An assessment of the elemental compositions of neem (*Azadirachta indica* A. Juss)products for biofertilizer production

Abstract

The use of soil-nutrients enhancers is crucial to crop and vegetable farmers. However, with increasing costs of mineral fertilizers, seeking alternatives in the form of biofertilizers may help to alleviate farmers concerns. Neem (*Azadirachta indica* A. Juss) products - seeds, tree bark, and leaves - have been documented in the literature to have soilenrichingproperties. This study examines the elemental compositions of neem tree bark, leaves, and mixture (leaves and bark) to suggest the most suitable for biofertilizer production.Fresh neem leaves (young and old leaves were discarded) and tree bark (harvested 0.4 – 1.70 m above ground) were harvested.chopped into bits, air-dried under the shade for 7 days, milled into powder using a mortar and pestle, sieved (with a 1.7 mm sieve) and packed into air tight nylon bags for moisture content and elemental composition determinations,atomic absorption spectrophotometer (AAS) were used to determine the elemental compositions of the samples of neem leaves, tree bark, and mixture of bark and leaves.The results revealed that there was no statistically significant difference between the samples at $p > 0.05$. This suggests that any of the samples can serve as a good source for biofertilizer production. Since neem leaves had the highest nutritional elements by composition. This suggests that neem leaves can be recommended as a green fertilizer to support crop and vegetable growth.However, its use as a straight fertilizer may require further investigations.

Keywords: Biofertilizer; Elemental composition; Neem plant; Neem product; Seed; Tree bark.

Introduction

The prices of mineral fertilizers are increasing in Nigeria. For example, shop-floor price of NPK 15:15:15 fertilizer moved from 10,000 Naira in 2015 to 45,000 Naira per 50 kg bag in 2023. Besides this, the use of mineral fertilizers has been observed to cause destruction to soil texture and structure, leading to soil acidity and erosion (Omidire et al., 2015). To serve as an alternative, various studies have examined the potentials of products derived from plant and animal matter for biofertilizer production. For example, the study of Ibrahim et al. (2018) has analysed samples of neem seeds cake (residue of neem seeds after oil extraction) and fruit to determine the percentages of nitrogen, phosphorous and potassium contents. The use of neem-seed kernels (Ayito et al., 2018), neem seeds cake (Lokanadhan et al., 2012; Chaudhary et al., 2017), neem leaves (Ekanem and Akpheokhai, 2019), and neem leaves extract(Shayaa and Hussein, 2019) as a biofertilizer has been investigated. Other plant materials considered include spent grain, oil palm bunch ash, and cocoa pod husk (Moyin-Jesu, 2008), and composts produced from the leftover of raw fruits and vegetables and pruning waste (Quirós et al., 2015). There are some other studies that have considered the use of cattle (Aderinoye-Abdulwahab and Salami, 2017; Shayaa and Hussein, 2019; Odhiambo and Magandini, 2020), turkey (Moyin-Jesu, 2008),poultry (Moyin-Jesu, 2008; Ekanem and Akpheokhai, 2019; Chah et al., 2019; Aderinoye-Abdulwahab and Salami, 2017), sheep, goat, pig (Chah et al., 2019), and poultry, cattle and oat (Muoneke et al., 2011)manureas an organic fertilizer. However, limited studies have investigated the biofertilizer potentials of neem leaves, neem tree bark, and mixture of leaves and bark. This study therefore fills the knowledge gap by evaluating the elemental compositions of neem leaves, tree bark, and mixture of bark and leaves. The essence is to understand and to suggest which of the neem products has the highest nutrients needed for plants and crops growth.According to Ibrahim et al. (2018), nitrogen, phosphorous and potassium are the three essential macro nutrients useful to crop growth.Generally, the use of biofertiizers is being promoted because of its soil conservation properties and eco-friendliness over mineral fertilizers (Aderinoye-Abdulwahab and Salami, 2017). It has been established in the literature that the application of organic manures has significant influence on crop growth and yield (Ekanem and Akpheokhai, 2019).

Neem (*Azadirachta indica* A. Juss) is a large, hardy, tropical evergreen tree, native to the Indian sub-continent (Gajalakshmi and Abbasi, 2004). The plant belongs to the*Meliaceae* family(Devi and Gogoi, 2023). Its bitter leaves and fruitare known to possess fungicidal and nematicidal properties. Neem, also found in Nigeria, is a fast growing tree, and can reach a height of 30 metres (m). It is a perennial, drought resistant plant. In the southern part of Nigeria, the plant starts tofruit as from May. Although a tree girth of 2.5m has been reported in the literature (Singh et al., 2021; Usharani et al., 2019), tree diameter, 1 m above ground, can be up to 0.69 m, and bark thickness 1 m above ground 0.14 cm.The mass of a mature leaf can be up to 0.22 g (mean: 0.18 g). Its fruit is ellipsoidal, smooth, yellow or greenish yellow in colour comprising of a sweet pulp when ripe enclosing a seed. The mass of a mature, unripe seed can reach 2.0 g (mean: 1.7 g). Neem tree will start to fruit after 3 to 5 years and may live for more than two centuries (Ibrahim et al., 2018).Products of neem tree have been found useful as insecticides, fertilizers, manure, soil conditioners, urea coating agents, antifeedants, hormonal, antifungal, antiviral, nematicides and fumigants (Singh et al., 2021; Lokanadhan et al., 2012). Neem leaves can be used as green manure (Lokanadhan et al., 2012) for the preparation of vermin-compost having both fertilizer and pesticidal properties (Ekanem and Akpheokhai, 2019). Therefore, this study examines the elemental compositions of neem tree bark, leaves, and mixture of leaves and bark to suggest the most suitable for biofertilizer production. Suitability in terms of having the highest essential nutrients by composition.

Materials and methods

Sample sourcing and preparation

Fresh neem leaves (young and old leaves were discarded) and tree bark (harvested 0.4 – 1.70 m above ground) were harvested between June and July 2022 around 7.00 am, chopped into bits, air-dried under the shade for 7 days, milled into powder using a mortar and pestle, sieved (with a 1.7 mm sieve) and packed into air tight nylon bags for moisture content and elemental composition determinations.

Moisture content analysis

The initial moisture contents (MCs) (wet basis (w. b)) of the freshly harvested neem leaves and bark and the dried samples were measured. 5 g of samples were dried in an air oven at 65 ^{o}C until constant mass. The MC (w. b.) was measured using equation 1.

$$\text{MC (w. b)} = \left(1 - \frac{\varepsilon}{\partial}\right) \text{x } 100 \text{ (\%)} \qquad 1$$

Where, ∂ = mass of sample before oven drying, kg, and ε = mass of sample after oven drying, kg

Elemental compositions determination

The methods estimated by atomic absorption spectrophotometer (AAS) as described by Raghuramulu et al. (2003)., were used to determine the elemental compositions of the samples of neem leaves, tree bark, and mixture of bark and leaves (mixed 0.2 kg of leaves to 0.15 kg of tree bark).Atomic absorption spectrometry, flame photometry and U/V visible spectrophotometer were used because of their high sensitivity and availability. The UV/Visible spectrometer (Okalebo et al., 2002) and volumetric (Nkana, 2001) were used to determine nitrogen, sulphur and phosphorous.In this study atomic absorption spectrometer (AAS) was used for analysis magnesium and calcium (Taylor et al., 2006). Potassium and sodiumthesewere determined by flame photometry (Association of official analytical chemists, 1970). Ca and Mg were determined by verse ate or (EDFA) titration method.

Analysis

The data obtained were subjected to Analysis of Variance (ANOVA) at 5 % level of probability using IBM SPSS version 2.0.

Results and discussion

The MCs (w. b) of the freshly harvested samples were 61% (for leaves) and 32.6 % (for tree bark). Post drying, the MCs (w. b.) of samples reduced to 9.8 % (for leaves) and 8.7 % (for tree bark). Below 10 % moisture level, the samples will store longer with minimal attack by micro-organisms.

Table 1 presents the results of the elemental compositions analysis. The elemental composition determined in the table 1, pH value of neem leaves, bark and mixture (leaves and bark) obtained were 4.72, 4.54 and 6.13 respectively, it was observed that the value of the mixture (leaves and bark) are slightly acidic and was greater than leaves and bark which were in the range of ±0.2.). the Organic carbon (90.20%), N (2.63%), P (39.42mg/kg), K (3.44cmol/kg), Ca (14.26cmol/kg), Mg (5.26cmol/kg), Na (2.32 cmol/kg) while those of neem bark were N (1.81%), P (37.74cmol/kg), K (1.48cmol/kg), Ca (6.32cmol/kg) and The mixture consist of the following: N (2.19%), P (36.32cmol/kg), K (1.99cmol/kg), Ca (9.26cmol/kg. The percentage compositions of nutrients such as nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca) and magnesium (Mg) present in the samples varied. The lowest percentages of nutrients were observed in samples of neem tree bark, except for the value oforganic carbon (93.75 %) which was compositionally higher than those obtained from neem leaves and mixture (neem leaves and bark). The value obtained in Table 1 for nitrogen (N)in neem leaves was slightly higher than the one obtained by Ekanem and Akpheokhai (2019) for N (2.13 %).

Table 1

Elemental compositions of the observed samples

Element	Neem leaves	Neem tree bark	Mixture (leaves and bark)
pH in water	4.72	4.54	6.13
Organic carbon (%)	90.20	93.75	91.13
Nitrogen (%)	2.63	1.81	2.19
Phosphorus (mg/kg)	39.42	37.74	36.32
Potassium (cmol/kg)	3.44	1.48	1.99
Sodium (cmol/kg)	2.32	1.14	1.40
Calcium (cmol/kg)	14.26	6.32	9.26
Magnesium (cmol/kg)	5.26	2.86	4.96

Mean value, n = 3

Table 2 shows the ANOVA results for the measured elemental compositions of the samples. As indicated in Table 2, there was no statistically significant difference between the samples at $p > 0.05$. This suggests that any of the samples can serve as a good source for biofertilizer production. However, since neem leaves were easier to harvest than tree bark, more abundant, and highest in nutrients by composition, this study suggests the use of neem leaves for biofertilizer production.Although neem tree bark possesses phytotoxic properties(Chaudhary et al., 2017), neem leaf manure is gaining popularity due to being environmental friendly and can increase nitrogen and phosphorus contents of the soil (Ekanem and Akpheokhai, 2019). As noted by Chah et al. (2019), the application of biofertilizersto soils can improve aggregate stability and resistance to soil compaction, enhance soil fertility and reduce nutrients leaching, increase biological activity, enhance water retention capacity and reduce greenhouse gases emissions through soil carbon sequestration.

Table 2
ANOVA of the elemental compositions of the selected samples

Source	Type III sum of squares	df	Mean square	F	Sig
Corrected model	21978.617[a]	10	2197.862	826.636	.000
Intercept	8017.291	1	8017.291	3015.379	.000
Parameters	9.305	2	4.653	1.750	.205
Elements	21969.312	8	2746.164	1032.858	.000
Error	42.541	16	2.659		
Total	30038.449	27			
Corrected Total	22021.158	26			

Conclusions

Increases in the costs of mineral fertilizers have necessitated research into bio fertilizers. The nutritional elements of neem leaves, neem tree bark and mixture (leaves and bark) were investigated in this study. By composition, neem leaves were found to contain the highest amounts of nitrogen (2.34 %), phosphorus (39.42 mg/kg), and potassium (3.44 cmol/kg) and recommended for bio fertilizer production. This is the initial conclusion and recommendation that can be drawn from this study. Further studies are needed to test the effect of this green fertilizer on soil quality, crop and plant yields.

Acknowledgements

Huge thanks to Atulute Bosede Caroline and Adejo Funmilayo who assisted with data collection for this study.

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