

Research paper

Comment [m1]:

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.

Abstract

The continuous destruction of rainforest threatens many useful and multipurpose plant species such as *Cedrella odorata*, *Entandrophragma angolensis* and *Terminalia superba*. In this study we evaluated the effect of fertilization on the growth performance of these species in nursery. We used 10 nutrients treatments, nine of which were nutrient combinations and one, a negative control. Urea was added at 75 mg and 112.50 mg while super phosphate simple was added at 30 mg and 60 mg. A total of 120 uniformly growing seedlings were treated with fertilizers two weeks after transplanting. Information on height (cm), collar diameter (mm), leaf number, leaf area (cm²) and biomass production (g) was collected fortnightly for a 120 days period. *Cedrella odorata* produced maximum seedling height (13.55 cm), leaf number (9.99), leaf area (509.20 cm²) and total biomass (18.47g), *Terminalia superba* showed maximum collar diameter (4.78 mm) while *Entandrophragma angolensis* had the least growth performances.

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Key words: Fertilizers, Growth characteristics, Nutrient combination, Performance,

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35 **Introduction**

36 Fertilization with organic and inorganic fertilizers during forest seedling culture is one of
 37 the most crucial factors with a positive effect on seedling quality, performance and
 38 establishment (Rafiqul *et al.*, 2004). Soil amendment, for forest nursery usually with
 39 organic matter, has also been reported to promote seedling quality (Focho *et al.*, 2011).
 40 Maintaining adequate fertility of forest nursery soils is of paramount importance to assure
 41 production of high quality planting stock (Hoque *et al.*, 2004). High quality planting
 42 stocks will have better adaptation, resistance to environmental stress and will have better
 43 field performance over long term (Davis and Jacob 2005).

44

45 Tropical soils and forest are deficient in Nitrogen and Phosphorus nutrients and uptake of
 46 these limited quantities of nutrients by plant roots from litter is difficult (Lawrence, 2003;
 47 Jose, 2003). Therefore, inadequate management of nursery soil can result in depletion of
 48 soil fertility and a corresponding reduction in seedling growth (Ang *et al.*, 1995; Hoque *et*
 49 *al.*, 2004). However, a healthy seedling must be supplied with all the nutrients in the

Comment [m5]: forests

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proper proportion for efficient growth (Craven *et al.*, 2006; Gbadamosi, 2006) and development following outplanting.

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 (Ingested, 1979b). Environmental conditions also influence nutrient requirements for plant species in nursery and in the field (Ingested, 1979b). Information on the fertilizer needs of plants in nursery for tropical forest species are available (Nwoboshi, 1982), 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 (Rafiqul *et al.*, 2004).

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 (Laird, 1995; Shono *et al.*, 2007). Natural regeneration is reported to be poor and the distributions as well as the abundance of these species are decreasing (Nwoboshi, 1982; Laird, 1995). 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 (FAO, 2000; Andre, 2001). Besides the timber, the leaves, barks and roots are used in traditional medicines for primary healthcare (Sofowora, 1993).

74 The production of quality seedlings in nursery will better the chances of seedlings
 75 survival on the field, since such seedlings are expected to better resist or tolerate stress
 76 and diseases (Nwoboshi, 1982). The present study involved the combination of two
 77 inorganic fertilizers (Urea and Super phosphate simple) and organic fertilizer. The
 78 nutrients were added at four different levels in the potting mixture to observe the effects
 79 of added inorganic fertilizers (N and P) on seedlings of the four timber species in nursery.
 80 The aim of this study was therefore to determine nutrient combinations that will ensure
 81 good seedling performance for *Cedrella odorata*, *Entandrophragma angolensis* and
 82 *Terminalia superba*.

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84 MATERIALS AND METHODS

85 Study site

86 This study was carried out in the screen house of the Department of Botany and Plant
 87 Physiology at the University of Buea campus, Cameroon. The Buea area has a humid
 88 tropical climate with an annual rainfall of about 2.800 mm, most of which is received
 89 between June and September (Ndam, 1996; Peguy *et al.*, 1999). The mean annual
 90 temperature is 28°C while the relative humidity was about 85 % and the annual sunshine
 91 is between 900 to 1200 hours per annum (Ndam, 1996). The topography of Buea is
 92 mountainous; soil type is basically volcanic making it suitable for agriculture (Cable and
 93 Cheek, 1998).

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95 Preparation of potting mixture

96 Top soil used in this experiment was collected from fallow land at the University of Buea
 97 Campus. The soils were air dried and visible roots, leaves and other debris were removed

by sieving. Poultry droppings were collected from a poultry farm and allowed to decompose for 8 weeks. 9 × 6 inch polythene bags were used for the experiment. In addition to poultry droppings, nitrogen (N) was in the form of Urea and phosphorus (P) as Super Phosphate Simple (SPS). 120 seedlings with a mean height of 4.0 cm were transplanted into polythene bags and 12 seedlings per species were used for each treatment.

The amounts of nutrients added to each potting mix and the experimental combinations were as follows: Treatment 1: N0P0 (organic manure only), Treatment 2: N1P0 (75 mg urea, 0 mg SPS), Treatment 3: N2P0 (112.5 mg urea, 0 mg SPS), Treatment 4: N0P1 (0 mg urea, 30 mg SPS), Treatment 5: N1P1 (75 mg urea, 30 mg SPS), Treatment 6: N2P1 (112.5 mg urea, 30mg SPS), Treatment 7: N0P2 (0 mg urea, 60 mg SPS), Treatment 8: N1P2 (75 mg urea, 60 mg SPS), Treatment 9: N2P2 (112.5 mg urea, 60 mg SPS) 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.

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 (Hanes, 1984). Total nitrogen was determined from wet acid digest (Buondonno et al., 1993), exchangeable cations (calcium, magnesium, and potassium) were extracted using the Mehlich-3 procedure (Mehlich, 1984) and determined by atomic absorption

122 spectrophotometry. Available phosphorus was extracted by the Bray-1 procedure and
123 analyzed using the molybdate blue procedure described by Murphy and Riley (1962).

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125 **Data Collection**

126 After establishment of the experiment, data were collected fortnightly. The measurements
127 of height were taken from the ground level to the tip of the seedlings using a meter rule.
128 Collar diameter was determined with the use of an electronic caliper (G02022 165). The
129 numbers of leaves produced by seedlings were counted. Leaf area measurements were
130 done using a leaf area measuring system (Delta T devices. Model RS232). After 120 days
131 of fertilisation of seedlings, seedlings were harvested and partitioned into leaf, stem and
132 root components. The fresh and dry weights of the different seedling components were
133 noted. Total biomass (total dry weights) was obtained by adding dry weights of leaves,
134 stems and roots.

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136 **Data analysis**

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

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143 **RESULTS**

144 **Soil analysis**

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

Comment [m11]: fertilization

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147 **Seedling heights**

148 Generally, the addition of fertilizer led to a significant ($P<0.05$) increase in height for *C.*
 149 *odorata* (table 2). The greatest height of 13.55 cm for this species was observed
 150 following the addition of urea (112.5 mg) and super phosphate simple (60 mg).
 151 Fertilization of *T. superba* also resulted in height increments but the difference was not
 152 significant for all nutrient additions. Exogenous addition of 30mg of SPS produced the
 153 best height of 9.57 cm for this species (table 2). This observation was similar for *E.*
 154 *angolensis* where the addition of Urea and SPS at 112.5 mg and 60 mg respectively
 155 produced the best height of 10.79 cm. The least heights were observed in situations where
 156 there were no nutrient additions except for *E. angolensis* in which the least height of 8.57
 157 cm was observed with the addition of poultry manure (table 2).

158

159 **Number of leaves**

160 Fertilizer applications significantly ($P<0.05$) increased leaf numbers for the species except
 161 for *E. angolensis*. *C. odorata* produced a maximum of 10 leaves following the addition of
 162 urea at 112.5mg. *T. superba* responded to nutrient addition by the significant production
 163 of more leaves. The addition of poultry manure led to the maximum of 9 leaves for this
 164 species (table 2). Fertilization had no significant effect on leaf numbers for *E. angolensis*
 165 nonetheless; the highest leaf number of 4 was recorded with the addition of super
 166 phosphate simple at 30 mg. All nutrient treatments resulted in the production of more
 167 leaves as compared to the control (table 2).

168

169 **Collar diameter**

170 Nutrient additions at all concentrations significantly ($P<0.05$) increased collar diameter
171 for *C. odorata*, with P additions at 30 mg producing the highest value of 4.33 mm (table
172 2). *T. superba* did not show any significant increase in collar diameter following the
173 addition of P and N; however, the addition of poultry manure caused a significant
174 increase in collar diameter (4.78 mm). *E. angolensis* did not show any significant gain in
175 collar diameter following addition of nutrients at all concentrations (table 2).

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179 **Total leaf area**

180 *C. odorata* and *T. superba* showed a similar response to P addition at 30 mg by producing
181 significantly larger leaves. Their maximum leaf areas were 509.2 cm² and 98.8 cm²
182 respectively (table 2). *E. angolensis* did not show any significant increase in leaf area
183 with nutrient additions. Nonetheless, the addition of N (urea 75 mg) resulted in the
184 highest leaf area (92.3 cm²) for this species.

185

186 **Total Biomass**

187 *C. odorata* and *T. superba* showed marked increase in total biomass with the addition of
188 nutrients (Table 3). Generally, the total biomass of *C. odorata* seedlings increased the
189 most with Nitrogen (N) than with combinations of Nitrogen (N) and Phosphorus (P)
190 while the biomass of *T. superba* was highest (18.46 g) with phosphorus only (N0P1) than
191 in combination. The maximum total biomass was 18.47 g recorded for *C. odorata* with
192 treatment combination (N1P0). *E. angolensis* also demonstrated an increase in biomass

193 (4.33 mg) following nutrient addition, but the values were inferior to those observed for
194 the other two species (table 3)

195

196 Discussion

197 The main morphological parameters used to evaluate seedling quality included seedling
198 height, number of leaves, collar diameter and leaf area (Focho *et al.*, 2011). These
199 morphological attributes are vital structures to assess quality of seedlings in nursery
200 (Focho *et al.*, 2011). The results of this fertilizer application study supports the general
201 expected response that seedlings treated with appropriate combination of fertilizers will
202 yield better growth performance than seedlings with no nutrient applications. This is also
203 in conformity with earlier works on other plantation species such as *Anthocephalus*
204 *chinensis* and *Dalium guineense* (Okeke and Omaliko 1997; Hoque, 2004). Positive
205 results of fertilization were also reported on *Xizyphus spinachristii* and *Zizypus*
206 *maldritania*.

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Comment [m13]: Zizyphus

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208 Fertilizer requirement of species differ, reasons why efforts must be made to identify the
209 appropriate fertilizer preference for all species. According to Offiong *et al.*, (2010), the
210 inherent characteristics of species and intraspecific genotypes play an important role in
211 restricting or enhancing efficiency of plants in the uptake, use and tolerance to mineral
212 elements. The different combinations of nitrogen, phosphorus and organic fertilizers
213 significantly ($p < 0.05$) affected some important morphological traits and biomass
214 production of *C. odorata*, *E. angolensis* and *T. superba* examined in this study. This
215 could be attributed to the two essential minerals (N and P) required for optimum plant

216 growth and development. Offiong *et al.*, (2010) reported that nitrogen, phosphorus and
217 potassium are essential for plant growth, particularly at the nursery state.

218

219 The best mean height of *C. odorata* and *E. angolensis* was recorded with the addition of
220 N (112.5 mg) and P (60 mg). This observed increase in growth in response to N and P
221 application is not unusual. Abod and Siddiqui (2002) had demonstrated that plants which
222 received adequate N showed vigorous elongation of stem thus, N promoted vegetative
223 growth of stems and leaves. Phosphorus is intimately associated with all life processes
224 and is a vital constituent of every living cell. It is also important because a high
225 concentration of P is found in plant parts that are growing rapidly (Abod and Siddiqui
226 2002). Similar findings had been reported by Okeke and Omaliko (1997) and Hoque,

227 (2004) in their studies on fertilizer treatments on plantation seedlings of *Anthocephalus*
228 *chinensis* and *Dalium guineense* in nursery. The maximum leaf number in this study was
229 obtained with treatment combination N2P0. Basically, N has been called the growth
230 element because it is a vital part of plant protoplasm. Protoplasm is the seat of cell
231 division and, therefore, plant growth (Abod and Siddiqui 2002). It is also one of the
232 fundamental units in proteins, nucleic acid and chlorophyll; it controls the formation of
233 seedlings foliage (Offiong *et al.*, 2010). The maximum collar diameter in this study was
234 recorded with treatment combination N0P0 (decomposed poultry manure). The slow
235 release of nutrients from organic origin gives rooms for maximum utilization of nutrients
236 for cell division, enlargement and building of stem biomass of seedlings. The gradual
237 release of nutrient prevented leaching of nutrients and allows ample time for fine roots to
238 take up nutrients for biomass increment (Offiong *et al.*, 2010). Poultry manure is very

Comment [m14]: Hoque et al

239 rich in nitrogen, a probable reason for the observed diameter increment (Abod and
240 Siddiqui 2002)

241

242 Leaf area production was optimal with treatment combination of N0P1. Subsequent
243 release of Phosphorus which was applied in a rock form as Super Phosphate Simple
244 increased the leaf area of seedlings. Phosphorus may have contributed in increasing the
245 leaf area by promoting photosynthesis, thus enhancing energy formation for cell division
246 and expansion. A similar observation was reported by Mariswamy *et al.*, (2011) on
247 influence of nutrients on seedlings of *Terminalia bellirica* in nursery.

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249 Total biomass was generally influenced by the addition of nitrogen and phosphorus solely
250 and in combination. The increased availability of N in the root zone might have
251 encouraged uptake by seedlings resulting in higher growth and eventual accumulation of
252 biomass. Similar results of increased biomass of seedlings due to nitrification inhibition
253 were reported by Rastovski (1997) in *Picea abies*, *Pinus sylvestris* and *Abies alba*
254 seedlings and Jacobs *et al.* (2003) in *Pseudotsuga menziesii* (Douglas fir) seedlings.

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256 The fact that nitrogen is essential for the formation of proteins in addition to its role in
257 photosynthesis, the high uptake of nitrogen resulted in higher production and partitioning
258 of photosynthates to the different plant parts resulting to high biomass production
259 (Mariswamy *et al.*, (2011). Phosphorus may also have contributed in enhancing biomass
260 production by increasing photosynthesis, cell division and cell enlargement, in which
261 phosphorus play a paramount role in the anabolic processes.

262

263 Conclusion

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

274

275 Acknowledgement

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 277 research. We also gratefully acknowledge Dr. Focho Derek Afa for his technical
 278 contribution to this work before his death and finally to the management of the Limbe
 279 Botanic Garden for species identification and advice on nursery techniques.

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371 **Table: 1. Chemical properties of soil used in the screen house experiment. Soil**
 372 **collected 0 to 20cm from fallowed land at the University of Buea campus**

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Parameter	Chemical Properties
p ^H	5.17
Ca Meq/100g	2.13
Mg Meq/100g	0.75
K Meq/100g	0.18
P ppm	3.20

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388	Org C %		9.57			
389						
	Species	Treatment	Height (cm)	Leaf number	Collar diameter (mm)	Leaf area(cm²)

390	Tot N %		0.61			
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411	Table 2. Growth parameters (height, leaf number, collar diameter and leaf area) of different					
412	seedling species.(Values in the same column of seedlings species followed by the same					
413	letters are not significantly different)					
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415						

<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

425

426 Table 3. Growth parameters (Dry weights of leaf, stem and roots as well as total biomass) of different seedling species. (Values in the same column of seedlings species followed by the same letters are not significantly different)

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