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A study of *Entada abyssinica Steud.* : A new nodulating indigenous tree legume with promising agroforestry potentials on unfertile acid soils

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1 SUMMARY

In order to enlarge tree genotype base towards its integration into farming systems in the tropics, a study was conducted to assess seed germination, early growth and nodulation performance of a wild indigenous parkland tree, *Entada abyssinica*. The study was conducted over five months on an acid nitrogen-poor sandy soil. Phosphorus P and Nitrogen (N) were variably combined to determine their effect compared to no-fertilization on this tree legume performance in a trial comprising 12 treatments replicated four times in a completely randomized design. Seeds of the tree revealed no dormancy and their germination was highest under hot water scarification for 30 min. Tree height, base girth and dry biomass yield were found to be best under no fertilization (NoPo). This treatment did not significantly differ from the supply of 40 kg P ha^{-1} that was the most performing in nodulation and the optimum P rate for this tree species. Without any rhizobium inoculation, *E. abyssinica* was found bearing nodules of indeterminate type, and of coralloid shape, Furthermore, its thriving in an unfertile soil with no supply of either P or N is a promising indication of its potential as N_2-fixing species for agroforestry in marginal soil areas and a potential alley cropping hedgerow species.

2 INTRODUCTION

Many woody plants, particularly nitrogen-fixing trees/shrubs are increasingly integrated into tropical farming systems to sustain food crop production (Kang *et al.*, 1984; Young, 1987), and to maintain productive and sustainable the ecosystems in which they could be involved (Ingram, 1990). One cropping system in which N_2-fixing trees (NFTs) have been successfully exploited during the last two decades, in humid and subhumid tropics, is the alley cropping (Kang *et al.*, 1990) despite its rather slow adoption.

The particular advantages of NFTs are their biological N_2-fixation, their ability to establish on nitrogen-deficient soils and the benefits of the fixed N_2 plus organic matter to succeeding or associated crops (Danso *et al.*, 1992). Thus their use into cropping systems can reduce farmers' dependence on expensive chemical N fertilizers. Yet despite the success of integrating trees on farm, there have been very few indigenous species tested. Exotic ones have been the most studied among which *Leucaena leucocephala, Gliricidia sepium* and *Calliandra calothyrsus*. Introduced exotic species are usually very demanding for soil fertility status mainly at their earlier establishment. Most of them are sensitive to soil acidity (Haque and Jutzi, 1984; Hutton, 1984) and cannot find appropriate rhizobium strains (Kang *et al.*, 1990; Dommergues *et al.*, 1999) to nodulate efficiently and fix N_2.

In addition, the poor performance of species like *L. leucocephala* in some ecological zones due to damage to stands by the psyllid, *Heteropsylla cubana* [Reynolds and Bimbuzi, 1993] has aroused the need for increasing tree diversity for alley cropping to match specific ecological conditions.

Searching for indigenous tropical tree species adapted to both soil and climate environment and that can thrive successfully on poor and acid soils and still keep high their N_2-fixing potential remains challenging (Kass, 1995; Dommergues *et al.*, 1999). Few tree species are well documented to the extent that the tree gene pool for agroforestry development in Africa remains still narrow (Kadiata, 1995). In particular, in Central Africa where tree biodiversity remains extremely rich, lack of appropriate tree species is due to little efforts invested in finding out indigenous species, some with multiple uses, to meet the challenge of agroforestry development. Vietmeyer (2008) stressed the existence of underexploited tropical plants with promising economic value. Yet, there is *Entada abyssinica* Steudel ex A. Rich, an understorey forest species usually found in a savannah habitat and preferring sandy loam soils that is less documented for its attributes (Salim *et al.* 2002). Pantropical, *E. abyssinica* extends from Liberia to Mozambique and is present in central, eastern and southern tropical Africa (Rich, 1993; Salim *et al.*, 2002).

It is used by peasant farmers in Eastern Kasaï Province Democratic Republic of Congo, as indicator of soil fertility such that usually, they spare it on the farm and subject it to regular lopping to reduce shade to food intercrops. Moreover, yearly, in season, *Entada* bears a large quantity of edible caterpillars as food for humans. It also withstands seasonal bushfires. It is used as a fodder tree, as firewood and harbours many healing virtues. Salim *et al.* (2002) reports the treatment of miscarriage. A decoction of the bark is taken for coughs, chronic bronchial engorgement, rheumatic and abdominal pains. An infusion of crushed roots is also good for bronchial problems. A root or leaf decoction is used as a fever remedy; powdered or roasted pulverized seeds for sneezing; root bark as a massage for swelling; and the raw fruit induces vomiting as an antidote to snake venom. The seeds treat cataracts and diseases of the back of the eye (Salim *et al.*, 2002).

It was thus found relevant to investigate the possibility of domesticating this tree species of which there is still little information (Rich, 1993; Salim *et al.*, 2002). As commonly encountered, nitrogen and phosphorus are the most deficient and thus most demanded macronutrients by tree species for establishment on a new site in most tropical soils (Kang and Wilson, 1987; de Lucena *et al.*, 1993; Schachtman *et al.*, 1998; Kadiata and Lumpungu, 2003).

This study on *E. abyssinica* was thus undertaken to document its possibility of propagation through seeds, its nodulation if any, and its early growth and biomass yield dynamics on an oxisol, and to assess the influence of key macronutrients most demanded at the earlier stage of establishment.

3 MATERIALS AND METHODS

3.1 Location: The study was conducted at the University of Kinshasa, on Mont Amba, southwestern Democratic Republic of Congo, located at 15°8’ E, 4°19’ S and 390 m altitude. It falls into Aw4 climate type according to Köppen classification. It is characterized by 4 months of dry season (from mid-May to August) and 8 months of rainy season, sometimes interrupted by a short dry period in January/ February. Daily temperature averages 24.5°C. The air relative humidity is maximal from August to October while annual rainfall is close to 1500 mm (Makoko *et al.*, 1991). Usually, the rainfall remains nil from June to September.

3.2 Soil characteristics and preparation: The study soil used (0-20 cm depth) was a sandy oxisol from Mont Amba, Kinshasa, characterized by a pH (H_20) of 4.58, 0.651% organic carbon, 0.069% N ; 1.121% organic matter ; 9.44 C/N ; 0.258 meq/100g Mg; 0.139 meq/100g Ca; 1.414 meq/100g potassium oxide K_2O and 25.55 mg.kg^{-1} diphosphorus pentoxyde P_2O_5. The site soil was air-dried, thoroughly mixed and then filled up to 10 kg in each polyethylene container bearing perforations at the bottom.

3.3 Experimental design and plant management: The trial was conducted on *Entada abyssinica* Steud. ex A. Rich (syn. *Entadopsis abyssinica* A. Rich, Gilbert & Boutique), of Mimosaceae subfamily (Rich, 1993), a parkland tree species found throughout the southern Congo. Seeds used were collected from a savannah around Kabinda, in the Eastern Kasaï province.

Figure 1: Specimen of 6-month old *Entada abyssinica* raised in potted soil.

Prior to trial, seeds were scarified by superficial scratching with blade, soaked in boiling water for 30 min, while others were kept untreated to assess a better method towards high and uniform germination. The seeds were then sown on a seedbed that received no fertilizer till one month growth, after which the best seedlings were transplanted individually into polyethylene bags being the experimental units. The soil was moistened to approximate field capacity before sowing. Seedlings were watered daily with 250 - 400 mL of tap water throughout the 5-month growth period.

A day after transplantation, plants were accordingly subjected to 12 treatments that included nitrogen (N) and phosphorus (P) combinations at various rates ranging from 0 to 80 kg ha^{-1}. Urea and triple super phosphate served as nutrient sources. The treatments were set in a completely randomized design with four replicates, and identified as control T0 (N_0P_0), T1 ($N_{30}P_0$), T2 (N_0P_{40}), T3 ($N_{30}P_{40}$), T4 ($N_{30}P_{80}$), T5 ($N_{60}P_0$), T6 ($N_{60}P_{40}$), T7 ($N_{60}P_{80}$), T8 (N_0P_{80}), T9 ($N_{80}P_0$), T10 ($N_{80}P_{80}$) and T11 ($N_{80}P_{40}$).

3.4 Data collection and analysis: Plant height and girth (as basal stem diameter) were measured monthly as from two months of age. At 5 months after planting (MAP), plants were harvested by cutting the stem at the soil line and separating shoot into leaves and stems. Each container was then emptied of soil, and the excavated belowground biomass (roots and nodules) retrieved from the loose soil were washed free of soil over a sieve to maximize nodules recovery. Nodules were collected, counted and weighed after drying. Coarse plant parts such as stems and taproots were chopped into shorter pieces, where necessary. Then above- and belowground plant parts were separately oven-dried at 67 ^{O}C to constant weight for plant biomass yield determination. Nodulation index (NI) was calculated as the percentage of nodule dry weight over shoot dry biomass (Hughes and Herridge, 1989). All data were subjected to the analysis of variance using IRRISTAT software package version 92-1 while the Duncan multiple range test (DMRT) was used to separate treatment means at 5% probability level.

4. RESULTS

4.1 Seed germination: The rate of *E. abyssinica* seeds germination following three scarification methods is given in Table 1. Seeds that were soaked for 30 min in hot water gave the highest rate of germination followed by physically scarified ones (73.9%). The untreated seeds comparatively yielded lesser seedlings but at a rate above 50%.

Table 1: Germination rate of *E. abyssinica* seeds in relation to the scarification methods

Treatment	Number of sown seeds	Number of seeds germinated	Germination rate (%)
None	46	28	60,8
Hot water	46	45	97,8
Physical	46	34	73,9

4.2 Plant height growth: The height of *E. abyssinica* over the study period is shown in Table 2. The unfertilized control treatment resulted in plants being taller than others that benefited the supply of either N, or P or both nutrients.

Table 2: Height growth (cm plant^{-1}) of *Entada abyssinica* over time as influenced by the different fertilizer treatments in an oxisol

Treatment	Height (cm plant^{-1}) at			
	2 MAP	3 MAP	4 MAP	5 MAP
T0 (N_0P_0)	12.7 b	15.2 cd	21.8 e	31.8 d
T1 ($N_{30}P_0$)	11.7 ab	13.6 abc	15.8 bcd	21.8 bc
T2 (N_0P_{40})	12.5 b	17.3 d	26.0 f	27.8 d
T3 ($N_{30}P_{40}$)	12.7 b	14.3 abc	15.9 cd	22.9 c
T4 ($N_{30}P_{80}$)	12.5 b	14.5 bc	17.1 d	22.6 c
T5 ($N_{60}P_0$)	12.4 b	13.6 abc	14.6 a-d	20.8 bc
T6 ($N_{60}P_{40}$)	11.9 ab	13.1 abc	13.1 abc	15.3 a
T7 ($N_{60}P_{80}$)	12.5 b	13.8 abc	17.0 d	22.3 c
T8 (N_0P_{80})	11.1 ab	11.9 a	12.8 ab	14.9 a
T9 ($N_{80}P_0$)	11.9 ab	13.8 abc	15.1 a-d	18.8 abc
T10 ($N_{80}P_{80}$)	12.8 b	13.8 abc	16.1 cd	17.4 ab
T11 ($N_{80}P_{40}$)	9.5 a	12.1 ab	12.6 a	14.6 a
Mean	12.0	13.9	16.5	20.9
CV (%)	12.6	10.7	11.7	14.5

In column, means sharing a same letter do not significantly differ at 5% level by the Duncan Multiple Range Test

From 4 to 5 months of growth, control plants were significantly ($p=0.05$) taller than most fertilized ones except those under application of 40 kg P ha^{-1} (T2). The worst growth in height was found with plants under treatments T11 ($N_{80}P_{40}$), T8 (N_0P_{80}) and T6 ($N_{60}P_{40}$) in this ascending order since they were significantly (p=0.05) shorter than the control throughout the growth period.

4.3 Plant girth: *E. abyssinica* stem growth at the base varied widely with applied fertilizer treatments (Table 3). At two MAP, before any treatment was applied, seedlings were of similar size (approximately 2 mm). As plants grew bigger with age, more significant differences arose among them, mostly from 4 to 5 MAP.

Table 3: Basal stem diameter growth (cm.plant^{-1}) of *E. abyssinica* over time as affected by the different fertilizer treatments in an oxisol

Treatment	**Stem diameter (cm.plant^{-1})**		
	3 MAP	**4 MAP**	**5 MAP**
T0 (N_0P_0)	3.8 ab	5.4 de	8.9 f
T1 ($N_{30}P_0$)	3.5 ab	4.6 bcd	6.5 e
T2 (N_0P_{40})	4.6 b	6.3 e	8.0 f
T3 ($N_{30}P_{40}$)	4.5 b	5.0 cd	6.1 de
T4 ($N_{30}P_{80}$)	3.5 ab	4.3 a-d	5.3 cde
T5 ($N_{60}P_0$)	3.8 ab	3.9 abc	4.5 abc
T6 ($N_{60}P_{40}$)	4.0 ab	4.1 abc	5.0 bcd
T7 ($N_{60}P_{80}$)	4.0 ab	4.1 abc	5.0 bcd
T8 (N_0P_{80})	2.8 a	3.3 a	3.5 a
T9 ($N_{80}P_0$)	3.5 ab	4.4 a-d	4.5 abc
T10 ($N_{80}P_{80}$)	3.0 a	3.5 ab	3.8 ab
T11 ($N_{80}P_{40}$)	3.1 a	3.6 ab	4.0 abc
Mean	3.7	4.4	5.4
CV (%)	21.4	16.8	16.4

In column, means sharing a same letter do not significantly differ at 5% level by the Duncan Multiple Range Test

Basal stem diameter of *E. abyssinica* revealed a similar trend under the different treatments as that observed for growth in height (Table 2). Indeed, the control plants (T_0) along with those fed with 40 kg P ha^{-1} performed better than others, mainly at 4 and 5 months of age. Moreover, the increment rate from 3 to 5 MAP was double for T0 and 1.7-fold for T2. The lowest stem diameter means occurred under treatments T8 (N_0P_{80}) and T10 ($N_{80}P_{80}$) which were significantly (p=0.05) lower than the control throughout the study period, except at 3 months. Most of other treatments remained intermediate in their ability to boost *E. abyssinica* basal stem girth (Table 3).

Table 4: Dry biomass yields of *E. abyssinica* at 5 MAP as affected by the different fertilizer treatments on an oxisol

Treatment	**Dry biomass (g.plant^{-1})**		
	Shoot	**Root**	**Total**
T0 (N_0P_0)	8.7 g	17.0 f	25.7 f
T1 ($N_{30}P_0$)	4.5 de	5.0 b	9.5 bc
T2 (N_0P_{40})	6.7 f	11.4 e	18.1 ef
T3 ($N_{30}P_{40}$)	4.1 d	8.3 d	12.4 d
T4 ($N_{30}P_{80}$)	3.8 d	7.1 c	10.9 c
T5 ($N_{60}P_0$)	2.9 c	5.3 b	8.2 b
T6 ($N_{60}P_{40}$)	1.5 ab	6.0 bc	7.5 b
T7 ($N_{60}P_{80}$)	5.2 e	8.9 d	14.1 de
T8 (N_0P_{80})	1.5 ab	2.7 a	4.2 ab
T9 ($N_{80}P_0$)	2.1 b	2.5 a	4.6 ab
T10 ($N_{80}P_{80}$)	0.7 a	2.5 a	3.2 a
T11 ($N_{80}P_{40}$)	1.1 a	2.5 a	3.6 a
Mean	3.6	6.6	10.2
CV (%)	15.0	11.0	13.0

In column, means sharing a same letter do not significantly differ at 5% level by the Duncan Multiple Range Test

4.3 Biomass yield: Dry biomass yield of *E. abyssinica* at 5 MAP on a sandy soil subjected to different fertilizers revealed very wide variation amongst the latter (Table 4).

Applied fertilizer treatments exhibited wider significant differences in influencing shoot, root or total dry matter production of the tree species. The unfertilized control significantly outperformed any fertilizing treatment for both shoot and root dry matter yields. Supply of 40 kg P ha^{-1} (T2) resulted in total biomass yield similar to that of the control (T0) over the 5 months of growth. The other treatments produced less than half of the biomass recorded for the control treatment. Treatments T10, T11, T8 and T9 produced significantly lower biomass in *E. abyssinica* than the control (Table 4). The highest rates of both N and/ or P ($N_{80}P_0$, $N_{80}P_{80}$, $N_{60}P_{80}$ and N_0P_{80}) induced mediocre response of the tree species tested.

In general for the 5 months growth period, *E abyssinica* allocated more of its biomass to below ground parts than to shoot biomass (Table 4). It was observed that *E. abyssinica* displays a very striking root system that comprises two distinct root types (Figure 2).

Figure 2: Root system of a 6-month old *Entada abyssinica* raised on a sandy soil

There were tuberous roots originating from the stem base and growing deep in the soil and ordinary roots. Tuberous roots, usually prolonged by normal fibrous roots, looked like those of cassava or either common tuber crop, and they bore no nodules. The ordinary fibrous roots grew at the same insertion point as the tuberous ones and much more after the tuber. Normal roots did all bear nodules.

4.4 Nodulation potential: At harvest done at 5 MAP, it was found that *E. abyssinica* was nodulating irrespective of the fertilization done. The nodules observed were of coralloid shape and of indeterminate type (Figure 3).

Figure 3: *Entada abyssinica* fibrous roots bearing collaroid nodules

Table 5 shows the extent of nodulation in sandy soil of *E. abyssinica* under the influence of different N and P fertilization rates. Nodule numbers per plant of *E. abyssinica* ranged from 4 to 32 with an overall mean of 12 per plant irrespective of treatments applied. The tree species bore more nodules when subjected to T7 and less under T8 (N_0P_{80}) (Table 5). T7 ($N_{60}P_{80}$) significantly ($p = 0.05$) outperformed in nodules number all other treatments applied to soil.

Table 5: Nodulation characteristics of *E. abyssinica* as influenced by the different fertilizer treatments at 5 MAP

Treatment	**Nodulation characteristics**[a]		
	Nodules no/plant	**Nodule dry weight (mg/ plant)**	**Nodulation Index**
T0 (N_0P_0)	15.5 ab	212.9 b	2.46 a
T1 ($N_{30}P_0$)	7.0 a	118.3 ab	2.66 a
T2 (N_0P_{40})	5.8 a	422.0 c	6.41 abc
T3 ($N_{30}P_{40}$)	20.0 b	204.6 b	4.75 abc
T4 ($N_{30}P_{80}$)	12.5 ab	333.7 c	9.08 c
T5 ($N_{60}P_0$)	5.0 a	51.7 a	1.92 a
T6 ($N_{60}P_{40}$)	9.3 ab	151.6 ab	9.42 c
T7 ($N_{60}P_{80}$)	32.0 c	345.5 c	6.68 abc
T8 (N_0P_{80})	4.3 a	43.6 a	2.92 ab
T9 ($N_{80}P_0$)	11.5 ab	110.3 ab	5.69 abc
T10 ($N_{80}P_{80}$)	12.8 ab	49.1 a	7.46 bc
T11 ($N_{80}P_{40}$)	6.8 a	59.7 a	5.73 abc
Mean	11.9	175.3	5.43
CV (%)	64.5	43.0	52.9

[a] In column, means sharing a same letter do not significantly differ at 5% level by the Duncan Multiple Range Test

However, for nodule dry yield per plant, the highest mean was observed under T2 followed by T7 and T4, which were not significantly (p=0.05) different.

As for nodulation index, the significantly high values over the control were recorded under the treatments T4 and T6 (*p= 0.01*) and under T7 and T10 (*p= 0.05*). In general, all the remaining six treatments involving N and P supply were not significantly different from the control (Table 5). Further, nodulation traits revealed a wide variation among and within treatments as high values of coefficients of variation (43 – 65%) occurred.

5 DISCUSSION

In general, all treatments applied to soil did influence variably the growth, biomass production and nodulation of *E. abyssinica.* Owing to pre-treatment of seeds to boost germination, soaking in hot water for 30 min resulted in highest germination rate (97.8%) as compared to physical and no-scarification (Table 1). Given that unscarified seeds produced up to 60.8% of seedlings after germination, it was concluded that there is no dormancy with these seeds. This corroborates earlier observation by Salim *et al.* (2002) that pretreatment of the seed is sometimes necessary because of the hardness of the seed coat and seed germination remains very high: 70-100%. However, hot water scarification should be recommended. Hot water stimulated efficient seed imbibition as *E. abyssinica* seeds are small, shining and very thin. Thus, slow but high germination rates were due only to seed hard coat that disables easy imbibition as observed earlier for other species by Skerman (1982) and Salim *et al.* (2002). For seeds of similar shape such as those of *Senna siamea* and *L. leucocephala,* scarification with hot water has been practiced (Kadiata *et al.*, 1996). In agreement with Skerman (1982) that 10% seed germination only per year would be sufficient to ensure any species survival. *E. abyssinica* seeds offer an advantage towards a high scale propagation of this tree species when need arises. Furthermore, it was observed that *E. abyssinica* naturally bears a very high numbers of pods and thus large quantity of seeds at maturity and this could be the reason why it persists in harsh savannah environment, characterized by yearly devastating bushfires.

The growth pattern in height (Table 2) as well as in basal stem diameter (Table 3) of *E. abyssinica* observed under T2 (N_0P_{40}) at 3 and 4 MAP could be ascribed to P supply (Skerman, 1982; Dommergues *et al.*, 1999). This growth trend slowed down by the end (at 5th month) such that the control (T0) became more performing than other treatments, probably because of P that got insufficient to plants due eventually to its adsorption or exhaustion in the soil.

The superiority of the control over other fertilizer treatments with regards to both growth and biomass production suggests that *E. abyssinica* plants are able to thrive on poor soil, and maintaining high N_2-fixing potential even in the absence of any fertilization. Thus, it is a low-demanding species for nutrients in contrast to *G. sepium* and *L. leucocephala* that require a good level of soil fertility for better start of growth (Dommergues *et al.*, 1999). Further, its nodulation without any rhizobium inoculation clearly indicates that it is not strain-specific and thus works with the “cowpea miscellany group” of rhizobia most common under the tropics.

The surprisingly special root structure of this species (Figure 3) marked by the existence of tubers could presumably explain why *E. abyssinica* withstands repeated bushfires in the savannah and still remains capable of sprouting yearly.

The results observed herein related to nodule dry weight that was nearly twice higher for T2 (N_0P_{40}) compared to the control T0 could be due to P application that might have stimulated the nod factors (McKay and Djordjevic, 1993). According to Dommergues *et al.* (1999), nodulation and N_2 fixation process do require more P than the plant growth, and often when a N_2-fixing plant responds positively to P application in its nodulation, its growth likewise improves. This is consistent with Sanginga *et al.* (1991) report on *L. leucocephala* inoculated with a rhizobium strain and subjected to 20 to 80 mg P kg^{-1} soil application that exhibited an increase in the nodule mass and in the amount of N_2 fixed as well.

Nevertheless, in the present study it was noted that *Entada* nodule dry weight rather decreased with the increasing amount of P applied to soil. Sanginga *et al.* (1989) also observed that the growth of *Casuarina*, *Allocasuarina torulosa* and *A. littoralis* was reduced when a higher P rate of 60 mg P kg^{-1} soil was applied. Further, it has been reported that in *G. sepium,* N_2-fixation does not increase following the application of P above 40 kg P ha^{-1} (Sanginga *et al.*, 1995). Thus, this study results suggest that the optimum P rate for *E. abyssinica* could be 40 kg P ha^{-1}.

High values observed of nodule numbers and nodulation index along with a rather low nodule dry weight did not give a clear picture of the nodulation status of the tree legume, likely due to a very high variation within treatments. In fact, this trend of nodulation parameters to exhibit very high variation (cv ≥ 52 - 65%) has been common in relation with the life span of nodules in leguminous plants and so they do mask some differences among treatments (Kadiata *et al*., 1996; Dommergues *et al*., 1999). Lower shoot yields compared to roots to which the species allocated much more of its biomass (above 50%), explains the highest index values recorded in most cases.

Most tree variables decreased with increasing amounts of N applied to soil in form of urea. This suggests that for the growth period considered, *E. abyssinica* does not require a supply of available N. Instead, the excess of available N appears to hinder nodulation of this tree (Richards and Soper, 1979; Oghoghorie and Pate, 1996).The presence of nodules on the control treatment (T0) confirms that (1) the N_2-fixing tree found an indigenous strain of rhizobium capable of nodulating in such an acid soil (pH 4.58), and that (2) in N and P-poor soil, *Entada* could grow and sustain its growth for many months.

6 CONCLUSION

Entada abyssinica seeds showed no dormancy. However, soaking of seeds in hot water for 30 min improves germination to 97.8 % and should be recommended to practice. Unfertilized *E. abyssinica* had enhanced performance in biomass yield, growth dynamics as well as in nodulation although application of 40 kg P ha^{-1} was outstanding for the latter. Thus, 40 kg P ha^{-1} is the optimal rate to apply. The species exhibited its capacity to establish, thrive and nodulate, and maintain high N_2 fixation on an unfertile sandy soil without any fertilization. This is unlike *L. leucocephala or G. sepium* among other exotic tree legumes so far tested in alley cropping. It is thus a promising, cheaper wild tree species for potential use in agroforestry particularly in most tropical savannah regions where soil deficiency in N and P prevail.

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