (Agele *et al.*, 2011). The results obtained for nutrient use efficiency showed that application of CPH manure and NPK fertilizer affected all nutrient use efficiency para-

meters measured for sole Bambara apart from the N-removed at harvest which was not affected. In our study AE values was less than 1, however it has been reported that AE values may be lower than 5 since it is dependent upon soil, crop, nutrient rate of absorption and losses. Low AE indicate that N was not fully utilized or limiting nutrient absorption. Results showed that AE values were greater than 5. Similar results was obtained by Mengel *et al.* [23] which was attributed to nitrogen fixing ability of legumes

Results showed that Agronomy efficiency (AE), Recovery efficiency (RE), Recovery efficiency by difference (RE%) and Utilization efficiency (UE) were higher in values for Sesame (NCRIBen04E, Ex-Sudan) under 9.68 kg pelletized fertilized treatments is an indication of high yield productivity. The Physiology efficiency (PE) and partial factor productivity (PFP) were significantly influence by 4.84 kg pelletized fertilizer. The results were consistent with those obtained by [5] [24] that soil nutrient availability increased and enhanced crop yields and NUE by fertilizer rates. The author concluded that differences in soil nutrient status are a major source of variation in yield and nutrient uptake and subsequently nutrient utilization efficiency of oil seed crops. Application of 9.68 kg POF produced highest nutrient N-use efficiency values (REF). However, E8 Sesame variety shows differences in variation for resources use efficiency. While 4.84 kg/plot POF increased internal use efficiency (IE), 9.68 kg enhanced PFP. According to Thobatsi [24], intercrops which differ in rooting and nutrient uptake patterns result in efficient use of nutrients, especially nitrogen uptake. In this study Sesame nutrient uptake response to N.P.K fertilizer is improved. The result also show that the application of Cocoa pod husk (CPH) manure and NPK fertilizer to the Cashew soil with Sesame intercropped, alternatively with Bambara affected nutrient up-take of leaves and seed, thus increased proper utilization of the nutrient available from the soil. The greatest mean values were obtained in the intercrop of Sesame plant alongside with Bambara crops. Agele *et al.* [5] [8] (2008, 2011) improved NUE for crops under application of organic and inorganic fertrtilizers. The result of the un-manure treated Sole sesame plants shows that N and P nutrient composition was significantly influence in seed production. This behavior could be attributed to nutritional balance in the soil. The results contradict the findings of Havlin *et al.* [25] who reported that P absorption is greater in soils with little P adsorbed to mineral surfaces. The highest nitrogen harvest index values for seed and leaf of Sesame plants were obtained from the un-manure treated plants. The superiority of these may be attributed to more vigorous nutrient exploitation advantage or to the legume effect from Bambara plants. Agele *et al.* [8] observed that without the applications of fertilizers, yield and NHI responses will be small. In this study the use of CPH manure, NPK fertilizer and the control (Un-manure) treatments enhanced Bambara leaf and seed nutrient composition. This could be attributed to differences in nutrient inputs by the fertilizers, differences in nutrient demand by the crops, one being a nitrogen fixing plants. It is reported that nutrient availability depended on nutrient concentration in the soil and environment and release

pattern in synchrony with the crop needs [26]. The highest leaf N up-take values were obtained for the un-manure. Sole Bambara plant, while NPK treated plants recorded the highest P and K leaves uptake. This indicates that physiologically, nutrients uptake depends on water availability in the soil and ease of nutrient release [27]. The Nitrogen harvest index of TVSu1199 Bambara variety was higher under the application of 9.68 kg pelletizer treatment compare to TVSu999 Bambara variety. This result was in line to the conclusion of Agele *et al.* [8] that the crop yields and nutrient availability were higher in plots farmyard manure (FYM), thereby increased yields and enhancing soil nutrients.

4. Conclusion

The initial soil analysis showed that the soils under Cashew were deficient in N, P, K, Ca, Mg and Zn. However, deficiency of N and P was most serious. The fertilizers, NPK fertilizer, CPH and Pelletized organic improved soil fertility. Growth and development variables of Sesame and Bambara nut varieties differed significantly for sole and intercrop combinations. Following manure application, significant increases in soil organic matter were observed in soil after harvest of Bambara and Sesame. Application of NPK, CPH and Pelletized organic fertilizer enhanced the vigour of Bambara and Sesame. Moreover, NPK, CPH and Pelletized organic fertilizer enhanced number of pods and seeds per plant, and dry matter yield.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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