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ASSESSMENT OF MACRONUTRIENTS OF THREE SELECTED LEGUMINOUS SHRUBS IN FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA

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ABSTRACT

Recycling of nutrients through pruning of leguminous shrubs has been noted to improve soil fertility by adding nitrogen (N) through N_2 fixation and other nutrients. The study assessed the macronutrients of selected leguminous shrubs at the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria. The leafy biomass pruned includes: *Cajanus cajan* (*CC*)*, Jatropha carcus (JC),* and *Piliostigma thonningii (PT)* which were from three plants at different locations within FUNAAB, and each specie was pooled together to make a composite sample, and replicated four times to make a total of twelve samples. These harvested leaves of shrubs were allowed to air-dry at room temperature until they were well dried, then ground, sieved through a 2 mm sieve of 20 cm×20 cm dimensions, and ready for laboratory analysis.Data were analyzed using One Way Analysis of Varianceat p = .05. *P. thonningii* had high nitrogen (20.20 g kg^{-1}), and lower in carbon-to-nitrogen ratio (0.25 g kg^{-1}), lignin-to-nitrogen ratio (7.19 g kg^{-1}), polyphenol-to-nitrogen ratio (1.47 g kg^{-1}), lignin-to- polyphenol ratio (4.13 g kg^{-1}). Furthermore, *PT* was also high in potassium (2914.53 C mol. kg^{-1}) and sulphur (38.10 C mol. kg^{-1}). However, *CC* had lower leafy biomass content in L (139.10 g kg^{-1}), lignin plus polyphenol-to-nitrogen ratio (143.98 g kg^{-1}), acid detergent fibre (326.30 g kg^{-1}) and cellulose (175.40 g kg^{-1}). However, *CC* had high concentration of calcium (381.11 C mol. kg^{-1}). Meanwhile, *JC* had lower content of PP (29.64 g kg^{-1}), and high content of phosphorus (178.40 C mol. kg^{-1}), sodium (56.11 C mol. kg^{-1}) and magnesium (384.48 C mol. kg^{-1}) respectively. It is concluded that the selected shrub species, and most importantly *PT,* have the capacity to improve soil fertility and enhance nutrient cycling in agroforestry systems, and is recommended as organic material for soil improvement strategies.

Keywords: Macro nutrients, nitrogen-fixing, shrub species, soil fertility, plant yield

Introduction

Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S) are the six major nutrients necessary for plant growth. These nutrients are further divided into primary (N, P, and K) and secondary (Ca, Mg, and S) categories based on the relative amounts that plants require. Major nutrients are the nutrients that are fundamentally used by plants in large quantities(Toor *et al.,* 2021). However, each one of these plant nutrients serves a distinctive purpose in plant growth and development (Batabyal *et al.,* 2014). It is important to note

that a deficiency in any of these vital nutrients in the soil may hamper plant growth to its full potential.

However, leguminous or nitrogen-fixing trees or shrubs are especially valuable for improving soil fertility in resource-limited farming systems. These species capture atmospheric nitrogen and convert it into a form that plants can absorb, reducing the reliance on synthetic fertilizers (Reid *et al.,* 2024). This is particularly important in developing countries, where farmers often cannot afford expensive chemical inputs. As a result, the ability of shrubs to enhance soil nutrient levels directly contributes to increased crop yields and soil health. This function becomes even more significant in agroforestry systems, where soil degradation due to overexploitation is a common challenge (Akter *et al.,* 2022). According to Adewale and Hassan (2023), integrating nitrogen-fixing shrubs into agroforestry systems improves nutrient cycling, enhances soil organic matter, and supports long-term agricultural productivity.

Moreover, these shrub species provide high-quality fodder for livestock, particularly in regions where conventional pasture grasses may not grow well. The macro nutritional assessment of these shrubs, including their protein, carbohydrate, and fat content, is crucial for determining their value in such systems. The macronutrient composition, including proteins, carbohydrates, and fats, is influenced by several factors, including the species itself, environmental conditions, and management practices (Hussain *et al.,* 2011).

Understanding these variations is important for developing best practices in agroforestry management. Smith *et al.* (2022) argued that while the focus has traditionally been on the environmental benefits of agroforestry, more attention should be paid to the nutritional aspects, as these are equally crucial for the long-term sustainability of the system. Researchers have highlighted that identifying species with high nutritional content can improve the overall efficiency of agroforestry practices, making them more viable for smallholder farmers (Williams, 2021). Recent studies have underscored the need to assess the macronutrient content of a wide variety of agroforestry species to better understand their potential contribution to both human and animal diets (Jung and Vendrametto, 2025).

The use of agroforestry shrubs is particularly relevant in the context of climate change, as these species often exhibit resilience to drought and poor soil conditions (Sharma *et al.,* 2016). Their ability to thrive in degraded landscapes makes them an ideal choice for regions facing the dual challenges of food insecurity and environmental degradation. The use of agroforestry shrub species, which fix nutrients such as nitrogen, phosphorus, and potassium, can at least alleviate some of the problems of declining soil fertility and complement efforts to improve soil for better crop yields (Oyebamiji *et al.,* 2017).

Materials and Methods

Study area

The leaf samples were harvested from the Federal University of Agriculture, Abeokuta (FUNAAB). The geographical coordinates of the study site are between latitude 7°15'N and 7°30'N and longitude 3°20'E and 3°35'E, at an elevation of approximately 150 m above sea level.Its overall land area is 10,000 hectares. July and September are the first and second peaks of this region's bimodal rainfall trend, respectively. There are separate dry and rainy seasons in the area, and the mean annual

rainfall is moderate at about 1290 mm. The dry season lasts from November until March. The dry season begins in March, and the wet season lasts from late March until November. The average annual number of wet days is between 260 and 290. The average monthly temperature is 35.80 °C, while the mean daily relative humidity is about 82.54% (Aiboni, 2001).

Collection of plant species and analytical procedures

The leaves of shrubs (*Cajanus cajan, Jatropha curcas,* and *Piliostigmathonningii*) were harvested from three plants at different locations within FUNAAB, and each species was pooled together to make a composite sample. These harvested leaves of shrubs were allowed to air-dry at room temperature until they were well dried, then ground, sieved through a 2 mm sieve, and ready for laboratory analysis on primary and secondary nutrients. Subsequently, a digestion flask containing 2.0 g of each sample from the chosen species was cleaned using distilled water. The samples were mixed with 10 millilitres of 4% perchloric acid ($HCLO_4$) under a fume cupboard. The mixture was thoroughly heated beneath the $HCLO_4$ fume cupboard on the digesting block. After letting the contents cool, 50 millilitres of distilled water was added. The mixture was added to a 100 ml Pyrex volumetric flask. The solution was labelled for analysis and kept in a plastic bottle. Laboratory analysis was performed on the digested plant sample solutions to determine the total amounts of nitrogen, phosphorus, and potassium (primary nutrients) and magnesium, calcium, sodium, and sulphur (secondary nutrients).

Plant tissue analysis of the selected shrubs and data analysis

Total N was analyzed by Macro-Kjeldahl digestion, followed by distillation and titration (Anderson and Ingram, 1993; Brandstreet, 1965). Lignin was determined using the Acid Detergent Fibre (ADF) method as outlined by Anderson and Ingram (1993). The polyphenol was extracted in hot (80 °C) 50% aqueous methanol and determined calorimetrically with tannic acid as a standard measurement (Hagerman, 1988; Anderson and Ingram, 1993). All data were performed using the Statistical Analysis System (SAS, 2015). The data were subjected to one way analysis of variance (ANOVA) using the generalized linear models (GLM) approach. Duncan's Multiple Range Test($p<0.05$) (Duncan, 1955) was used to separate means that were significantly different among treatments.

Results

The composition of a few biomass samples from the agroforestry shrub species

P. thonningii was observed to have significantly ($p<0.05$) higher value (20.20 g kg^{-1}) and significant lower values (0.25 g kg^{-1}, 7.19 g kg^{-1}, 1.47 g kg^{-1} and 4.13 g kg^{-1}) in carbon to nitrogen ratio (C: N) lignin to nitrogen ratio (L: N), polyphenol to nitrogen ratio (PP: N) and lignin to polyphenol ratio (L: PP) respectively. However, *C. cajan* had significantly lower values (139.10 g kg^{-1}, 143.98 g kg^{-1}, 314.50 g kg^{-1}, and 175.40 g kg^{-1}) in lignin (L), lignin plus polyphenol to nitrogen ratio (L+PP: N), acid detergent fibre (ADF), and cellulose. Meanwhile, *C. cajan* had a significantly higher organic carbon content (6.28 g kg^{-1}) than the others. *J. carcus* had a significantly lower value (29.64 g kg^{-1}) in polyphenol among others (Table 1).

Nutrient concentration in the selected leafy biomass

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P. thonningii had significantly higher values (20.20 g kg^{-1}, 2914.53 C mol kg^{-1}, and 38.10 C mol kg^{-1}) in nitrogen (N), potassium (K), and sulphur (S). However, *J. carcus* showed significantly higher values (178.40 mg kg^{-1}, 56.11 C mol kg^{-1}, and 384.48 C mol kg^{-1}) for phosphorus (P), sodium (Na), and magnesium (Mg). *C. cajan* also had significantly higher value (381.11 C mol kg^{-1} in calcium (Ca), among others (Table 2).

Correlation coefficient of nutrients of the selected leafy biomass

Calcium and nitrogen, magnesium and nitrogen, sulphur and phosphorus, and magnesium and potassium, cation exchange capacity and magnesium, and sulphur and magnesium (-0.257 C mol kg^{-1}, -0.242 C mol kg^{-1}, -0.518 C mol kg^{-1}, and -0.704 C mol kg^{-1}, -0.704 C mol kg^{-1}, and -0.425 C mol kg^{-1}) had significantly negative correlation on one another at ($p<0.05$). Moreover, sulphur and potassium, calcium and potassium, magnesium and sodium, and cation exchange capacity and calcium had significant positive correlation (0.942 C mol kg^{-1}, 0.274 C mol kg^{-1}, and 0.506 C mol kg^{-1}) with one another at $p<0.05$. Furthermore, phosphorus and nitrogen, sodium and nitrogen, potassium and phosphorus, cation exchange capacity and phosphorus, calcium and phosphorus, sodium and potassium, sulphur and sodium, cation exchange capacity and sodium, magnesium and calcium, and sulphur and cation exchange capacity (-0.342 mg kg^{-1}, -0.954 C mol kg^{-1}, -0.775 C mol kg^{-1}, -0.775 C mol kg^{-1}, -0.820 C mol kg^{-1}, -0.965 C mol kg^{-1}, -0.991 C mol kg^{-1}, and -0.965 C mol kg^{-1}, -0.876 C mol kg^{-1}, and -0.942 C mol kg^{-1}) had significant negative correlation among one another at $p<0.01$ respectively. However, potassium and nitrogen, sulphur and nitrogen, cation exchange capacity and nitrogen, magnesium and phosphorus, cation exchange capacity and potassium (0.859 C mol kg^{-1}, 0.981 C mol kg^{-1}, 0.859 C mol kg^{-1}, 0.995 C mol kg^{-1}, and 1.000 C mol kg^{-1}). Meanwhile, calcium and sodium, and sulphur and calcium, and sodium and phosphorus (-0.030 C mol kg^{-1}, -0.064 C mol kg^{-1}, and 0.592 C mol kg^{-1}) had no significant negative and positive correlation with one another at both $p<0.05$ and $p<0.01$, respectively (Table 3).

The comparative amount of nitrogen, phosphorus, and potassium nutrients in the leafy biomass

P. thonningii had a significantly higher value (20.20 g kg^{-1}) in nitrogen, followed by *C. cajan* (16.45 g kg^{-1}), and the least was *J. carcus* (13.28 g kg^{-1}). However, *J. carcus* had a significantly higher phosphorus value (178.40 mg kg^{-1}), followed by *P. thonningii* (156.38 mg kg^{-1}) and the lowest value for *C. cajan* (121.12 mg kg^{-1}). *P. thonningii* also had a significantly higher value (2914.53 C mol. kg^{-1}) in potassium, followed by *C. cajan* (2867.13 C mol. kg^{-1}), and *J. carcus* (1452.84 C mol. kg^{-1}), respectively (Figure 1).

The comparative amount of sodium, calcium, magnesium, and sulphur in the shrub species' foliar biomass

C. cajan had a significantly higher value (381.11 C mol. kg^{-1}) in calcium, followed by magnesium. *J. carcus* had a significantly higher value (384.48 C mol. kg^{-1}) in magnesium, followed by sodium (51.23 C mol. kg^{-1}) and sulphur (36.91 C mol. kg^{-1}) respectively. However, *J. carcus* and *P. thonningii* had significant higher values (384.48 C mol. kg^{-1} and 361.54 C mol. kg^{-1}) both in magnesium, followed by calcium (316.74 C mol. kg^{-1} and 279.87 C mol. kg^{-1})

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then followed by sodium (56.11 C mol. kg^{-1} and 49.31 C mol. kg^{-1}) and sulphur (34.85 C mol. kg^{-1} and 38.10 C mol. kg^{-1}) respectively (Figure 2).

Table 1: The average chemical makeup or concentration of the chosen leafy biomass of the shrub species

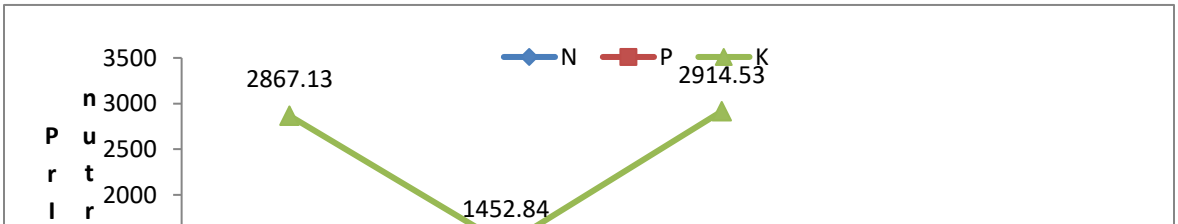
Species	N	OC	C: N	L	PP	L: PP	L: N	PP: N	(L+PP): N	ADF	Cellulose
CC	16.45^{b}± 0.01	6.28^{a}± 0.01	0.38^{a}± 0.01	139.10^{c}± 0.01	30.86^{b}± 0.01	4.51^{b}± 0.01	8.46^{b}±0. 01	1.88^{b}± 0.01	143.98c± 0.01	314.50^{c}± 0.01	175.40^{c}± 0.01
JC	13.28^{c}± 0.01	4.82^{c}± 0.01	0.36^{b}± 0.01	159.30^{a}± 0.01	29.64^{c}± 0.01	5.37^{a}± 0.01	12.01^{a}± 0.01	2.65^{a}± 0.01	161.53^{a}± 0.01	361.40^{b}± 0.01	202.10^{a}± 0.01
PT	20.20^{a}± 0.01	5.11^{b}± 0.01	0.25^{c}± 0.01	145.20^{b}± 0.01	35.12^{a}± 0.01	4.13^{c}± 0.01	7.19^{c}±0. 01	1.47^{c}± 0.01	146.94^{b}± 0.01	326.30^{a}± 0.01	181.10^{b}± 0.01

a,b,c,: indicate the mean with rows with different superscripts are significantly different at 5% probability level using Duncan's multiple range test. CC: *Cajanus cajan*; JC: *Jatropha carcus*; PT: *Piliostigma thonningii*. N: Nitrogen; OC: Organic carbon; C: N: Carbon to nitrogen ratio; L: Lignin; PP: Polyphenol; L: PP: Lignin to polyphenol ratio; L: N: Lignin to nitrogen ratio; PP: N: Polyphenol to nitrogen ratio; (L+PP): N: Lignin plus polyphenol to nitrogen ratio; ADF: Acid detergent fiber; Cellulose.

Table 2: Primary and secondary nutrient concentration in the selected leafy biomass of agroforestry shrub species

Species	N	P	K	Na	Ca	Mg	S
CC	16.45^{b}±0.01	121.12^{c}±0.01	2867.13^{b}±0.01	51.23^{b}±0.01	381.11^{a}±0.01	312.83^{c}±0.01	36.91^{b}±0.01
JC	13.28^{c}±0.01	178.40^{a}±0.01	1452.84^{c}±0.01	56.11^{a}±0.01	316.74^{b}±0.01	384.48^{a}±0.01	34.85^{c}±0.01
PT	20.20^{a}±0.01	156.38^{b}±0.01	2914.53^{a}±0.01	49.31^{c}±0.34	297.87^{c}±0.70	361.54^{b}±0.01	38.10^{a}±0.01

a,b,c,: indicate the mean with rows with different superscripts are significantly different at 5% probability level using Duncan's multiple range test. CC: *Cajanus cajan*; JC: *Jatropha carcus*; PT: *Piliostigmathonningii*.N: Nitrogen; P: Phosphorus; K: Potassium; Na: Sodium; Ca: Calcium; Mg: Magnesium; S: Sulphur.



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Figure 1: Amount of the primary nutrients in the shrub leafy biomass

CC: *Cajanus cajan*: JC: *Jatropha carcus*; PT: *Piliostigmathonningii*. N: Nitrogen; P: Phosphorus; K: Potassium.

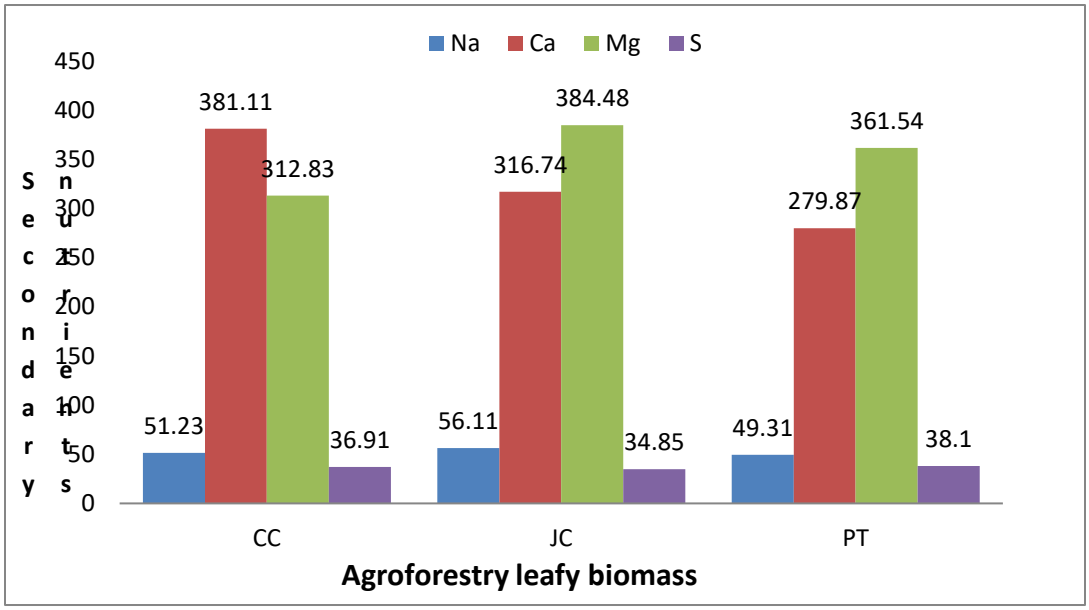


Figure 2: Amount of the secondary nutrients in the shrub leafy biomass

CC: *Cajanus cajan*: JC: *Jatropha carcus*; PT: *Piliostigmathonningii*. Na: Sodium; Ca: Calcium; Mg: Magnesium; S: Sulphur.

Discussion

In *P. thonningii, C. cajan,* and *J. carcus* leafy biomass, the higher the chemical composition

of N and the lower concentration of C: N, L: N, L: PP, PP: N, L, PP, (L+PP): N, acid detergent fibre (ADF), and cellulose, the faster the decomposition and release of nutrients. This is consistent with the findings of Oyebamiji *et al.* (2020) who reported that the higher the N content and the lower the C: N, the faster the decomposition and release of nutrients. *P. thonningii,* among other leafy biomass investigated had the highest nitrogen content and lowest C-to-N (C: N) ratio. This helps in rapid decomposition of its organic materials and early nutrient release. The statement agreed with the findings of Oladoye *et al.* (2018), who stated that higher-quality plant residues, in terms of chemical composition, tend to decompose more rapidly, with net nitrogen mineralization after incorporation into the soil. The decomposition of leguminous leafy biomass is important in the nutrient cycle because the cycled nutrients become readily available to plants as observed by Oyebamiji *et al.*(2016).

The high concentration of nitrogen, potassium and sulphur in *P. thonningii,* calcium in *C. cajan* and phosphorus, sodium and magnesium in *J. carcus* leafy biomass is as a result of reliability in their residue quality and mineralization dynamics, and the ability of their residues to achieve balanced nutrient release and long-term soil health enhancement in low-input farming systems as observed by Yaro *et al.* (2020). These nutrients are vital for plant growth and development, especially when incorporated into the soil as mulch or residues, making them a cornerstone of agricultural productivity (Ribeiro-Barros *et al.,* 2018). They are also essential for producing plant dry matter and many energy-rich compounds that regulate photosynthesis, helping maintain soil health for plant production (Williams, 2021).

The higher nitrogen and potassium contents observed in *P. thonningii*, and the higher phosphorus content in *J. carcus,* were due to their greater potential for long-term organic matter accumulation. Furthermore, the higher magnesium content in *J. carcus*and *P. thonningii*, and the calcium content in *C. cajan,* were due to the quality of their nutrient content, facilitating effective nutrient mobilization. The submission aligns with the findings of Saxena *et al.* (2022), who reiterated that the decomposition of agroforestry shrubs creates an eco-friendly environment for soil and plants by releasing nutrients for their biological activities.

Conclusion

The chemical and nutrient compositions of agroforestry shrub species revealed significant interspecies variations with direct implications for their utility in sustainable soil fertility management. *P. thonningii* exhibited superior nutrient profiles of nitrogen, potassium, and sulphur concentrations, and possesses low lignin-to-nitrogen (L: N), polyphenol-to-nitrogen (PP: N), and lignin-to-polyphenol (L: PP) ratios, and these have offered it the ability to decompose and release nutrients in order for plant to utilize them for their biological activities. The selected shrub species, and most importantly, *P. thonningii,* have the capacity to improve soil fertility and enhance nutrient cycling in agroforestry systems.

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