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Original Article

Seedling Growth and Survival of the Endangered *Pterocarpus indicus* Willd. (Fabaceae) as Affected by Provenances and Biofertilizer Amendments

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ABSTRACT

The endangered *Pterocarpus indicus* Willd., or narra, is one of the priority species for biodiversity conservation and protection in the Philippines. However, no studies were conducted about the impact of provenance in the seedling performance and survival of narra. The present study aimed to address this gap and study the impact of seed sources and biofertilizer amendment on the growth and survival of *P. indicus* seedlings. Three seed provenances (natural forest, urban forest, commercial) and three biofertilizer treatments (no amendment, uncomposted chicken manure, MYKOVAM®) were used. Two-way ANOVA and Tukey's post hoc analysis were used to assess the differences among treatments in terms of survival and growth performance indicators. Results showed that all treatments achieved maximum survival except the seedlings treated with chicken manure. Variations in growth performances among treatments revealed that seedlings from the natural forest exhibited significantly better performance in terms of root collar diameter, seedling height and leaf count. MYKOVAM® was found to significantly improve the growth of seedlings in terms of root collar diameter, root length, seedling height, leaf count, and nodulation. Lastly, significant correlational relationships were found among all of the growth parameters. The most significant relationship was observed for root collar diameter and seedling height. The results can serve as basis for future reforestation programs and further research aiming to improve the conservation of *P. indicus*.

Keywords: Biofertilizer, growth response, provenance variation

Introduction

Pterocarpus indicus Willd., commonly known as narra or rosewood, is a large deciduous tree native to Asia, particularly in Southeast and East Asia, and to the Pacific region (Flores et al., 2021). It belongs to the Fabaceae, the leguminous family, mostly found in closed and secondary forests. Narra typically reaches a height of 25–35 m, with a growth rate of 2 m per year in the first 3–4 years and then slowing to 1 m per year (Thomson, 2006). It has a diameter of 2 m and is well-suited to thrive at elevations up to 1300 m in sub-tropical and tropical regions. Due to its excellent working properties, narra is highly valued and is considered a commercially important species with extremely high demand due to the quality products that can be made from it (Mendoza et al., 2019). Ecologically, narra trees provide windbreaks and have the potential to provide surface mulching and building up organic matter due to its ability to fixate nitrogen and deciduous habit (Thomson, 2006). However, due to overexploitation and illegal cutting, *P. indicus* is currently classified by the International Union for Conservation of Nature as an "Endangered" species (IUCN, 2023) and is also listed as "Critically Endangered" in the country by the Philippine National Red List for Plants (Department of Environment and Natural Resources, 2017). Thus, these threatened classifications of Narra signify the high degree of threats being faced by the species.

In the recent years, reforestation programs had attempted to preserve and manage the populations of Philippine native plants such as *P. indicus*. Various government and non-government programs were implemented in support to alleviate forest degradation and loss of key biodiversity species such as *P. indicus* while providing sustainable livelihoods to the community (Posa et al., 2008; Von Kleist et al., 2021). The most recent initiative was the massive National Greening Program (NGP) which intended to plant 1.5 billion seedlings of native plant species found in the Philippines among 1.5 million hectares of land (Goltiano et al., 2021). However, the successes of this kind of activities depends on a wide range of factors such as biophysical, socio-economic, institutional, and management (Le et al., 2014). In planting narra, it requires in-depth assessments of factors such as site conditions, management strategies, seedling quality, and genetic factors which all play significant roles in the growth

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and survival of *P. indicus* seedlings (Combalicer et al, 2005). Many reforestation programs have failed partially or completely because of the lack of studies in these factors particularly in the quality of seeds from various provenance and applying management and maintenance strategies (Le et al., 2012; Reyes et al., 2016). Therefore, understanding the morphology, germination, and seedling growth from different sources is crucial in determining the most appropriate and suitable seedlings for establishing reforestation activities (Fredrick et al., 2015).

Seed provenance refers to the geographic origin of a seed, and the environmental conditions and genetics of that location can have a significant impact on the growth, survival, and adaptation of the resulting trees (Atkinson et al., 2021). By using seeds from a provenance that is similar to the reforestation site, the trees are more likely to thrive in the local conditions, leading to a more successful reforestation effort (Potter & Hargrove, 2012). Also, selecting the best quality of seeds and seedlings from various sources are prerequisite to the best growth and survival performances of seedlings (Tsuyama et al., 2020). Moreover, biofertilization or the use of organic matter such as microorganisms have been proven to provide essential nutrients to plants (Román-Dañobeytia, 2015; Trivedi, 2020) and is another important aspect of reforestation (Domínguez-Núñez, 2019). Thus, this has been acknowledged worldwide tosignificantly improve the growth of seedlings.

For *P. indicus,* most studies only focused on the germination rate and the effect of applying biofertilizers and microbes in the growth performance of narra without looking at the possible impact of provenance on the seedling performance (Aggangan & Anarna, 2019; Aquino & Samson, 2021; Husna et al., 2021; Capiltan et al., 2022). The only study that looked at the provenance variations in terms of the quality of seed dwelled on the genetic diversity of *P. indicus* populations but did not push through the acquisition of the seeds and study its impact on the growth performance of the seedlings (De los Reyes et al., 2016). The limited studies local and international studies on the quality of planting materials as affected by provenance in *P. indicus* Willd. is a dilemma in the success of biodiversity conservation and protection programs. Furthermore, using uncomposted manures such as chicken dung is still observed in the Philippines despite recommendations not to do so (The Organic Fertilizer Production and Utilization Committee, 2006). This prompted the authors to pioneer the investigation of the impacts of seed source or provenance and biofertilizer amendment on the seedling growth and survival of *P. indicus*, aiming to contribute to the success of future reforestation and regreening activities. We hypothesize that seed source or provenance significantly influences the growth and survival of *P. indicus* seedlings, with variations in seedling performance expected among different seed sources or provenances. Additionally, we also hypothesize that biofertilizer amendment positively affects the growth and survival of *P. indicus seedlings*, resulting in improved seedling growth parameters compared to the control group.

Materials and Methods

Seed Collection

In our study we limited the definition of provenance to seed source, thus giving rise to three general seed sources in the Philippines, namely, the natural forest, urban forest, and a commercial store selling seeds. These sources are commonly viewed and used as potential sources of seeds and planting materials for reforestation and regreening activities in the country (Delos Reyes et al., 2016; Mula, 2014; Peque & Hölscher, 2014). Seeds of *P. indicus* were obtained from three different types of provenances in June 2022. For the natural forest and urban ecosystem, mature pods were collected only from at least 20 phenotypically desirable trees to represent the variation from the provenances. However, the commercial seeds were from unknown number of maternal trees. Collected pods were air-dried for one week prior to seed extraction. Meanwhile, the commercially available pods were simply bought, and the seeds were extracted. narra seeds were extracted manually from the pod using tweezers and scissors and stored at room temperature before planting. Each pod usually contains an average of 3 seeds. Below is the detailed description of the seed provenances.

Mt. Makiling Forest Reserve or MMFR (14° 7′48″N, 121° 12′0″E) in Laguna, Luzon Islands, Philippines, was selected to be the source of seeds for the natural forest. It is a biodiversity rich ASEAN Heritage Park managed by the University of the Philippines Los Baños. MMFR has a tropical monsoon climate under the Climate Type I having two pronounced season – dry from November to April and wet throughout the rest of the year (Racelis et al., 2019). Furthermore, it has a clay-loam soil type derived from volcanic ash (Alcala et al., 2019).

The representative of urban ecosystem was Bayugan City (8° 42′ 36″ N, 125° 45′ 0″ E), Agusan del Sur, a fifth-class city in in Mindanao Islands, Philippines. The area is classified to have type II climate with no dry season but very pronounced wet season with heavy precipitation (Dapar et al., 2020). The province of Agusan del Sur where Bayugan is located, generally, has a clay and sandy loam soil (Allan & Egirani, 2008).

Lastly, for the commercially available seeds, a business that sells seeds and seedlings in Marikina City (14° 39′ 0″ N, 121° 6′ 0″ E), Metro Manila, Philippines, was chosen which they claim to be harvested from their farm in Bukidnon, Philippines. It is a duly registered business in various government agencies such as the Department of Trade and Industry, Bureau of Internal Revenue, and Bureau of Customs and is certified by the Bureau of Plant Industry. The business regularly secures a phytosanitary certificate from the Department of Agriculture. Lastly, they claim to have a rigorous and strict procedure of maintaining their seeds by having a technician who regularly inspects the quality of the seeds in cold storage to increase its viability. The business was anonymized in this study to avoid violating its privacy policies. While the commercially available seeds may not have the same origin as seeds collected from urban and natural forests, their sourcing from reputable businesses that comply with legal requirements and follow quality assurance procedures warrants their consideration as a separate provenance. This current study acknowledges and includes commercially available seeds as a distinct category to encompass the range of seed sources available to practitioners and reflect the realities of seed procurement for reforestation and other planting programs and activities.

Seed Germination and Planting Operation in the Nursery

Seed germination was done in July 2022 at the shaded portion of the nursery at Nagcarlan Laguna in the Philippines. A total of 100 seeds per provenance, obtained from at least 20 morphologically desirable trees per provenance, were sown using equal mixture of sterilized garden soil and organic potting mix containing decomposed saw dust and rice hull. Watering with distilled water was done as needed. One month after sowing, the seedlings were transplanted to polyethylene bags to avoid competition among planting stocks. The potting media used was a mixture of sandy soil and coir dust with a ratio of 2:1. The seedlings were then arranged in a nursery in complete randomized design (CRD) with nine treatments (20 replications for URBAN and NATURAL, 10 replications for COMMERCIAL) having a total of 150 seedlings (Table 1). The treatments were the products of two categorical variables, seed provenance and biofertilizer amendment.

Table 1.
Treatments Used in the Study with the Categorical Variables (Provenance and Amendment), Corresponding Code, and Number of Seedlings

Seed Provenance	Biofertilizer Amendment	Code	Number of Seedlings
Commercial (COM)	Control/No amendment (CON)	COM-CON	10
	Chicken manure (MAN)	COM-MAN	10
	Mykovam (MYKO)	COM-MYKO	10
Natural Forest (NAT)	Control/No amendment (CON)	NAT-CON	20
	Chicken manure (MAN)	NAT-MAN	20
	Mykovam (MYKO)	NAT-MYKO	20
Urban (URB)	Control/No amendment (CON)	URB-CON	20
	Chicken manure (MAN)	URB-MAN	20
	Mykovam (MYKO)	URB-MYKO	20

For treatments concerning the use of seedlings from the natural forest (NAT) and urban ecosystem (URB), 20 individual planting materials were used for each treatment. Meanwhile, 10 individual planting materials were used for each treatment concerning the commercial (COM) provenance. Only 10 were used per treatment in the COM because most of the seeds were unviable and only the healthy germinant were included in the study which tells something about the germinative energy of seeds from this source probably contributed by errors in handling and other activities that the commercial source does. The unequal number of experimental units per treatment was a result of practical considerations and the availability of viable seeds for each provenance. The goal was to obtain a sufficient sample size to ensure statistically meaningful results while working within the constraints of seed availability and germination success. The unequal number of experimental units per treatment may introduce some variability in the data; however, it was necessary to work with the seeds that exhibited successful germination and were suitable for the study. The study design and statistical analysis were adjusted to account for this unequal distribution of sample sizes, ensuring appropriate statistical comparisons and valid interpretation of the results.

For the biofertilizer amendment, three treatments were co-applied with the provenances namely, control/CON (no amendment), +10 g uncomposted chicken manure (MAN), and +5 g MYKOVAM® (MYKO). The amounts of biofertilizers were decided based on the available literatures. Studies that applied chicken manure (whether composted and uncomposted) used varying amounts of chicken dung which ranged from 5 to 20 g per seedling (Orisajo & Alofami, 2009; Molik et al., 2016; Agbo-Adediran et al., 2020). Similarly, experiments dealing with MYKOVAM® used 5g as standard amount to be applied per seedling which is the result of series of trials (Aggangan et al., 2019, Cortes et al., 2021).

Uncomposted chicken manure was included since it is the most common fertilizer being used by the farmers in the area for their vegetable and tree crops. However, there were limited studies on the effects of uncomposted chicken manure on the growth of narra despite its common usage and familiarity among farmers, which motivated its inclusion in our research. Also, the potential phytotoxicity and nitrogen release associated with uncomposted chicken manure have been reported in previous studies involving other kinds of species, albeit not in the exact experimental set up of our study. Acknowledging these limitations, our aim is to assess the performance of *P. indicus* seedlings treated with commonly available fertilizers used by local farmers, particularly the uncomposted chicken manure, to provide insights into the practical implications for reforestation efforts in the region. Meanwhile, MYKOVAM® is a soil-based biofertilizer developed by the National Institute of Molecular Biology and Biotechnology at the University of the Philippines Los Baños (BIOTECH – UPLB) that contains beneficial arbuscular mycorrhizal fungi (AMF) suitable for agricultural crops, fruit crops, and forest trees (Siababa et al., 2019). In terms of care and maintenance, watering was done by weight when necessary. This approach involved monitoring the weight of each container and providing additional water as needed to maintain optimal moisture levels. Furthermore, the amount of sunlight received by plants in the nursery varies which can alter their responses to the treatments. Thus, the seedlings were re-randomized once a week to avoid bias based on the procedure of Aggangan and Moon (2013).

Growth Parameters Measured

Growth parameters were measured during the observation period of August to December 2022. The parameters included were root collar diameter (RCD), root length (RL), seedling height (SH), leaf count (LC), and root nodules (Nod). RCD and SH were measured weekly using caliper and ruler, respectively. RL, LC, and Nod were counted during the beginning and termination of the set-up only. The increase in the growth parameters were obtained by subtracting the initial measurement from the final measurement.

Determination of Percent Seedling Survival

The percent seedling survival (PSS) was determined during the termination of the experiment. The number of dead seedlings was recorded from each treatment. Those seedlings with dried-up aboveground biomass were considered dead based on the procedure of Bad-e et al. (2020). The percent seedling survival was computed as the ratio of remaining number of seedlings (RS) to that of the total number of seedlings (TNS) planted.

Statistical Analysis

Two-way ANOVA was performed using JASP (v.0.16.1; JASP Team, 2022). The ANOVA results with significance were subjected to Tukey's post hoc analysis with confidence level set at $p < .05$. Results of ANOVA and Tukey's post hoc test for each growth parameters are presented in tabular form with corresponding p values. Pearson's correlation test was also performed at $p < .05$ using the same software to know the relationship among the growth parameters.

Results

Percent Seedling Survival

Percent seedling survival is presented in Figure 1. It was found that only the seedlings treated with uncomposted chicken manure (MAN) did not achieve a 100% survival. A total of 14 seedlings with chicken manure (5 from NAT, 5 from URB, and 4 from COM) exhibited burnt/dried base portion during first month of the experiment until it died soon after.

Effect of Treatments on Growth Parameters

Root Collar Diameter

Two-way ANOVA test revealed significant differences on the increase in root collar diameter of narra seedlings brought about by provenance ($p < .001$) and biofertilizer amendment ($p = .006$). Thus, Tukey's post hoc test was performed (Table 2). For the significant variation among provenance, the NAT seedlings with a mean increase in RCD of 2.43

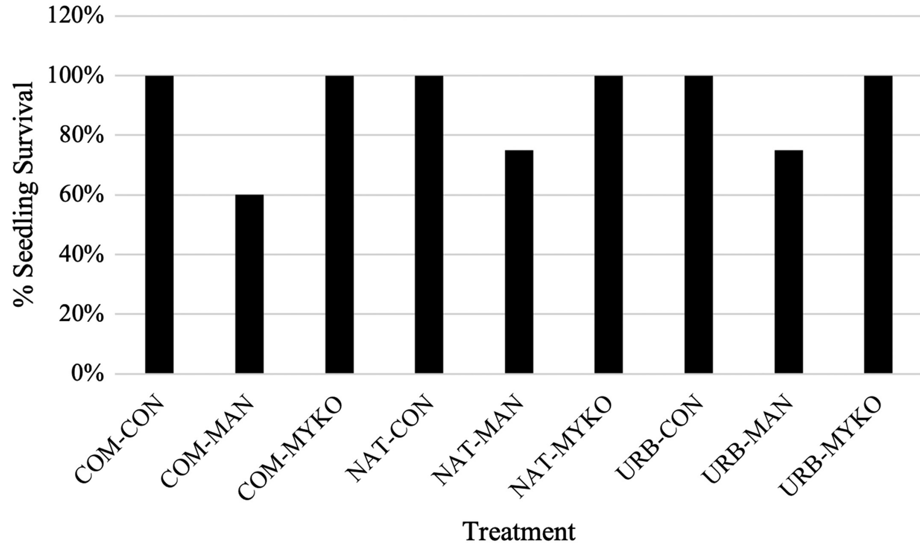

Figure 1.
Percent Seedling Survival per Treatment.

Table 2.
Summary ANOVA with Tukey Post Hoc Analysis of the Significant Effect of Provenance and Biofertilizer Amendment on the Root Collar Diameter of P. indicus Seedlings

ANOVA Results					
Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Amendment	3.12	2	1.56	5.417	.006
Provenance	7.167	2	3.584	12.442	<.001
Amendment + Provenance	11.493	4	2.873	5.976	.0058
Residuals	36.58	127	0.288		
Post Hoc Comparisons—Provenance					
		Mean Difference	SE	*t*	p_{Tukey}
Com	Nat	−0.508	0.131	−3.891	<.001***
Nat	Urb	0.455	0.103	4.405	<.001***
Post Hoc Comparisons—Amendment					
		Mean Difference	SE	*t*	p_{Tukey}
Man	Myko	−0.402	0.126	−3.175	0.005**

cm performed better than the URB seedlings and COM seedlings with mean increase in RCD of 2.0 and 1.86, respectively, both at $p < .001$ (Figure 2). No significant difference was found between the seedlings from URB and COM. In terms of the significant difference among amendment, MYKO seedlings with a mean increase in RCD of 2.45 cm performed better than MAN seedlings with a mean increase in RCD of 1.84. No significant differences were found between MYKO and CON seedlings, and MAN and CON seedlings.

Root Length

The two-way ANOVA found that only the biofertilizer amendment significantly contributed to the growth in root length at $p < .001$. Further, the post hoc analysis revealed that MYKO and CON seedlings with a mean growth in root length of 16.94 cm and 16.90 cm, respectively, performed better than MAN seedlings with a mean growth in root length of 10.75 cm, both significant at $p < .001$ (Table 3, Figure 3). No significant difference was found between MYKO and CON seedlings.

Seedling Height

Two-way ANOVA revealed significant differences in the mean increase in seedling height due to provenance ($p < .001$) and the use of biofertilizer ($p = .034$). Tukey's post hoc test further revealed that NAT and URB seedlings, with mean increase in height of 15.97 cm and 15.36 cm, performed better than COM seedlings (mean increase in height = 10.57 cm) at $p < .001$ (Table 4, Figure 4). No significant difference was found between NAT and URB seedlings. In terms of the effect of biofertilizers, it was found that MYKO seedlings (mean increase in height = 16.36 cm) performed better than the MAN seedlings (mean increase in height = 13.71 cm) and CON seedlings (mean increase in height = 13.73 cm) significant at $p = .036$ and $p = .017$, respectively. No significant different was found between MAN and CON seedlings.

Leaf Count

Two-way ANOVA for leaf count of narra revealed significant contributions of provenance only ($p = .007$). Tukey's post hoc analysis also

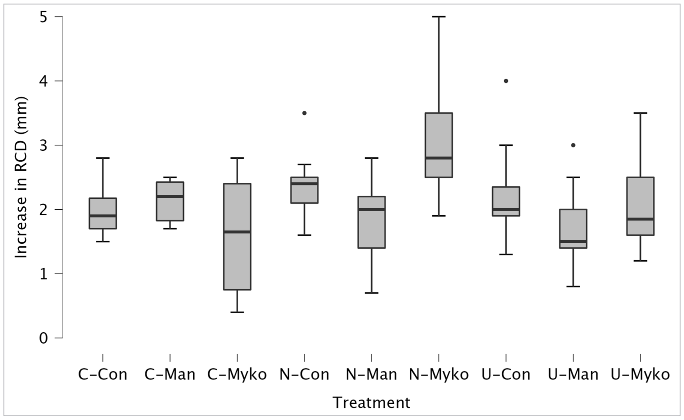

Figure 2.
Provenance and Biofertilizer Amendment Variation in Mean Increase in Root Collar Diameter of Narra Seedlings.

revealed that NAT seedlings, with a mean increase in leaf count of 7.72 leaves, performed better than COM with a mean increase in leaf count of 4.731 leaves at $p = .005$ (Table 5, Figure 5). Also, NAT and COM seedlings were found to have no significant difference with URB seedlings.

Nodulation

Two-way ANOVA test for the root nodulation of narra revealed the significant difference in terms of biofertilizer amendment at $p < .001$. Tukey's post hoc analysis further revealed that MYKO seedlings, with a mean of 5.54 root nodules per seedling, performed better than CON seedlings (mean number of nodules = 2.70) and MAN seedlings (mean number of nodules = 0.58), both significant at $p < .001$ (Table 6, Figure 6). It was also found that CON seedlings performed better than MAN seedlings in terms of nodulation at $p = .008$.

Correlation Among Growth Parameters

Pearson's correlation analysis revealed that all measured growth parameters were positively correlated among each other. Pearson's r heatmap shows the strongest correlation for RCD and SH ($r = .71$, $p <. 001$) followed by LC and SH ($r = .568$, $p < .001$). Other notable correlations were RCD and LC ($r = .447$, $p < .001$), RCD and RL ($r = .426$, $p < .001$), SH and RL ($r = .369$, $p < .001$), and RCD and Nod ($r = .314$, $p < .001$) (Figure 7).

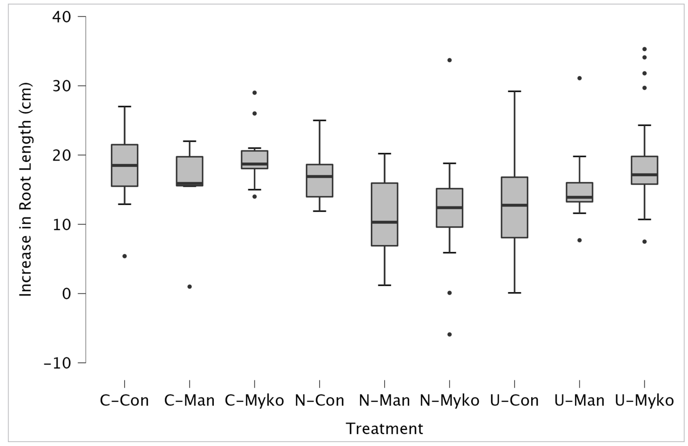

Figure 3.
Provenance and Biofertilizer Amendment Variation in Mean Increase in Root Length of Narra Seedlings.

The remaining correlational relationships were also significant at either $p < .01$ or $p < .05$.

Discussion and Conclusion

The achievement of maximum plant growth and survival is the primary goal of any reforestation activities being a nature-based solution to habitat and biodiversity losses (Di Sacco et al., 2021). Thus, modifications of the natural process (e.g., use of fertilizers and other soil amendments) are being experimented on and are being introduced for application in various greening activities (Wang et al., 2020).

In this study, the percent survivals of the treatments were at maximum (100%) except for those treated with uncomposted chicken manure that died due to the dried base portions of the plants. The inability of these plants to survive may have been due to the phytotoxicity of the uncomposted chicken manure which burned the plant tissues. This aligns with the information from various literatures which state that fresh or uncomposted chicken manure can burn plants due to its high nitrogen content, which is attributed to excessive ammonia (Hue & Silva, 2000; Chaudhry et al., 2013). The study of Mar Delgado et al. (2010)

Table 3.
Summary ANOVA with Tukey Post Hoc Analysis of the Significant Effect of Provenance and Biofertilizer Amendment on the Root Collar Length of P. indicus Seedlings

ANOVA Results					
Cases	Sum of Squares	df	Mean Square	*F*	*p*
Provenance	22.278	2	11.139	0.308	.735
Amendment	754.19	2	377.095	10.438	<.001
Provenance + amendment	261.533	4	65.383	1.81	.131
Residuals	4588.039	127	36.126		
Post Hoc Comparisons—Amendment					
		Mean Difference	SE	*t*	p_{Tukey}
CON	MAN	5.768	1.417	4.071	<–.001***
MAN	MYKO	–5.811	1.417	–4.102	<–.001***

Note: ***$p < .001$.

Table 4.
Summary ANOVA with Tukey Post Hoc Analysis of the Significant Effect of Provenance and Biofertilizer Amendment on the Seedling Height of P. indicus Seedlings

ANOVA Results					
Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Amendment	181.956	2	90.978	3.476	.034
Provenance	531.038	2	265.519	10.145	<.001
Amendment + Provenance	91.02	4	22.755	0.869	.484
Residuals	3323.75	127	26.171		
Post Hoc Comparisons—Provenance					
		Mean Difference	SE	*t*	p_{Tukey}
COM	NAT	−5.479	1.245	−4.4	<.001***
	URB	−4.641	1.245	−3.726	<.001***
Post Hoc Comparisons—Amendment					
		Mean Difference	SE	*t*	p_{Tukey}
Con	Myko	−2.504	1.079	−2.523	.017*
Man	Myko	−2.600	1.206	−2.093	.036*
Note: *$p<.05$, ** $p < .01$, *** $p < .001$.					

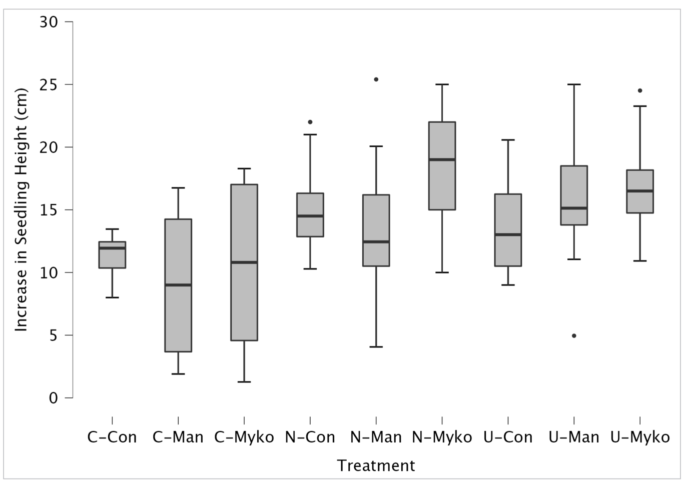

Figure 4.
Provenance and Biofertilizer Amendment Variation in Mean Increase in Seedling Height of Narra Seedlings.

also found that uncomposted chicken manure has relatively more phytotoxic compounds than composted chicken manure that can lead to plant damage and even death. Furthermore, uncomposted chicken manure was found to release nitrogen content faster than the composted one which act as a source of environmental contamination (Tyson & Cabrera, 1993).

The current study also found provenance as a significant contributory factor to plant growth. Provenance was found to significantly affect root collar diameter, seedling height, and leaf count. No significant differences due to provenance were observed in root length and nodulation. The seedlings propagated with the seeds collected from the natural forest exhibited the best performance among the three provenances in terms of root collar diameter, seedling height, and leaf count. Meanwhile, the seedlings produced from commercially available seeds yielded lower performances in growth parameters namely, root collar diameter, seedling height, and leaf count. This is corroborated by the study of Zhu et al. (2006) which reported that seeds from quality mother trees in the natural forest significantly affected the growth rates of the propagated seedlings. They also stated that seeds from natural

Table 5.
Summary ANOVA with Tukey Post Hoc Analysis of the Significant Effect of Provenance and Biofertilizer Amendment on the Leaf Count of P. indicus Seedlings

ANOVA Results					
Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Provenance	183.336	2	91.668	5.181	.007
Amendment	59.833	2	29.916	1.691	.189
Provenance + Amendment	113.414	4	28.353	1.602	.179
Residuals	2247.217	127	17.695		
Post Hoc Comparisons—Provenance					
		Mean Difference	SE	*t*	p_{Tukey}
COM	NAT	−3.294	1.024	−3.217	.005**
Note: **$p < .01$.					

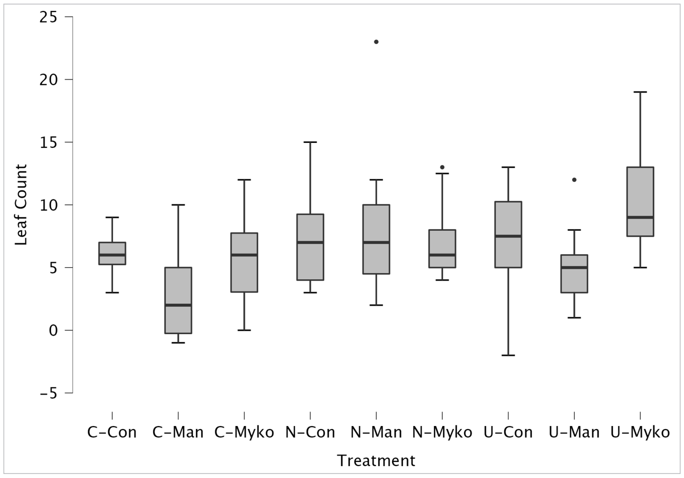

Figure 5.
Provenance and Biofertilizer Amendment Variation in Mean Increase in Leaf Count of Narra Seedlings.

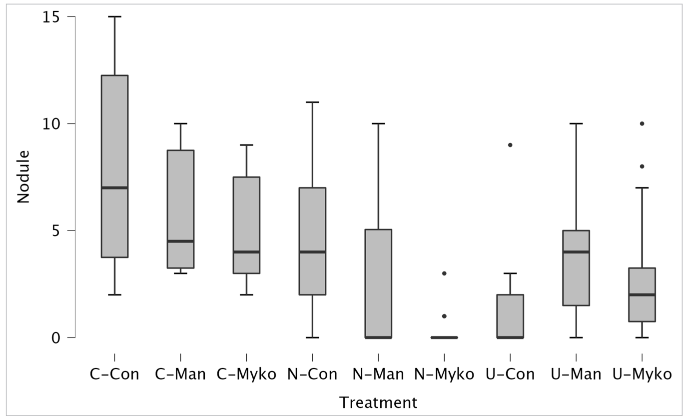

Figure 6.
Provenance and Biofertilizer Amendment Variation in Mean Increase in Nodulation of Narra Seedlings.

forest have a generally higher adaptability in the changes in environmental conditions. However, the seedling quality still depends on the proper forest and tree management strategies (Konijnendijk et al., 2005). In the case of the natural forest used in our study, the MMFR is under the jurisdiction of a premiere academic university in the Philippines which ensure the protection of the area (Lumbres et al., 2016; Magcale-Macandog et al., 2022). Thus, producing higher quality seeds and seedlings which according to Šerá (2021) is a vital prerequisite to a successful regeneration, structure, and succession of trees in the forests.

This present study also observed the significant contributions of biofertilizer amendment to the differences among treatments in all the growth parameters except for the leaf count. As found, the seedlings with MYKOVAM® performed best in terms of root collar diameter, root length, seedling height, and nodulation, among others. The exceptional performance of these seedlings conforms with the findings of many studies on the effect of MYKOVAM® as compared with other organic and inorganic fertilizers when applied in *P. indicus* and other plant species (Aguilar et al., 2018); Siababa et al., 2019; Ultra, 2020;). This result in *P. indicus* can also be explained by the legume-microbial symbiosis exhibited by narra and the AMF spores (*Gigaspora* and *Glomus* species) present in MYKOVAM®. According to Aggangan et al. (2019), AMFs are soil microbes that enhance the uptake of nutrients among plants by creating direct linkage between plant roots and soil especially in leguminous species like narra, thus contributing to enhance plant growth. On the other hand, seedlings treated with uncomposted chicken manure had lower performance in terms of root collar diameter, root length, seedling height, leaf count, and nodulation. This result may have been due to the phytotoxicity of the chicken manure which coincides with the study of Aryantha et al. (2000) which reported that chicken manure, both the composted and uncomposted, especially in larger amounts, can be strongly phytotoxic for phosphorus sensitive plants. However, some studies reported that chicken manure performed best in terms of plant growth as compared to other fertilizers but in composted form and in suitable amounts that may vary across different species (Friend et al., 2006; Han et al., 2016; Manirakiza & Şeker, 2020). Also, it is important to note that composting can decrease phytotoxicity and rapid release of N contents in the soil which can lead to maximized plant growth and reduced environmental contamination (Tyson & Cabrera, 1993; Ravindran et al., 2017). Thus, composted manure with suitable

Table 6.
Summary ANOVA with Tukey Post Hoc Analysis of the Significant Effect of Provenance and Biofertilizer Amendment on the Nodule Formation of P. indicus Seedlings

ANOVA Results					
Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Provenance	5.669	2	2.834	0.421	.657
Amendment	426.545	2	213.273	31.692	< .001
Provenance ∗ Amendment	12.926	4	3.232	0.480	0.750
Residuals	854.650	127	6.730		
Post Hoc Comparisons—Amendment					
		Mean Difference	SE	*t*	p_{tukey}
CON	MAN	1.867	0.611	3.053	.008**
	MYKO	−2.850	0.547	−5.211	<.001***
MAN	MYKO	−4.717	0.611	−7.714	< .001***

Note: ***p* < .01, ****p* < .001.

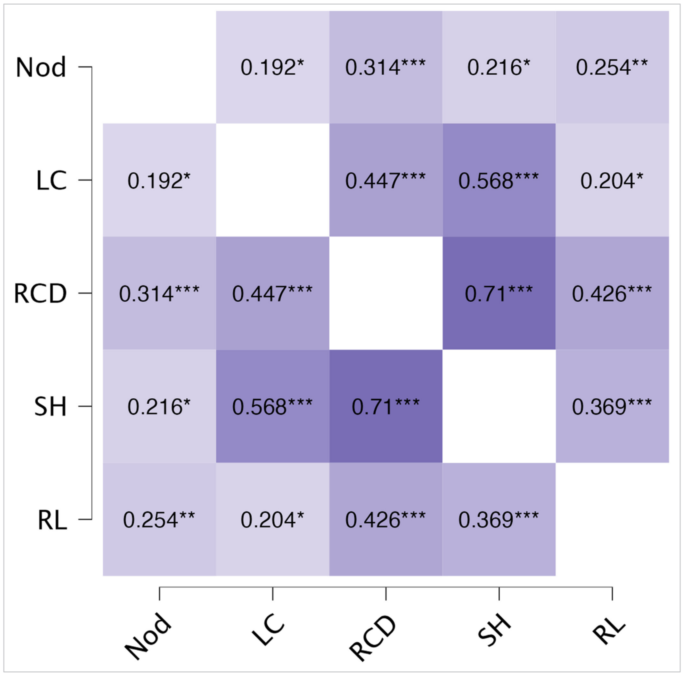

Figure 7.
*Heatmap of the Pearson's r correlation among growth parameters (Nod = Root nodules, LC = Leaf count, RCD = Root collar diameter, SH = Seedling height, RL = Root length) (*p < .05, **p < .01, ***p < .001).*

amounts shall be determined for each species that will be treated with such animal manure for improved growth performances of plants.

Lastly, the current study revealed significantly positive correlations among all the growth parameters. It means that an increase in any of the growth parameters may result to the increase of the other growth parameters. Most notable was the correlation between seedling height and root collar diameter, as well as leaf count and seedling height. No other studies about narra seedlings looked at the correlation among growth parameters but this is comparable with the results of the study of Binotto et al. (2010) on *Eucalyptus grandis* seedlings which also found significant correlation for height and diameter (r = .7176), as well as leaf count and seedling height (r = 0.4703). The same is also true with the study of Yucedag et al. (2019) which found that there is positive correlation between seedling height and diameter (r = .297) for *Euonymus japonicus* cultivars. Thus, with our data about the correlation among the growth parameters of *P. indicus,* it can be said that any of the measurements (root collar diameter, seedling height, leaf count, root nodules, and root length) are indicators of the other growth parameters.

With our findings in the current study, it is proper to recommend that greening activities and other conservation advocacies, especially for *P. indicus*, may opt to acquire seeds from the natural forest's high quality mother trees. For enhanced nutrient uptake, treating the seedlings with biofertilizers rich in AMF such as MYKOVAM® is ideal which can be testified by its growth response. Lastly, in using chicken manure, composting may be considered as found in many studies and the suitable amounts to be applied must first be experimented on. Performing these recommendations will help in realizing a more successful and effective nature-based solution in addressing biodiversity and habitat losses.

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