

**An Evaluation of the Effects of Organic and Inorganic Fertilizers on the
Growth Performance of Three Timber Species: *Cedrella odorata* L.,
Entandrophragma angolensis Welw. and *Terminalia superba* Diel., in
Nursery.**

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43
44 **ABSTRACT**

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46 **Aim:** To evaluate the effects of fertilization on the growth performance of *Cedrella*
47 *odorata*, *Entandrophragma angolensis* and *Terminalia superba* in nursery.

48 **Study Design:** A complete randomized block design was used.

49 **Place and Duration of the Study:** Screen house of the Department of Botany and Plant
50 Physiology, from September 2011 to July 2012.

51 **Methodology:** We used 10 nutrient treatments, nine of which were nutrient
52 combinations and one, a negative control. Urea was added at 75 mg and 112.50 mg
53 while super phosphate simple was added at 30 mg and 60 mg. Poultry manure from
54 broilers was added at 625 g. A total of 180 uniformly growing seedlings were treated with
55 fertilizers two weeks after transplanting. There were six replicates per treatment per
56 species. Information on height (cm), collar diameter (mm), leaf number, leaf area (cm²)
57 and biomass production (g) was collected fortnightly from the day of fertilizer application,
58 for a 120 days period.

59 **Results:** *Cedrella odorata* produced maximum seedling height (13.55 cm), leaf number
60 (9.99), leaf area (509.20 cm²) and total biomass (18.47g), *Terminalia superba* showed
61 maximum collar diameter (4.78 mm) while *Entandrophragma angolensis* had the least
62 growth performances.

63 **Conclusion:** Fertilization of seedlings of threatened species in nursery would be
64 necessary, because this will ensure their survival and improve their regeneration
65 following out planting.

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68 **Key words:** Fertilizers, Growth characteristics, Nutrient combination, Performance,
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1. INTRODUCTION

Fertilization with organic and inorganic fertilizers during forest seedling culture is one of the most crucial factors with a positive effect on seedling quality, performance and establishment [1]. Soil amendment, for forest nursery usually with organic matter, has also been reported to promote seedling quality [2]. Maintaining adequate fertility of forest nursery soils is of paramount importance to assure production of high quality planting stock [3]. High quality planting stocks will have better adaptation, resistance to environmental stress and will have better field performance over long term [4].

Tropical soils and forests are deficient in Nitrogen and Phosphorus nutrients and uptake of these limited quantities of nutrients by plant roots from litter is difficult [5, 6]. Therefore, inadequate management of nursery soil can result in depletion of soil fertility and a corresponding reduction in seedling growth [7, 3]. However, a healthy seedling must be supplied with all the nutrients in the proper proportion for efficient growth [8, 9] and development following out planting.

Timber seedlings have varied needs for nutrients and the demand for a particular element or nutrient depends upon the growth requirements of the species in question [10]. Environmental conditions also influence nutrient requirements for plant species in nursery and in the field [10]. Information on the fertilizer needs of plants in nursery for tropical forest species are available [11], but more of such information would be necessary, since conditions change and also because species-specific records are very essential for producing quality seedlings for out planting [1].

Cedrella odorata, *Entandrophragma angolensis* and *Terminalia superba* are important tree species found in the dense forests of Equatorial Africa including Cameroon, these species are amongst the most exploited and exported species of the region [12, 13]. Natural regeneration is reported to be poor and the distributions as well as the abundance of these species are decreasing [11, 12]. The wood from these species are light to moderately hard, exhibit characteristic strength and resistance to rot as compare to other softwood, durable and serve as

timber. They are exploited commercially for local consumption, used for the making of doors and window panels, in house construction, scantling and other uses [14, 15]. Besides the timber, the leaves, barks and roots are used in traditional medicines for primary healthcare [16].

The production of quality seedlings in nursery will improve the chances of seedlings survival on the field, since such seedlings are expected to better resist or tolerate stress and diseases [11]. The present study involved the combination of two inorganic fertilizers (Urea and Super phosphate simple) and organic fertilizer. The nutrients were added at four different levels in the potting mixture to observe the effects of added inorganic fertilizers (N and P) on seedlings of the three timber species in nursery. The aim of this study was therefore to determine nutrient combinations that will ensure good seedling performance for *Cedrella odorata*, *Entandrophragma angolensis* and *Terminalia superba*.

2. MATERIALS AND METHODS

2.1 STUDY SITE

This study was carried out in the screen house of the Department of Botany and Plant Physiology at the University of Buea campus, Cameroon. The Buea area has a humid tropical climate with an annual rainfall of about 2.800 mm, most of which is received between June and September [17, 18]. The mean annual temperature is 28°C while the relative humidity is about 85 % and the annual sunshine is between 900 to 1200 hours per annum [17]. The topography of Buea is mountainous; soil type is basically volcanic making it suitable for agriculture [19].

2.2 PREPARATION OF POTTING MIXTURE

Top soil used in this experiment was collected from fallow land at the University of Buea Campus. The soils were air dried and visible roots, leaves and other debris were removed by sieving. 1875 g soil was used to fill each 9 × 6 inch polythene bag for the experiment. Poultry droppings were collected from a broiler poultry farm and allowed to decompose for 8 weeks. In addition to poultry droppings, nitrogen (N) was in the form of Urea and phosphorus (P) as Super Phosphate Simple

(SPS). 180 seedlings with a mean height of 4.0 cm were transplanted into polythene bags and 6 seedlings per species were used for each treatment.

The amounts of nutrients added to each potting mix (1875 g soil) and the experimental combinations were as follows: Treatment 1: N0P0 (625 g poultry manure only), Treatment 2: N1P0 (75 mg urea, 0 mg SPS, 625 g Poultry manure), Treatment 3: N2P0 (112.5 mg urea, 0 mg SPS, 625 g poultry manure), Treatment 4: N0P1 (0 mg urea, 30 mg SPS, 625 g poultry manure), Treatment 5: N1P1 (75 mg urea, 30 mg SPS, 625 g poultry manure), Treatment 6: N2P1 (112.5 mg urea, 30mg SPS, 625 g poultry manure), Treatment 7: N0P2 (0 mg urea, 60 mg SPS, 625 g poultry manure), Treatment 8: N1P2 (75 mg urea, 60 mg SPS), Treatment 9: N2P2 (112.5 mg urea, 60 mg SPS, 625 g poultry manure) and Treatment 10: (top soil only). Watering was done with deionised water three times a week. Data on height, collar diameter, leaf area, leaf number and biomass were recorded fortnightly from the day of nutrient application.

2.3 DETERMINATION OF SOIL NUTRIENTS

Soil samples were collected at different sites of the fallowed land and air-dried. The following parameters were determined: Soil pH in a 2:5 (w/v) soil water suspension; organic carbon by chromic acid digestion and spectrophotometer analysis [20]. Total nitrogen was determined from wet acid digest [21], exchangeable cations (calcium, magnesium, and potassium) were extracted using the Mehlich-3 procedure [22] and determined by atomic absorption spectrophotometry. Available phosphorus was extracted by the Bray-1 procedure and analyzed using the molybdate blue procedure [23].

2.4 DATA COLLECTION

After establishment of the experiment, data were collected fortnightly. The measurements of height were taken from the ground level to the tip of the seedlings using a meter rule. Collar diameter was determined with the use of an electronic caliper (G02022 165). The numbers of leaves produced by seedlings were counted. Leaf area measurements were done using a leaf

area measuring system (Delta T devices. Model RS232). After 120 days of fertilization of seedlings, seedlings were harvested and partitioned into leaf, stem and root components. The fresh and dry weights of the different seedling components were noted. Total biomass (total dry weights) was obtained by adding dry weights of leaves, stems and roots.

2.5 DATA ANALYSIS

The effect of fertilization on the different growth parameters was evaluated by subjecting the collected data to one way and two way analysis of variance for within and between species interactions. The significance of the difference between means was tested using least significant differences (LSD). All statistical analyses were conducted using Minitab version 14.0 software (Minitab Inc., State College, PA, USA)

3. RESULTS

3.1 SOIL ANALYSIS

The chemical properties of the soil used in this experiment are shown on table 1.

Table 1. Chemical properties of experimental soil (0-20 cm)

Particulars	Value	Methods
pH (1:2.5:: Soil : Water)	5.17	Glass Electrode pH meter
Ca (Meq/100g)	2.13	Mehlich-3 and atomic absorption [22]
Mg (Meq/100g)	0.75	
K (Meq/100g)	0.18	
P ppm	3.20	Bray-1 and Molybdate blue [23]
Organic C, %	9.57	Chromic acid digestion [20]
Total N, %	0.61	Wet acid digest [21]

3.2 SEEDLING HEIGHTS

Generally, the addition of fertilizer led to a significant ($P = .00$) increase in height for *C. odorata* (table 2). The greatest height of 13.55 cm for this species was observed following the addition of urea (112.5 mg) and super phosphate simple (60 mg). Fertilization of *T. superba* also resulted in height increments but the difference was not significant for all nutrient additions. Exogenous addition of 30mg of SPS produced the best height of 9.57 cm for this species (table 2). This observation was similar for *E. angolensis* where the addition of Urea and SPS at 112.5 mg and 60 mg respectively produced the best height of 10.79 cm. The least heights were observed in situations where there were no nutrient additions except for *E. angolensis* in which the least height of 8.57 cm was observed with the addition of poultry manure (table 2).

3.3 NUMBER OF LEAVES

Fertilizer applications significantly increased leaf numbers for the *C. odorata* ($P = .00$) and *T. superba* ($P = .02$) but for *E. angolensis* there was no significant difference ($P = .82$). *C. odorata* produced a maximum of 10 leaves following the addition of urea at 112.5mg. *T. superba* responded to nutrient addition by the significant production of more leaves. The addition of poultry manure led to the maximum of 9 leaves for this species (table 2). Fertilization had no significant effect on leaf numbers for *E. angolensis* nonetheless; the highest leaf number of 4 was recorded with the addition of super phosphate simple at 30 mg. All nutrient treatments resulted in the production of more leaves as compared to the control (table 2).

3.4 COLLAR DIAMETER

Nutrient additions at all concentrations significantly ($P = .00$) increased collar diameter for *C. odorata*, with P additions at 30 mg producing the highest value of 4.33 mm (table 2). *T. superba* did not show any significant increase in collar diameter following the addition of P and N; however, the addition of poultry manure caused a significant ($P = .00$) increase in collar diameter (4.78 mm). *E. angolensis* did not show any significant gain ($P = .57$) in collar diameter following addition of nutrients at all concentrations (table 2).

Table 2. Mean height, leaf number, collar diameter and leaf area of three timber species following nutrient additions. Each value is a mean of six replicates. (Values in the same column of seedlings species followed by the same letters are not significantly different).

Species	Treatment	Height (cm)	Leaf number	Collar diameter (mm)	Leaf area(cm ²)
<i>C. odorata</i>	T1:N0P0	11.83 ^b	9.33 ^a	4.31b ^c	372.8 ^b
	T2:N1P0	12.83 ^{bc}	9.58 ^a	4.26b ^c	493.2 ^{b-d}
	T3: N2P0	12.88 ^{bc}	9.99 ^{ab}	4.21b ^c	500.8 ^{b-d}
	T4: N0P1	13.23 ^{bc}	9.38 ^a	4.33b ^c	509.2 ^{b-d}
	T5: N1P1	12.65 ^{bc}	9.13 ^a	4.30bc	465.8 ^{b-d}
	T6: N2P1	11.84 ^b	9.38 ^a	4.06 ^b	426.7 ^{bc}
	T7: N0P2	11.68 ^b	9.55 ^a	3.67 ^b	395.1 ^b
	T8: N1P2	11.21 ^b	9.46 ^a	4.05 ^b	399.9 ^b
	T9: N2P2	13.55 ^{bc}	9.46 ^a	4.07 ^b	503.9 ^{b-d}
	T10 :Control	9.06 ^a	7.91 ^b	3.06 ^a	216.4 ^a
<i>E. angolensis</i>	T1:N0P0	8.57 ^{ac}	3.71 ^a	2.88 ^a	90.8 ^{a-c}
	T2:N1P0	9.01 ^{ac}	3.91 ^a	2.90 ^a	92.3 ^{a-c}
	T3: N2P0	9.05 ^{ac}	3.94 ^a	2.64 ^a	59.3 ^d
	T4: N0P1	8.88 ^{ac}	4.10 ^a	2.66 ^a	75.0 ^a
	T5: N1P1	8.96 ^{ac}	3.49 ^a	2.73 ^a	85.5 ^{ac}
	T6: N2P1	9.56 ^{bc}	4.08 ^a	2.59 ^a	85.3 ^{ac}
	T7: N0P2	10.6 ^b	4.08 ^a	2.83 ^a	91.4 ^{a-c}
	T8: N1P2	10.5 ^b	3.91 ^a	2.89 ^a	90.6 ^{a-c}
	T9: N2P2	10.7 ^b	3.57 ^a	2.59 ^a	86.7 ^{ac}
	T10 :Control	9.14 ^{bc}	3.48 ^a	2.73 ^a	57.4 ^{bd}
<i>T. superba</i>	T1:N0P0	9.49 ^a	9.21 ^a	4.78 ^a	97.5 ^a
	T2:N1P0	9.01 ^{ab}	8.49 ^{ac}	2.84 ^b	97.6 ^a
	T3: N2P0	9.22 ^{ab}	8.69 ^{ac}	2.94 ^b	90.3 ^{ac}
	T4: N0P1	9.57 ^a	8.33 ^{ac}	3.27 ^b	98.8 ^a
	T5: N1P1	9.47 ^a	8.52 ^{ac}	2.82 ^b	86.3 ^{ac}
	T6: N2P1	9.12 ^{ab}	8.19 ^{ac}	2.64 ^b	77.0 ^b
	T7: N0P2	8.98 ^{ab}	8.46 ^{ac}	2.74 ^b	87.4 ^{ac}
	T8: N1P2	8.63 ^b	8.35 ^{ac}	2.67 ^b	79.6 ^b
	T9: N2P2	8.65 ^{ab}	7.94 ^{ac}	2.59 ^b	88.6 ^{ac}
	T10 :Control	8.24 ^b	7.02 ^b	2.45 ^b	72.4 ^d

3.5 TOTAL LEAF AREA

C. odorata and *T. superba* showed a similar response to P addition at 30 mg by producing significantly larger leaves. Their maximum leaf areas were 509.2 cm² and 98.8 cm² respectively

(table 2). *E. angolensis* did not show any significant increase in leaf area with nutrient additions. Nonetheless, the addition of N (urea 75 mg) resulted in the highest leaf area (92.3 cm²) for this species.

3.6 TOTAL BIOMASS

C. odorata and *T. superba* showed marked increase in total biomass with the addition of nutrients (Table 3). Generally, the total biomass of *C. odorata* seedlings increased the most with Nitrogen (N) than with combinations of Nitrogen (N) and Phosphorus (P) while the biomass of *T. superba* was highest (18.46 g) with phosphorus only (N0P1) than in combination. The maximum total biomass was 18.47 g recorded for *C. odorata* with treatment combination (N1P0). *E. angolensis* also demonstrated an increase in biomass (4.33 mg) following nutrient addition, but the values were inferior to those observed for the other two species (table 3)

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240 **Table 3. Mean dry weights of leaf, stem and roots as well as total biomass of**
 241 **seedlings of the three timber species.** Each value is a mean of six replicates. (Values in
 242 the same column of seedlings species followed by the same letters are not significantly
 243 different).

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Species	Treatment	Dry Wt. of leaf(g)	Dry Wt. of stem (g)	Dry Wt. of root (g)	Total biomass (g)
<i>C. odorata</i>	T1:N0P0	7.90 ^{bc}	3.70 ^b	3.86 ^a	15.46 ^b
	T2:N1P0	11.80 ^b	3.30 ^{bc}	3.37 ^c	18.47 ^a
	T3: N2P0	11.57 ^b	3.13 ^{bc}	3.40 ^c	18.10 ^b
	T4: N0P1	8.70 ^{bc}	3.50 ^{bc}	2.70 ^b	14.90 ^b
	T5: N1P1	9.07 ^{bc}	2.56 ^d	4.20 ^a	15.83 ^b
	T6: N2P1	4.73 ^d	2.80 ^d	2.60 ^b	10.13 ^c
	T7: N0P2	9.70 ^{bc}	3.20 ^{bc}	2.53 ^b	15.43 ^b
	T8: N1P2	8.50 ^{bc}	3.30 ^{bc}	5.87 ^d	17.67 ^a
	T9: N2P2	7.90 ^{bc}	3.30 ^{bc}	4.57 ^a	15.77 ^b
	T10 :Control	2.40 ^a	1.33 ^a	2.30 ^b	6.03 ^d
<i>E. angolensis</i>	T1:N0P0	1.33 ^b	0.86 ^{bc}	1.20 ^{ab}	3.40 ^{ac}
	T2:N1P0	2.90 ^a	0.63 ^{bc}	0.80 ^{ab}	4.33 ^b
	T3: N2P0	0.68 ^c	1.26 ^a	1.63 ^b	3.57 ^{a-c}
	T4: N0P1	1.43 ^b	0.53 ^{bc}	0.53 ^a	2.50 ^{ac}
	T5: N1P1	1.233 ^b	0.60 ^{bc}	0.73 ^a	2.57 ^{ac}
	T6: N2P1	1.167 ^b	0.56 ^{bc}	0.77 ^{ab}	2.50 ^{ac}
	T7: N0P2	1.467 ^b	0.70 ^{bc}	1.10 ^{ab}	3.27 ^{ac}
	T8: N1P2	1.50 ^b	0.86 ^{bc}	0.97 ^{ab}	3.33 ^{a-c}
	T9: N2P2	0.733 ^c	0.56 ^{bc}	0.50 ^a	1.80 ^a
	T10 :Control	0.66 ^c	0.43 ^{bc}	0.67 ^{ab}	2.97 ^{ac}
<i>T. superba</i>	T1:N0P0	9.40 ^d	2.43 ^c	1.90 ^{bc}	13.73 ^{ab}
	T2:N1P0	6.00 ^c	1.33 ^b	3.50 ^b	10.83 ^{bc}
	T3: N2P0	9.27 ^d	1.46 ^b	2.07 ^c	12.80 ^d
	T4: N0P1	11.43 ^b	3.70 ^a	3.33 ^b	18.46 ^a
	T5: N1P1	8.07 ^{dc}	1.46 ^d	2.23 ^c	11.77 ^{cd}
	T6: N2P1	6.40 ^c	1.63 ^d	1.07 ^a	9.10 ^c
	T7: N0P2	9.033 ^d	1.50 ^d	2.17 ^c	12.70 ^d
	T8: N1P2	10.07 ^{bc}	2.30 ^c	1.67 ^{bc}	14.03 ^{ab}
	T9: N2P2	7.13 ^{ab}	1.23 ^b	1.07 ^a	9.43 ^c
	T10 :Control	3.10 ^a	1.13 ^b	1.07 ^a	5.30 ^b

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250 4. DISCUSSION

251 The main morphological parameters used to evaluate seedling quality included seedling height,
252 number of leaves, collar diameter and leaf area [2]. These morphological attributes are vital
253 structures to assess quality of seedlings in nursery [2]. The results of this fertilizer application
254 study supports the general expected response that seedlings treated with appropriate
255 combination of fertilizers will yield better growth performance than seedlings with no nutrient
256 applications. This is also in conformity with earlier works on other plantation species such as
257 *Anthocephalus chinensis* and *Dalium guineense* [24, 3]. Positive results of fertilization were also
258 reported on *Xizyphus spinachristii* and *Zizyphus maldritania*.

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260 Fertilizer requirement of species differ, reasons why efforts must be made to identify the
261 appropriate fertilizer preference for all species. The inherent characteristics of species and
262 intraspecific genotypes play an important role in restricting or enhancing efficiency of plants in the
263 uptake, use and tolerance to mineral elements [25]. The different combinations of nitrogen,
264 phosphorus and organic fertilizers significantly ($P < .05$) affected some important morphological
265 traits and biomass production of *C. odorata*, *E. angolensis* and *T. superba* examined in this study.
266 This could be attributed to the two essential minerals (N and P) required for optimum plant growth
267 and development. Nitrogen, phosphorus and potassium are reported to be essential for plant
268 growth, particularly at the nursery state [25].

269

270 The best mean height of *C. odorata* and *E. angolensis* was recorded with the addition of N (112.5
271 mg) and P (60 mg). This observed increase in growth in response to N and P application is not
272 unusual. It had been demonstrated that plants which received adequate N showed vigorous
273 elongation of stem [26] thus, N promoted vegetative growth of stems and leaves. Phosphorus is
274 intimately associated with all life processes and is a vital constituent of every living cell. It is also
275 important because a high concentration of P is found in plant parts that are growing rapidly [26].
276 Similar findings had been reported by other researchers in studies on fertilizer treatments on

plantation seedlings of *Anthocephalus chinensis* and *Dalium guineense* in nursery [24, 3]. The maximum leaf number in this study was obtained with treatment combination N2P0. Basically, N has been called the growth element because it is a vital part of plant protoplasm. Protoplasm is the seat of cell division and, therefore, plant growth [26]. It is also one of the fundamental units in proteins, nucleic acid and chlorophyll; it controls the formation of seedlings foliage [25]. The maximum collar diameter in this study was recorded with treatment combination N0P0 (decomposed poultry manure). The slow release of nutrients from organic origin gives rooms for maximum utilization of nutrients for cell division, enlargement and building of stem biomass of seedlings. The gradual release of nutrient prevented leaching of nutrients and allows ample time for fine roots to take up nutrients for biomass increment [25]. Poultry manure is very rich in nitrogen, a probable reason for the observed diameter increment.

Leaf area production was optimal with treatment combination of N0P1. Subsequent release of Phosphorus which was applied in a rock form as Super Phosphate Simple increased the leaf area of seedlings. Phosphorus may have contributed in increasing the leaf area by promoting photosynthesis, thus enhancing energy formation for cell division and expansion. A similar observation was reported on influence of nutrients on seedlings of *Terminalia bellirica* in nursery [26].

Total biomass was generally influenced by the addition of nitrogen and phosphorus solely and in combination. The increased availability of N in the root zone might have encouraged uptake by seedlings resulting in higher growth and eventual accumulation of biomass. Similar results of increased biomass of seedlings due to nitrification inhibition were reported in *Picea abies*, *Pinus sylvestris* and *Abies alba* seedlings [27] and in *Pseudotsuga menziesii* (Douglas fir) seedlings [28].

The fact that nitrogen is essential for the formation of proteins in addition to its role in photosynthesis, the high uptake of nitrogen resulted in higher production and partitioning of

305 photosynthates to the different plant parts resulting to high biomass production [27]. Phosphorus
306 may also have contributed in enhancing biomass production by increasing photosynthesis, cell
307 division and cell enlargement, in which phosphorus play a paramount role in the anabolic
308 processes.

310 **5. CONCLUSION**

311 From all aspects, it was observed that, nitrogen and phosphorus fertilizers obviously had
312 beneficial effects, thus the increase in heights, leaf numbers, collar diameter, leaf area and total
313 biomass production of these timber seedlings in nursery. It was also observed that generally, all
314 the fertilizer combinations influenced the growth of seedlings in nursery as the values were better
315 than those observed with the control treatment. The results of the present study indicated that *C.*
316 *odorata* and *T. superba* had better performances with treatment applications than *E. angolensis*.
317 This pot experiment provides a basis for fertilizer trials in the field. There is need for many of such
318 studies so that nursery quality of endangered species could be improved and thus guaranteeing
319 their survival following out planting in regeneration programs.

321 **ACKNOWLEDGEMENTS**

322 Authors are grateful to the University of Buea for providing partial funding for this research. We
323 also gratefully acknowledge Dr. Focho Derek Afa for his technical contribution to this work before
324 his death and finally to the management of the Limbe Botanic Garden for species identification
325 and advice on nursery techniques. We would like to thank the anonymous reviewers, whose
326 comments have helped to greatly improve the quality of the manuscript.

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