



PRIORITIZATION OF TREE SPECIES BASED ON GREEN LEAF NUTRIENT LEACHING: AN APPROACH FOR SUSTAINABLE AGROFORESTRY PRACTICES

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Abstract

Nutrients leaching from litter (leaves, bark, needles and twigs) have a major contribution to the supply and cycling of nutrients to crops. Among the litter parts, leaves are the main and quick source of organic matter to the soil whereas, green leaves return more nutrients than other forms of leaves. The return potentiality of K, P and N through leaching from green leaves of the major agroforest tree species: *Zizyphus jujuba*, *Melia azadirachta*, *Albizia saman*, *Dalbergia sissoo* and *Azadirachta indica* are presented on this study. Green leaves of the studied tree species were collected and then leached in water (deionized). Nutrient release through a leaching experiment was conducted for 192 hours. Percentage (%) of green leaf mass loss and Total Dissolved Solid with Electrical Conductivity of the collected leaching water showed a curvilinear relationship with time significantly ($p < 0.05$). NH_4 , PO_4 and K concentration of the collected leaching water of the individual cropland agroforest tree species was significantly ($p < 0.05$) increased for 72 hours in the initial stage but at the later stage remained constant. Individual tree species showed the same nutrient release ($\text{K} > \text{NH}_4 > \text{PO}_4$) pattern. The highest concentration of 5121 ppm NH_4 and potassium (13357 ppm) was found for *Melia azadirachta* and the lowest concentration of 1424 ppm NH_4 and potassium (4410 ppm) was observed for *Albizia saman*. Results from the study highlighted that *M. azadirachta* was the best among the studied tree species in terms of nutrient return followed by *A. indica* and *D. sissoo*.

Keywords: Cropland agroforestry, green leaf leaching, nutrient return, prioritization, sustainability

Introduction

Bangladesh is a deltaic country, and its major economic activity depends on agriculture. Cropland agroforestry has become an important production system (Hasanuzzaman & Mahmood, 2015). Farmers plant trees for various purposes i.e., production of fruits, fuel wood, fodder, timber, and medicine (herbal) with ecological as well as environmental benefits (Ahmed, 2001; Ahmed et al., 2004). Around forty tree species (timber, fodder, fruit etc.) are used in different agroforestry practices in Bangladesh (Hasanuzzaman et al., 2014a). Whereas *Dalbergia sissoo*, *Zizyphus jujuba*, *Albizia saman*, *Azadirachta indica* and *Melia azadirachta* are common in Bangladesh (Aktar et al., 1992; Quddus, 2001; Hasanuzzaman et al., 2014a).

Trees and crops in a system have a positive contribution to nutrient availability for crops. Trees uptake nutrients from the sub-soil and a portion of these nutrients are returned to the topsoil of the cropland agroforests through microbial decomposition of litter (Hasanuzzaman & Mahmood, 2014b) and leaching from green leaves (Limon et al., 2018). The nutrients leaching from green leaves and leaf litter improve the fertility of the topsoil (Kimmins, 2004; Kumar et al., 2010; Kibriya et al., 2019) whereas, green leaves return more nutrients than other forms of leaves (Limon et al., 2018). Nutrients from the green leaves of the standing trees as well as from the cutdown branches (through different tending operations: thinning /pruning) can be released through precipitation. The nutrients released through the leaching mechanism for green leaves may have great implications in nutrient supplies to agroforestry practices (Hasanuzzaman & Mahmood, 2014b; Limon et al., 2018; Kibriya et al., 2019) without significant negative impact on the biodiversity.

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The nature and capacity of nutrient return through the leaching process vary with species, incubation time, the nutrient concentration of leaves and life form of individual trees etc. (Marschner, 1995; Jones, 1998; Mahmood & Saberi, 2007; Ali et al., 2013). Morphological characteristics, site suitability and people's demand are mostly considered for agroforest tree species selection in Bangladesh (Quddus, 2001; Mahmood et al., 2011; Sharmin et al., 2021). Whereas ecological and environmental benefits of the sustainability of agroforestry system are highly ignored. Therefore, this study was conducted to prioritize the commonly used cropland agroforest tree species based on the efficiency of nutrient return through leaching from green leaves. The outcome of this study can draw peoples' interest to consider as another criterion to select tree species in agroforestry practices.

Materials and Methods

Site description

The southwest region of Bangladesh is a fertile deltaic plain with a composition of calcareous - noncalcareous alluvium soils which is low and flat (BBS, 2004). Khulna, Jessore and Satkhira districts of the south-west part of Bangladesh were selected for this study which lies between 89°01'-89°36' E and 22°44'-23°14' N (Figure 1).

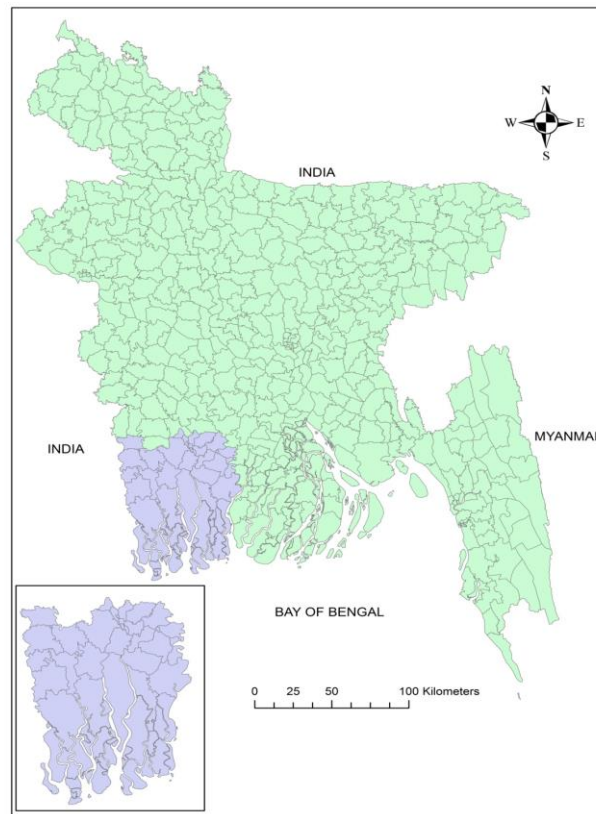


Figure 1. Location of the study area.

Three distinct seasons i.e., rainy, winter and summer prevail in this area having a tropical-subtropical monsoon climate. The average annual rainfall is about $1,800 \pm 268$ mm. The mean annual temperature is 26 °C. During the years, January and May are the coldest and warmest months respectively (Kabir & Webb, 2008). The

highest relative humidity (86%-88%) prevails during July-August whereas, whereas the lowest relative humidity (72%-74%) prevails during February-April in this area.

Green leaf Collection and experimental setup

Two kilograms of green (newly flushed) leaves were collected from the individual tree of *M. azadirachta*, *A. indica*, *Z. jujuba*, *A. saman* and *D. sissoo* from March to April from study sites. In this period, new leaves flash on the trees which contain a higher portion of nutrients (Lin & Wang, 2001; Wright & Westoby, 2003; Fonte & Schowalter, 2004). In addition, this is the driest period in Bangladesh and almost no rainfall occurs during that period. So, there is no chance of leaching from leaves on the existing trees. The collected green leaves were thoroughly mixed and air-dried for one week in natural conditions at room temperature (Figure 2) and then weighed to five gram as an individual sample.



Figure 2. Air drying of green leaves for leaching experiment.

At the same time, five leaves of a sample of each species were kept for four days in the oven at 80 °C (Hasanuzzaman & Mahmood, 2014c) and then the conversion weight ratio (air dry to oven dry) was calculated. The dust particles on the surface of the leaves were removed by soft brushing and rinsing them for a few seconds with deionized water (Turner et al., 1992; Kumar et al., 2010). Eighty-five leaves samples were put in each beaker of 500 ml. Then deionized water of 200 ml with a few drops of mercuric chloride solution (HgCl_2 , 50 mg/L) was provided in every beaker for preventing fungal attack (Ibrahima et al., 2008). At last, the beakers were placed in a normal condition at room temperature (30 °C) for continuing the experiment for up to 192 hours.

Collection of samples and measurements

Five samples were collected at an interval of short duration (0.5, 1, 1.5, 2, 2.5, 3, 4, 8, 12 hours) in the initial stage and at the end it was longer (24, 48, 72, 96, 120, 144, 168, 192 hours) for each species (Kibriya et al., 2019). After the collection of leaf samples, it was dried in an oven for 96 hours at 80 °C (Hasanuzzaman & Mahmood, 2014c). The mass loss calculation was performed by deducting the initial weight from the final (oven-dried) weight of the samples. The mass loss rate was calculated using the mass loss of the leaf with respective leaching time. TDS and EC of the collected water were measured at the time of sample collection by an Electrical Conductivity meter (Model: EC-470L, Istek, Inc., Korea). 100 ml of the collected leaching water of each species were stored for future analysis.

Nutrients addition in leaching water

NH₄, PO₄ and K concentrations were measured from the collected leaching water at different time intervals. NH₄ concentration was measured by following Weatherburn, (1967); PO₄ concentration was measured using a UV-Spectrophotometer (HITACHI, Model: U-2910, Japan) by following Timothy et al., (1984) whereas K concentration was measured using a Flame Photometer (Model: PFP7, Jenway Limited, England).

Statistical analysis

The percentage (%) of mass loss through the green leaves leaching process was arcsine transformed. Mass loss among the species was compared and analysis of variance (Two-Way ANOVA) was calculated using statistical software (SAS 6.12). EC, TDS, Potassium (K), Phosphate (PO₄) and Ammonium (NH₄) concentrations in the collected water of different time intervals were evaluated by ANOVA using statistical software (SAS 6.12). Furthermore, the relationship of leaching time with EC & TDS of the collected leaching water and mass loss of leaf were evaluated by using statistical software (SPSS 17).

Results and Discussion

Mass loss of leaf

The mass loss of green leaves, TDS and EC were significantly ($p < 0.05$) varied among time and species (Table 1). Mass loss variation of green leaves of the studied species may be due to the variable composition of organic and inorganic substances as well as morphological features of leaves of each tree species (Taylor & Parkinson, 1988; Ibrahima et al.,1995; Mahmood et al., 2013).

Table 1. Relationship among mass loss of green leaf, electrical conductivity (EC) and total dissolved solids (TDS) of leaching water and leaching time of selected cropland agroforest tree species (where ML = Mass Loss, EC = Electrical Conductivity, TDS = Total Dissolved Solid, LT = Leaching Time, R² = Regression Coefficient, F=value).

Name of species	ML Vs LT Relationship			EC Vs LT Relationship			TDS Vs LT Relationship		
	Equation	R ²	F	Equation	R ²	F	Equation	R ²	F
<i>M. azadirachta</i>	Y=4.70ln(x)+9.66	0.80	57.31	Y=478.9ln(x)+931.7	0.81	60.75	Y=385.7ln(x)+411.5	0.84	76.31
<i>A. indica</i>	Y=4.19ln(x)+3.60	0.77	46.38	Y=503.5ln(x)+444.0	0.81	58.16	Y=377.0ln(x)+279.1	0.80	57.73
<i>D. sissoo</i>	Y=3.44ln(x)+3.25	0.83	68.58	Y=224.1ln(x)+304.3	0.84	72.00	Y=173.4ln(x)+195.7	0.70	32.12
<i>Z. jujuba</i>	Y=2.75ln(x)+5.18	0.78	48.33	Y=2264.8ln(x)+586.6	0.70	39.78	Y=190.5ln(x)+324.1	0.85	77.45
<i>A. saman</i>	Y=1.79ln(x)+7.01	0.65	26.19	Y=234.0ln(x)+328.0	0.82	65.96	Y=187.1ln(x)+185.4	0.72	36.43

Comparatively the highest (35.20%) mass loss was observed for *M. azadirachta* and the lowest (16.03%) was found for *A. saman* at the end of the experiment (Figure 3).

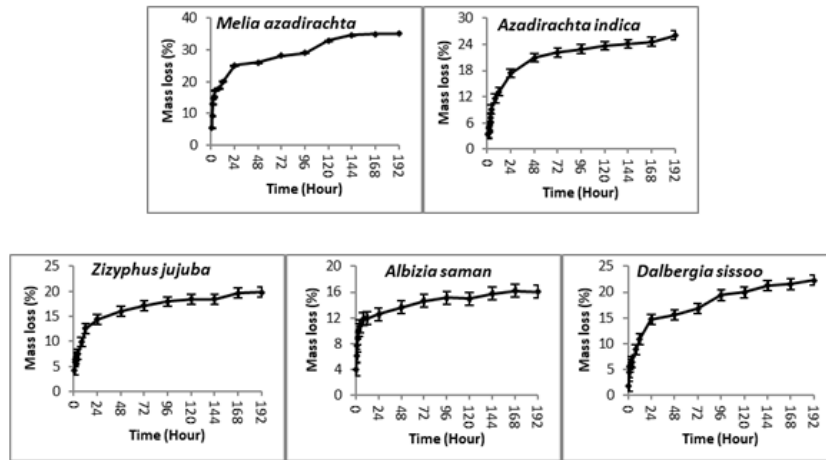


Figure 3. Mass loss (%) at different times of the leaching process.

While, the highest electrical conductivity (3521 $\mu\text{S}/\text{cm}$) was detected for *M. azadirachta* followed by *A. indica* (3380 $\mu\text{S}/\text{cm}$) and the lowest (1526 $\mu\text{S}/\text{cm}$) was for *D. Sissoo* (Figure 4).

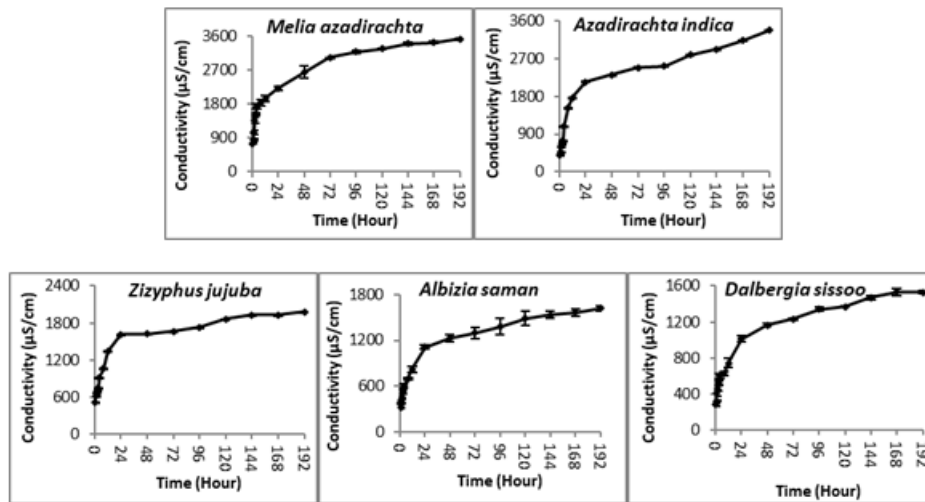


Figure 4. Electrical conductivity ($\mu\text{S}/\text{cm}$) of leaching water at different times of the leaching process.

On the other hand, the highest total dissolved solid (2503 mg/l) was identified for *M. azadirachta* followed by *A. indica* (2407 mg/l) and the lowest (1067 mg/l) was detected for *D. Sissoo* (Figure 5).

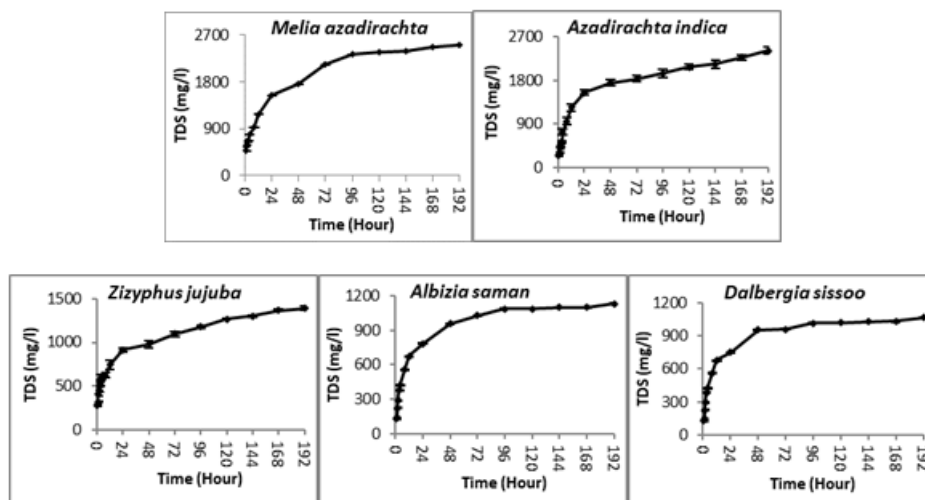


Figure 5. Total Dissolved Solid (mg/l) of leaching water at different times of the leaching process.

Mass loss, TDS and EC showed a positive curvilinear relationship significantly ($p < 0.05$) with leaching time (Table 1). High mass loss of leaves indicates the potentiality of providing readily available nutrients (Wetzel, 1995). On the other hand, the positive curvilinear relationship of leaching time with mass loss, EC and TDS indicates that mass loss can be the result of the release of nutrients which increase with time (Mahmood et al., 2009).

Nutrients released through leaching

Ammonium, Phosphate and Potassium concentrations in the collected leached-out water of the studied species significantly ($p < 0.05$) varied with species and time. The highest concentration (5121 ppm) of NH_4 was observed in the collected water of *M. azadirachta* whereas the lowest (1784 ppm) was for *A. saman* (Figure 6).

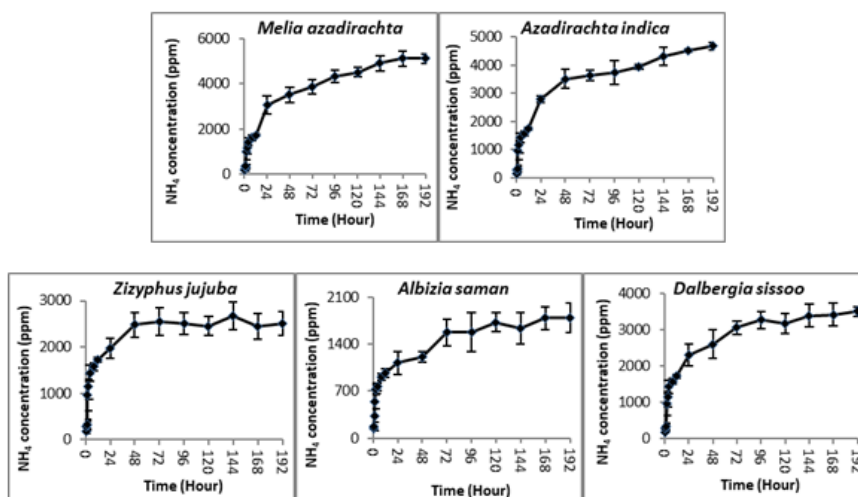


Figure 6. Ammonium concentration (ppm) in leaching water at different times of the leaching process.

The highest concentration (2040 ppm) of PO_4 was found in the collected water of *Z. jujuba* whereas the lowest (1700 ppm) was for *D. sissoo* (Figure 7).

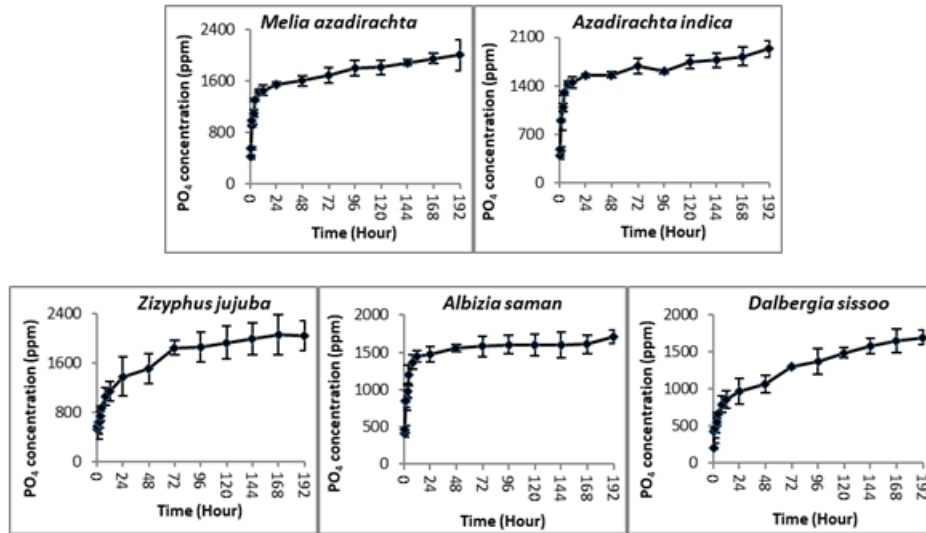


Figure 7. Phosphate concentration (ppm) in leaching water at different times of the leaching process.

The highest concentration (13357 ppm) of K was found in the leaching water of *M. azadirachta* whereas the lowest (5429 ppm) was for *A. saman* (Figure 8).

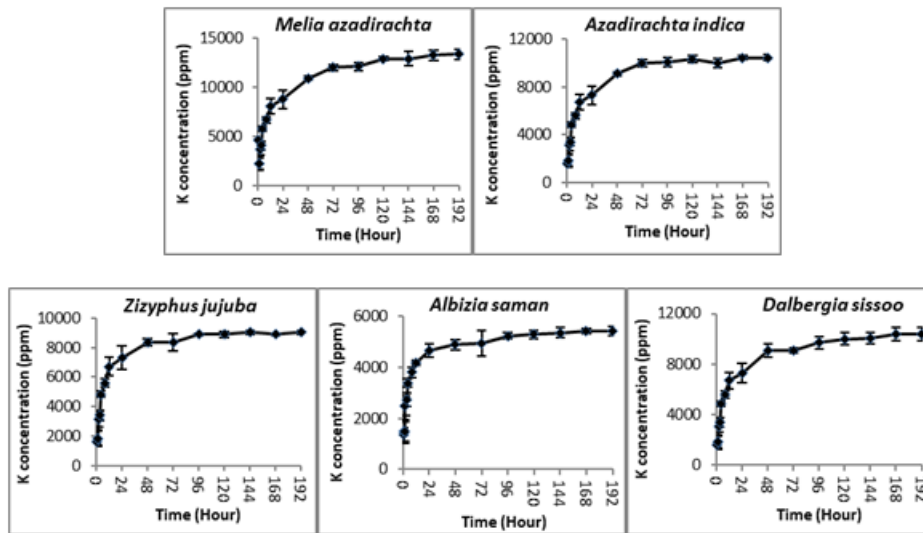


Figure 8. Potassium concentration (ppm) in leaching water at different times of the leaching process.

The comparatively higher portion of potassium (K) was released through leaching followed by NH_4 and PO_4 (Figure 6 - 8) for every studied species. Variation in ammonium (NH_4), phosphate (PO_4) and potassium (K)

concentration in collected leaching water among the species may be depended on the initial composition of different substances of leaves of each species (Ibrahima et al., 1995; Mahmood et al., 2013). In addition to this, the rate of leaching of nutrients varies with the individual characteristics of every nutrient as well as their structural involvement in the leaves (Meyer et al., 1973). Rate of nutrients release was higher at the initial stage because of water soluble organic and inorganic substances of leaves are leached quickly whereas, the rate of nutrient leaching process ceased at the later stage for structurally bound components which leach slowly (Kibriya et al., 2019). Ammonium and phosphate concentration in the leaching water was observed to significant ($p < 0.05$) increase for 72 hours at the initial stage but at the later stages (72 to 192 hours) remained almost constant (Figure 6 and 7). While potassium concentration was found to significantly ($p < 0.05$) increased for 48 hours at the initial stage but from 48 to 192 hours (at the later stages) remained almost constant (Figure 8). Mobility of K is very high and presents in the buds, roots and leaves (Marschner, 1995) while nitrogen is a major substance of cell wall which is structurally bound with that (DeFelice, 1993; Smil, 2000) but Phosphorus is mostly available in seeds and fruits whereas lower concentration presents in leaves (Meyer et al., 1973). For this reason, K concentration in leaching water initially rapidly increased in comparison with NH_4 and PO_4 (Marschner, 1995; Mahmood et al., 2009).

Conclusion

The highest nutrient return was observed from green leaves of *M. azadirachta* and lowest was reported for *A. saman* among the studied species. It is believed that, the added nutrients from the green leaf leaching may contribute to the sustainability of soil fertility. *M. azadirachta* and *A. indica* are suitable for agroforestry practices in terms of nutrient return from green leaves. While, *D. sissoo* is found to infested by die-back disease in different areas of Bangladesh. Therefore, this study suggests to prioritize *M. azadirachta* as the best followed by *A. indica* for different agroforestry practices considering the nutrient return.

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Conflicts of Interest

The authors declare no conflict of interest.

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