Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 2(2) pp. 047-058, February, 2013.
Available online http://garj.org/garjas/index.htm

Full Length Research Paper

Early growth, biomass allocation and water use efficiency of three species of tropical tree seedlings at four moisture level

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Accepted 19 February, 2013

Afforestation or reforestation of degraded water catchment with tree species that have good growth performance and low water-use efficiency is paramount in sustainable water catchment management. This study evaluates the growth performance of three species of tree seedlings (*Eucalyptus grandis*, *Albizia ferruginea* and *Erythrina excelsa*) treated at four moisture levels (12.5, 25, 50 and 100%) of the soil field capacity for a period of six months. The species were also assessed for their rate of transpiration, evapotranspiration and water-use efficiency. Results indicates that the species had best morphological growth when treated with 50% soil moisture level and this was not significantly different from seedlings with 100% soil moisture level. The least growth performance was in seedlings treated with 12.5% soil moisture level. Total biomass of *Albizia* seedlings was best in 50% soil moisture level (51.9g) while 100% was best for *Erythrina* (54.6g) and *Eucalyptus* (27.7g). Root/shoot ratios were greater than 1.0 in all the treatments for *Albizia* while in *Eucalyptus* it was less than 1.0. Rate of transpiration varied significantly (P≤ 0.03) with the highest value in *Erythrina* (0.23g$H_2O/s/m^2$) and the least in *Eucalyptus* (0.11g$H_2O/s/m^2$). Rate of evapotranspiration did not differ significantly (P≤ 0.13) for the different tree seedlings. Water-use efficiencies differed significantly (P≤ 0.001) with *Albizia* requiring the least (1173ml/g) and *Eucalyptus* needing the highest (2388ml/g)amount of water to produce 1g of biomass. *Albizia ferruginea* is more suitable for aforestation/reforestation of water catchment areas than the other two species.

Keywords: Growth parameters, Soil moisture levels, Transpiration, Water-use efficiency, Water catchment areas, soil field capacity.

INTRODUCTION

Tree growth parameters are commonly studied to understand the behaviour of trees under different nutrient, water or light conditions (Zahid and Nawaz, 2009). These have often provided important clues in mitigating resource depletion. Studies have demonstrated that soil moisture variation affect plant distribution at the global scale

(Chuyong et al., 2003; Engelbrecht et al., 2005). At the microhabitat scale, soil moisture influences plant anatomy and physiology (Engelbrecht and Krursar, 2003). The growth rate hypothesis (Stamp, 2003) remarks that plants that have evolved in low resource or stressful environments exhibit inherently slower growth rates than plants from more productive habitats (Zandt, 2007). Trees adjust their morpho-physiological traits to cope successfully with changes in soil water availability (Bucci et al., 2008). When soil water is gradually depleted, a number of tree functions are inhibited (Li et al., 2005), leaf pigmentation change (Cernusak et al., 2007; Shaltout et al., 2009) and biomass allocation is either decreased or increased (Glynn and Ian, 2008).Higher drought tolerance employs a conservative water-use strategy while lower drought tolerance employs a prodigal water-use strategy (Li et al., 2005). High rates of productivity in trees are often associated with high rates of water use (Zahid and Nawaz, 2009).

Anthropogenic activities affect environmental systems and water catchment processes more severely than the natural factors in the North West Region of Cameroon (Ndenecho, 2009).This is consistent with findings in South Africa that there are water shortages in areas where *Eucalyptus* forests have replaced native trees (Whitehead and Beadle, 2004; Otieno et al., 2005). Where slash-and-burn agricultural practices are used, the soils and streams are exposed to the full strength of solar radiation and erosion (Margulis, 2005). . In the North West Region of Cameroon the use of understudied- and low water-use efficiency exotic plants coupled with indiscriminate deforestation have dried up many aquifers, springs, surface streams, pools and riffles Ndenecho (2009).

The adoption of good strategies in water catchment area management (Andah, 2003) is therefore indispensable, yet requires significant research. In the North West Region of Cameroon, *Eucalyptus species* are predominantly used in afforestation and reforestation, yet Zahid and Nawaz (2009) have shown that these species have increased water-use (lower Transpiration Coefficient) which may lead to desertification and lowering ground water-table. Therefore for effective afforestation and reforestation in catchment areas, it is essential to understand the water requirements and efficiency of target species, and tree seedlings are amenable to laboratory studies. This study evaluated the effect of different soil moisture levels on the early growth performance and water use efficiencies of tree seedlings of three species commonly used in the area, to assess their suitability for water catchment reforestation/afforestation.

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MATERIAL AND METHODS

Study Site

This study was carried out in the lathe house of the Department of Botany and Plant Physiology, University of Buea. This area is located in the Southwest Region of Cameroon between latitude $3^0 57^1$ to $4^0 27^1$N and longitude $8^0 58^1$ to $9^0 25^1$E. Buea is located on the eastern slope of Mount Cameroon. It has a mean annual rainfall of about 2800mm, received mostly between June and September (Egbe and Tabot, 2011). The mean annual temperature, mean relative humidity and sunshine are 28^0, 86% and 900 to 12000 hours per annum respectively (Egbe and Tabot, 2011). Buea is mountainous with thick evergreen forest vegetation and transitional changes along altitudinal gradient. Agriculture is the major activity in this region and this is done mostly by shifting cultivation and organized commercial plantations by CDC (Egbe and Tabot, 2011).

Study species

Albiziaferruginea (Guill. and Perr.) Benth is a Fabaceace and the tree can reach a height of 40 m when mature.It grows best at altitudes of 0-1200 m above sea level in the tropical rainforest (Agyare et al., 2006). This species has distribution in Angola, Burkina Faso, Cote d'Ivoire, Cameroon, Guinea-Bissau, Nigeria, Senegal and Uganda (Orwa et al., 2009). The plant is use as timber and has other uses such as in apiculture, fodder for goats, fuel, nitrogen fixation, ornamental, saponins, sterols, tannins, and medicine. According to Agyare et al. (2006), an ethyl alcohol extract of the tree bark is significantly active against bacterial and fungal infections. It has a high potential for economic exploitation but its utilisation for reforestation of water catchment have not been evaluated.

Erythrina excelsa Baker (Fabaceace) is a deciduous medium-sized tree, which can attain a height of 35m. It occurs mostly around riverside and swampy forest and at altitude of 110-1500 m. It is common in Democratic Republic of Congo, Cameroon, Ivory Coast, Mali, Southern Nigeria, Sudan throughout East Africa except Zanzibar (Mackinder et al., 2001). It is reported as good fuel wood and Ornamental (Lemmens, 2008), furniture wood (Omeja et al., 2004), and medicinal tree. The bark sap is antidote for snakebites (Owuor and Kisangau, 2007).

Eucalyptus grandis Hill ex Maid is a rapidly growing tree that attains a height of about 75 m in natural stands. It has a smooth white bark above a short rough basal stocking (Hunde et al., 2003). *Eucalyptus species* is probably the most widely planted of all eucalyptus for industrial wood production. It grows best between 0-1100 m altitudes; 725-3750 mm mean annual rainfall and $0\text{-}34^oC$ mean annual temperature (McMahon et al., 2010). *Eucalyptus grandis* has enormous economic importance in apiculture

Table 1. Chemical properties of the top soil used in the study

PROPERTIES	CONCENTRATIONS
Organic Carbon	4.09%
Total nitrogen	0.4%
Carbon/nitrogen	10
Mean phosphorus	7 mg/kg
PH (H_2O)	6.22
PH (KCl)	4.92
Na^+	0.07 cmol/kg
K^+	0.64 cmol/kg
Mg^{2+}	6.29 cmol/kg
Ca^{2+}	10.83 cmol/kg
Al^{3+}	0.65 cmol/kg
ECEC	18.48 cmol/kg
CEC	28.36 cmol/kg

(McMahon et al., 2010), fibre like sulphate pulp and fuel (Orwa et al., 2009), processed wood (Orwa et al., 2009), solid timber and wood Panels (McMahon et al., 2010). Despite all these economic importance, there are growing concerns on the water use efficiency of these species on the water catchment stability.

METHODOLOGIES

Growth performance of three species of tree seedlings at four moisture levels

Seeds of *Albizia ferruginea*, *Erythrina excelsa*, and *Eucalyptus grandis* were collected from local stands in the North West region of Cameroon. The seeds were sown into seed boxes in the shade house of the University of Buea. After germination, the seedlings were pre-transplanted into 12.5 by 25 cm polythene pots filled with topsoil. The soil type was basically volcanic, rich in mineral content. The analysed top soil had the following chemical properties (Table 1).

All the pre-transplanted seedlings were hardened for five weeks to acclimatize them before application of the various treatments. Soil moisture levels (25, 50,100 and 200ml) were determined as12.5, 25, 50 and 100% of the soil moisture field capacity. Soil moisture field capacity was gravimetrically determined. Five pots to be used in the experiment were filled with the topsoil used in the experiment. The pots were watered to saturation and allowed to stand for at least three hours for water in the soil macro-pores to drain completely by gravity. The soil at field capacity was weighed and transferred to weighed containers and oven dried at 105^0Cto constant weight in an air flow oven (Gallenhamp Hotbox). The soil moisture at field capacity was determined as the difference between the mass of soil moisture at field capacity and that of oven dried soils and the mean value calculated.144 seedlings were treated to different soil moisture levels. The experiment was a completely randomized design in three replicates and the seedlings were placed in a lathe house. The pots were watered twice weekly with the various volumes of water as indicated in Masinde et al. (2006).

The water levels of 12.5, 25 and 50-100% of the soil field capacity which mimicked the soil water potential levels recorded in tropical regions in the dry season, after the rainy season and during the rainy season (Martinez-Berdeja and Valverde, 2008). Initial measurements of growth parameters were taken by non-destructive method and subsequent measurements were carried out at 14 days intervals for a total duration of 6 months. The parameters included collar diameter that was measured with an electronic veneer calliper (Shenzhen® G02022615) to the nearest 0.1mm.The height was measured from a point at the soil surface to tip of terminal bud with a meter rule to the nearest 0.1cm. Fully open leaves were counted.

At the end of the experiment, the seedlings roots were carefully removed from the pot and washed with tap water repeatedly to remove all the soil particles and main lateral roots counted. The length of tap root was measured with a meter rule. The seedlings were partitioned into roots, stems and leaves and their fresh weights recorded with an electronic balance (Ohaus Scout TM Pro) to the nearest 0.01g.These were oven dried to constant weight at 70^0C and dry weight recorded. Leaf area was measured with a leaf area meter (Orsenigo 121TM35) to the nearest 1.0cm^2. Leaf area ratio (LAR), leaf mass fraction (LMF), stem mass fraction (SMF), root mass fraction (RMF), specific leaf area

(SLA), specific stem length (SSL) and root shoot ratio (RSR) were determined according to Bloor and Grubb, (2003).

Evaluation of rate of transpiration, evapotranspiration and water-use efficiencies of the tree seedlings in nursery

18 potted seedlings at six months were selected from the three species and supplied with 100% field capacity. The pots were watered to saturation, allowed to drain completely of gravitational water after 3 hours. Three of the 6 pots with seedlings for each species were covered with polythene bags from the bottom of each pot to the soil surface of the pots to prevent evaporation of water from the soil surface. The other three pots, the soil surfaces were not covered. The latter were used to determine the evapotranspiration of the tree seedlings. The potted seedlings with soil moisture at field capacity were weighed using an electronic balance (Scout TM Pro) and placed in an open environment (100% light). The weights of the pots were measured at 30 minutes intervals for 6 hours (10 am to 4pm) each day for three days. The rate of transpiration/evapotranspiration was determined by the gravimetric method. Light intensity was measured at 30 minutes intervals using a photo detector luxmeter (MASTECH ® MS6610). Data on relative humidity was obtained from Cameroon Development Co-operation (CDC) meteorological Centre in Tiko which is about 12 km from Buea and is the closest weather station.

Rate of transpiration and evapotranspiration for each square meter of leaves of species was calculated from equation (1).

$\varepsilon = (wi - \mathrm{wf})/(tf - ti) \times \mathrm{TLA}/10000$---------(1)

Where, ε = rate of transpiration or rate of evapotranspiration as appropriate.

Wi and Wf were masses measured at an initial time ti and after a given time lapse, time tf respectively

TLA= Total leaf area of the seedling measured in cm2 and using a leaf area metre (Orsenigo 121TM35).

Changes in masses were plotted against time where the fraction $(wi - \mathrm{wf})/(tf - ti)$was obtained as the slope of the plot.

Water use efficiency calculated as milliliters of water needed to produce 1g of biomass was achieved by using the equation described by Jones (2004).

$\boldsymbol{WUE} = \mathbf{1}/(\boldsymbol{TDB}/\boldsymbol{TW})$-----------------------------(2)

Where, WUE = Water use efficiency of the tree seedling, TDB = Total dry biomass (g) and TW = Total water use (ml) in the experiment and this was 9.6 litres in six months

Data analyses

The resulting data were tested for normality and homogeneity and the following positive tests; Analyses of Variance were carried out on the resulting data using GENSTAT statistical package version 14 to test the effect of different treatments on plant growth parameters, and biomass allocation, rate of transpiration and Water use efficiency. Comparisons were done using the least square differences (LSD) of means. Tables and graphs were drawn using the Microsoft Office Excel 2007

RESULTS

Mean heights, collar diameters and leaf number

The growth pattern with respect to height showed that there was a sharp increase in height in seedlings for Albizia supplied with, 50% and 100% soil field capacity (SFC) at12thweeks after treatment. Seedlings of Erythrina showed a sharp increase in height as from the 10th week after treatment for all the treatments. Eucalyptus seedlings had a sharp increase in all the treatment as from the 8th week after treatment (Figure 1). Colar diameter growth pattern for all the species showed a sharp increase as from the 10th week after treatment (Figure 2) Increase in leaf number showed a sharp increase as from the 12th week for Erythrina and Eucalyptus species (Figure 3) for all the treatment.

The 25 % field capacity treatment recorded the highest heights (44.7 and 74.8 cm for *Albizia ferruginea* and *Erythrina excels* seedlings respectively), 6 months after treatment application. Their least heights (19.8, 53.6 and 69.9 cm for *A. ferruginea*, *E. excels* and *E. grandis* respectively) were observed in the 12.5% field capacity treatment (Tables 2, 3 and 4). The best height of *Eucalyptus grandis* seedlings attained was 98.9 cm in the 100% field capacity treatment.

The effects of soil moisture levels on the growth of collar diameters of the tree seedlings were significantly different (P≤ 0.05). The best collar diameters (7.5and 8.0cm for *A. ferruginea* and *E.grandis* seedlings respectively)were recorded in the 50% field capacity treatment (Tables 3 and 4). For seedlings of *Erythrina excelsa,*the best collar diameter (16.o cm) was observed in the 100% field capacity treatment. The differences in collar diameters between the 50 and 100% field capacity treatments were not significantly different for all the species (Tables 2, 3 and 4). The least collar diameters (4.2, 8.6 and 5.0 cm respectively for *A. ferruginea, E. excelsa* and *E. grandis* seedlings) were observed in the 12.5% field capacity treatment.

The effects of the treatments on the number of leaves of *Albizia* and *Erythrina* seedlings was not significantly (P≤ 0.05) (Tables 2 and 3). *Eucalyptus grandis* seedlings produced several leaves with the highest (333) and the

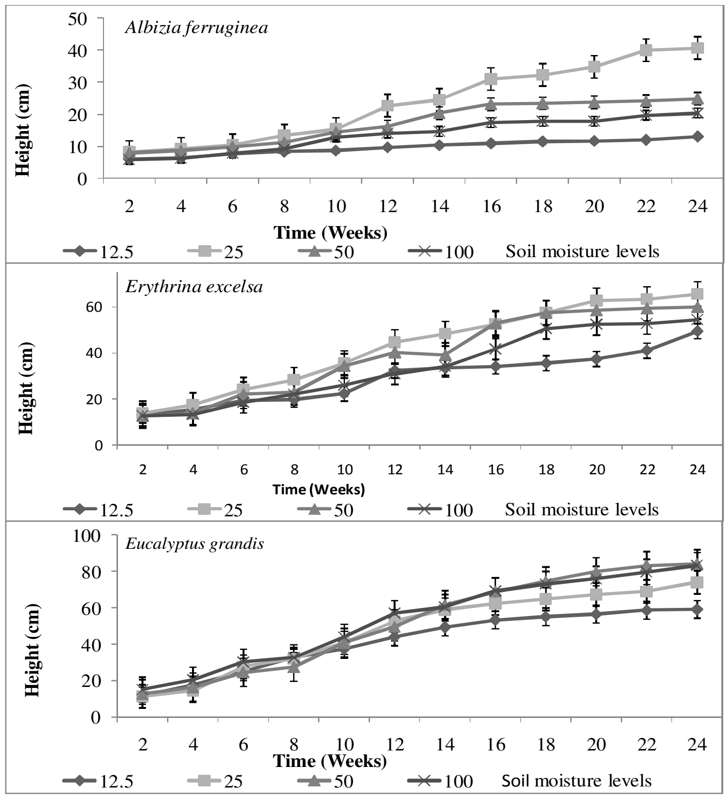


Figure 1. Growth patterns of height of the three tree seedlings supplied with four moisture levels.

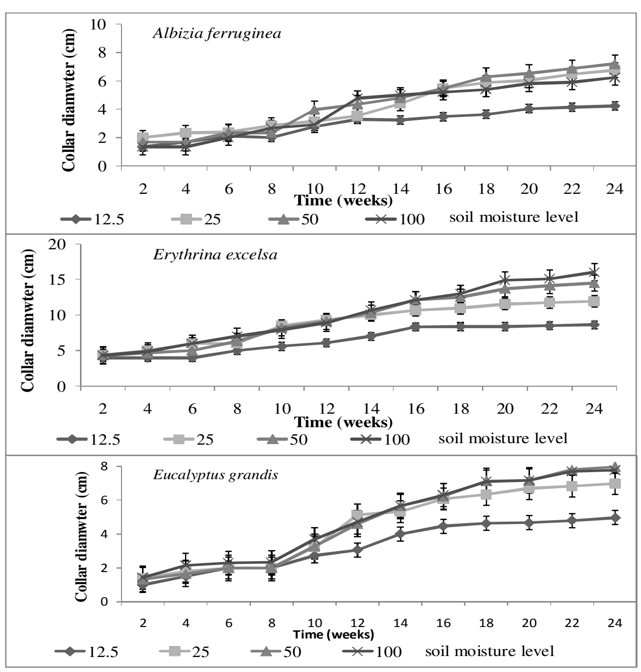


Figure 2. Growth patterns of collar diameter of the different tree seedlings supplied with four moisture levels.

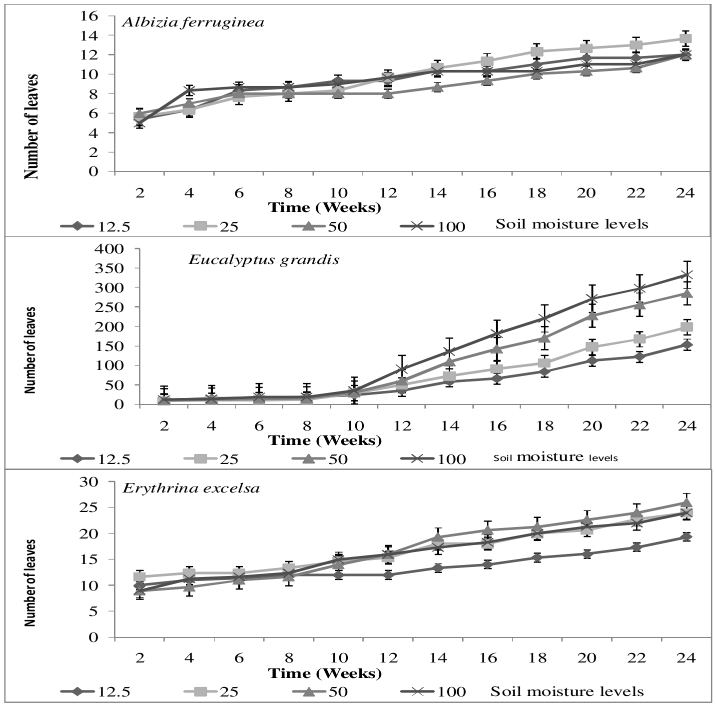
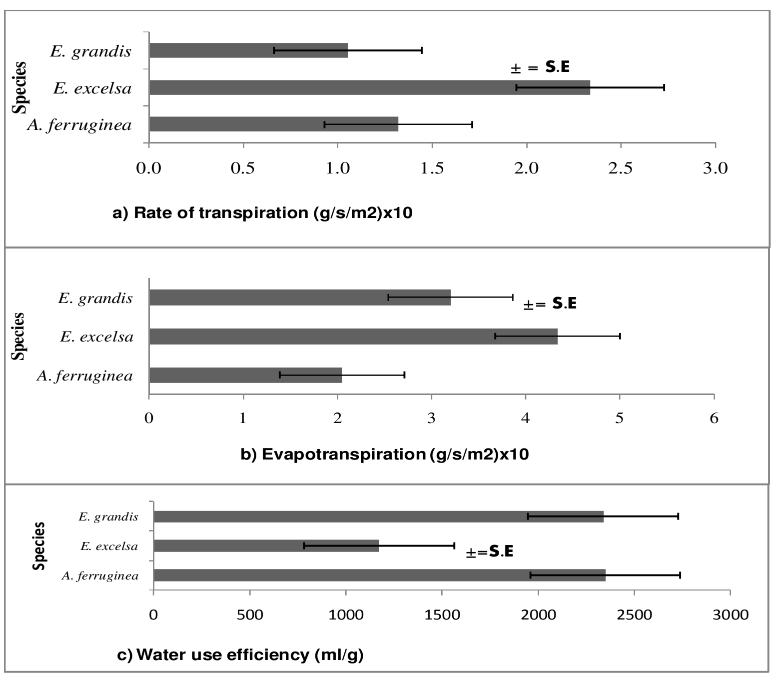


Figure 3. Growth patterns in the number of leaves of the different tree seedlings supplied with four moisture levels.



S.E= Standard error

Figure 4.a) Rate of transpiration, b) rate of evapotranspiration and c) the water use efficiencies of the various studied tree seedlings.

Table 2. Means and calculated morphological parameters of *Albiziaferruginea* supplied with four moisture levels.

Treatments	Mean Height (cm)	Mean Collar diameter (cm)	Mean Leaf number	Mean Leaf area (cm^2)	Mean Lateral roots	Mean Tap root length (cm)	Leaf area ratio (cm^2/g)	Specific leaf area (cm^2/g)	Specific shoot length (cm/g)	Specific Root length (cm/g)
12.5	19.8	4.2*	12	814	8*	23.3	75.8	341.3	13	3.4*
25	44.7	6.8	14	1086	14	23.3	31.8	109.9*	7.6	1.3*
50	29.1	7.2	12	1884*	25*	21.7*	36.3	369.1	5.3	0.5*
100	29.7	6.2	11	1305	15	30.7*	48	365.3	12.2	1.4*
Mean	30.8	6.1	12	1272	16	24.8	48	296.4	9.5	1.7
LSD	25.34	1.52	4.43	448	2	0.6	15.3	108.5	4.6	0.04
F.Pr	0.22	0.01	0.56	0.01	0.001	0.001	0.002	0.003	0.02	0.001

Where LSD=Least square difference,
%SFC= Percentage soil field capacity
Pr is the variance probability.

Table 3. Mean and calculated morphological parameters of *Erythrina excesa* seedlings supplied with four moisture levels

Treatments % SFC	Mean Height (cm)	Mean Collar diameter (cm)	Mean Leaf number	Mean Leaf area (cm^2)	Mean Lateral roots	Mean Tap root length (cm)	Leaf area ratio (cm^2/g)	Specific leaf area (cm^2/g)	Specific shoot Length (cm/g)	Specific root length (cm/g)
12.5	53.6	8.6	19	1034	5	21.6	115.8	371.2	17.4	7.0
25	71.0	12.0	24	1951	5	15.3	112.6	366.5	10.9	0.5
50	74.8	14.5	26	2379	9	31.4	59.8	541.1	7.6	1.8
100	72.4	16.0	24	2416	10	43.8	44.3	643.3	6.9	1.1
Mean	67.9	12.8	23	1945	7	28.03	83.1	480.5	10.7	2.6
LSD	28.03	4.31	4.16	370	1	1.1	10.2	148.8	4.2	0.23
F.Pr	0.32	0.02	0.04	<0.001	<0.001	< 0.001	< 0.001	0.01	0.003	< 0.001

Where LSD=Least square difference,
%SFC= Percentage soil field capacity
Pr is the variance probability.

least number of leaves (154) recorded in 100 and 12.5% field capacity treatments respectively.

Treatment effects on leaf area, number of lateral roots, length of tap roots, leaf area ratio, specific shoot length differ significantly for all the three species seedlings at at least P ≤ 0.05. (Table 2, 3 and 4).

Leaf area: The highest leaf area for *Albizia* seedlings was in seedlings treated with 50% soil field capacity (SFC) (1884cm2) and least in seedlings treated with 12.5% SFC, The Erythrina and *Eucalyptus* seedlings had the highest leaf area with 100% SFC(2416 and 2299 cm2 respectively) while the least leaf area was with the treatment 12.5% SFC (1034 and 766 cm2 respectively) (Tables 3 and 4)

***Number of main lateral roots**:* The number of main lateral roots were significantly different for *Albizia* and *Erythrina* seedlings (P=0.001). *Albizia* seedlings traeted with 50% SFC had the highest main lateral roots (25) while the highest for *Erythrina* seedlings was with 100% SFC

Table 4. Means and calculated morphological parameters of *Eucalyptus grandis* seedlings treated with four moisture levels

Treatments % SFC	Mean Height (cm)	Mean Collar diameter (cm)	Mean Leaf number	Mean Leaf area (cm^2)	Mean Lateral roots	MeanTap root length (cm)	Leaf area ratio (cm^2/g)	Specific leaf area (cm^2/g)	Specific shoot length (cm/g)	Specific root length (cm/g)
12.5	69.9	5	154	766	13	21.5	56.0	421.8	15.2	10.7
25	79.9	7	198	840	16	15.1	97.9	341	11.4	3.4
50	98.9	8	286	2204	15	31	85.8	568.9	7.1	3.6
100	90.8	7.8	333	2299	17	24.5	82.8	350.7	6.9	3.2
Mean	84.8	6.9	243	1527	15	23	80.6	420.6	10.2	5.2
LSD	11.88	1	61	421	8	10.98	26.2	230.1	2.2	3.4
F. Pr	0.004	0.001	0.001	0.001	0.74	0.06	0.04	0.16	< 0.001	0.004

Where LSD=Least square difference,
%SFC= Percentage soil field capacity
Pr is the variance probability.

Table 5. Means and calculated biomass parameters of *Albizia ferrugine a* seedlings supplied with four soil moisture levels.

Albiziaferruginea								
Treatments % SFC	Mean Leaf Biomass (g)	Mean Stem biomass (g)	Mean Root biomass (g)	Root/ shoot ratio (g)	Total biomass (g)	Leaf mass fraction (g/g)	Shoot mass fraction (g/g)	Root Mass fraction (g/g)
12.5	2.4	1.6	6.8	1.7	10.8	0.22	0.14	0.63
25	9.9	5.9	18.4	1.7	34.1	0.29	0.17	0.54
50	5.2	5.5	41.3	3.9	51.9	0.10	0.11	0.80
100	3.6	2.4	21.2	3.5	27.2	0.13	0.09	0.78
Mean	5.3	3.8	21.9	2.58	31.0	0.19	0.13	0.69
LSD	0.47	0.32	0.67	1.00	0.99	0.01	0.02	0.03
V. r	581.05	544.59	5503.53	80.91	3541.55	969.37	30.04	214.74
F. Pr	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Where LSD= Least square difference,
%SFC= Percentage soil field capacity
Pr = Variance probability.

(10). The least main lateral root for both species was with 12.5% SFC (8 and 5 respectively)(Tables 2 and 3).

***Length of tap roots**:* The tap root length was significantly different for various treatments for *Albizia* and *Erythrina* seedlings only. *Albizia* and Erythrina had the longest tap root in seedlings treated with 100% SFC (30.2 and 43.8cm respectively). The shortest tap roots for *Albizia* was in seedling treated with 12.5% SFC (23cm) while those of *Erythrina* seedlings was with treatment 35% SFC (15.3cm) (Tables 2 and 3)

***Leaf area ratio**:*The leaf area ratio was highly significantly different for all the species. The highest leaf area ratio for *Albizia Erythrina* and *Eucalyptus* seedlings was with treatment 12.5% (75.8, 115.8 and 97.7 cm2/g respectively). The least leaf area ratio was observed in seedlings of *Albizia*, *Erythrina* and *Eucalyptus* was in treatments 25, 100 and 25 % SFC respectively (Tables 2, 3 and 4).

Specific leaf area: The 100% field capacity treatment achieved the highest specific leaf area (643.3 cm^2/g for

Table 6. Means and calculated biomass parameters of *Erythrina excelsa* seedlings supplied with four moisture levels.

Erythrinaexcelsa Treatments %SFC	MeanLeaf biomass (g)	MeanStem biomass (g)	MeanRoot biomass (g)	Root/ shoot ratio	Total biomass (g)	Leaf Mass fraction (g/g)	Shoot mass fraction (g/g)	Root mass fraction (g/g)
12.5	2.8	3.1	3.1	0.5	9.0	0.31	0.35	0.34
25	4.4	6.9	9.9	0.9	21.1	0.21	0.32	0.47
50	5.4	9.4	17.9	1.2	32.6	0.17	0.29	0.55
100	3.8	10.5	40.3	2.8	54.6	0.07	0.19	0.74
Mean	4.1	7.5	17.8	1.36	29.3	0.19	0.29	0.52
LSD	0.55	0.19	0.09	0.09	0.5	0.01	0.006	0.01
F. Pr	<0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.001	< 0.001	< 0.001

Where LSD= Least square difference,
%SFC= Percentage soil field capacity
Pr = Variance probability.

Table 7. Means and calculated biomass parameters of *Eucalyptus grandis* seedlings supplied with four soil moisture levels.

Eucalyptus grandis Treatments % SFC	MeanLeaf biomass (g)	MeanStem biomass (g)	MeanRoot biomass (g)	Root/ shoot ratio (g)	Total biomass (g)	Leaf Mass fraction (g/g)	Shoot Mass fraction (g/g)	Root mass fraction (g/g)
12.5	2.1	4.6	2.0	0.3	8.7	0.24	0.53	0.23
25	2.5	7.1	4.5	0.5	14.1	0.17	0.50	0.32
50	3.9	13.9	8.9	0.5	26.7	0.15	0.52	0.33
100	6.8	13.2	7.7	0.4	27.7	0.24	0.48	0.28
Mean	3.8	9.7	5.8	0.6	19.3	0.20	0.51	0.29
LSD	2.63	1.77	2.66	0.17	6	0.07	0.05	0.07
F. Pr	0.02	0.001	0.003	0.04	0.001	0.04	0.13	0.07

Where LSD= Least square difference,
%SFC= Percentage soil field capacity
Pr = Variance probability.

Erythrina seedlings) while the 25% soil field capacity treatment had the least value (109.9 cm^2/g for *Albizia* seedlings).

Specific root length: The 12.5% field capacity treatment had the highest mean specific root length (10.7 cm/g for *Eucalyptus* Seedlings) while 50% soil field capacity treatment had the least value(0.5cm/g for *Albizia seedlings*).

Specific shoot length: The 12.5% field capacity treatment recorded the highest specific shoot length (17.4 cm/g for *Erythrina* seedlings) while the 50% soil field capacity treatment recorded the least value of 5.3 cm/g in *Albizia* seedlings.

Biomass parameters

The effects of treatments on the biomass parameters were highly significant ($P \leq 0.001$) (Table 5, 6 and 7). The seedings of *A. ferrugimea* treated with 50% soil field capacity had the highest total biomass allocation of 51.9g while the least for this species was observed in seedlings treated with 12.5% SFC(10.8g). The leaf mass fraction, stem mass fractions and root mass fractions was highly signicantly diffrerent with respect to treatments of *A ferruginea* seedlings (Table 5). The root biomass of *A. ferruginea* was greater for the treatments than the shoot and therefore the root/shoot ratios were greater than 1.0

(Table 1). Seedlings of *E. excelsa* and *E. grandis* had highest total biomass with 100% SFC (54.6g and 27.7g respectively Tables 6 and 7). The least total biomass for these species was with the 12.5% SFC for *E. Excelsa (*8.7g) and *E. grandis* (9.0g). The leaf mass, stem mass, and root mass fractions for *E. excelsa* were variable and showed significant diffferences (Table 6) while for *E. grandis* there was no signifcant differences with treatment with respect to these mass fractions (Table 7). The biomass of roots *of E.excelsa* seedlings treated at 50 and 100% SFC were higher than shoots and the root/shoot ratios were greater than 1.0 (Table 6). *Ecalyptus grandis* had root/shoot ratios less than one for the various treatments with the highest in seedlings supplied with 25 and 50% SFC(0.5) and the least in seedlings treated with 12.5% SFC (0.3) Table 7.

Rate of transpiration, evapotranspiration and water use efficiencies of the species seedlings.

The mean temperature, light intensity and relative humidity during this experiment were 29.9^0C, 275000 lux and 64% respectively. The minimum temperature (24^0C), light intensity (73000 lux) and relative humidity (56%) were also recorded. The maximum temperature (33.5^0C), light intensity (497000 lux) and relative humidity (71%) were noted.

Rate of transpiration calculated for *E. grandis* was 0.11 $gH_2O/s/m^2$, *E. excelsa* (0.23 $gH_2O/s/m^2$) and *A. ferruginea* (0.13 $gH_2O/s/m^2$) were significantly different ($P \leq 0.03$) for the different species (Figure 4a).The rates of evapotranspiration recorded with *E. grandis* was 0.32 $gH_2O/s/m^2$, *E. excelsa* (0.43 $gH_2O/s/m^2$) and *A. ferruginea* (0.20 $gH_2O/s/m^2$) were signiicantly different for the different species (Figure 4b). The values of evapotranspiration were about twice the values of the rate of transpiration. Water use efficiencies were significantly different ($P \leq 0.001$) with values of 2388, 2349 and 1173 mlH_2O required to produce 1g of biomass by *E. grandis*, *E. excelsa* and *A. ferruginea* respectively.

DISCUSSION

Soil moisture availability and plant water-use efficiency are important drivers of both vegetation cover and water-table dynamics in catchment areas. A study of these parameters is especially important in the context of catchment restoration ecology in which appropriate selection of species is critical to both the success of the afforestation/reforestation project and the health of the surrounding communities where these water catchments are found. The early growth performance of these parameters have important ecological implications in seedling establishment in the field.

It was observed that except for their heights, the soil moisture levels had significantly effects on the growth performance of the tree seedlings.The best growth performances of seedlings were observed with the 50 and 100% soil field capacity treatments than those in 12.5% soil field capacity treatment. The seedlings with 50 and 100% soil moisture had adequate water for the various biochemical processes taking place in the plants such as photosythesis and respiration. These results are consistent with the findings of Cernusak et al.(2007) and Gonzalez-Rodriguez et al. (2010), who reported enhanced higher growth of these parameters in many tropical tree seedlings grown in field capacities between 50-100% compared to those growing under water stress conditions. Siam et al. (2010) had reported similar results with tree species showing improved growth performance in the wet season as compared to the dry season in tropical tree seedlings. In this light, Engelbrecht and Herz (2004); Ripullone et al. (2009) remarked that tree seedlings in wet plots showed enhanced growth compared to those grown in drought plots. These findings all re-iterated the fact that water is essential for plant growth and development. Specifically, Gonzalez-Rodriguez et al. (2010) observed that seedlings in well-watered treatments (100% field capacity) produced large foliage compared to the drought stress treatments (40% field capacity) produced less foliage. This means that water stress might reduce leaf emergence and expansion that lowers the net rate of photosynthesis and thus net biomass assimilation and hence poor growth.

Albizia ferruginea had the ability to allocate greater biomass in the drought treatment (12.5% soil field capacity treatment). This suggested that *A. ferruginea* is more drought resistant than *E. grandis* and *E. excelsa*. The dependency of *E. Grandis* and *E. excels* seedlings on high soil moisture levels to produce high biomass might indicate that they are less drought resistant. Bunker and Carson (2005) remarked that drought resistant species did not show significant differences in growth performance in different irrigation treatments (0, 30 and 120 ml applied twice a week). Therefore, *Albizia ferruginea* which is an indigenous tree species can be used in the restoration of water catchment from excess irradiance and erosion under drought conditions. The water physiology of trees is controlled by biochemical, physiological as well as leaf anatomical features expressed through the morphological adjustments of these parameters. Otieno et al.(2005) realised that drought resistant in Eucalyptus species is a function of deep rooting ability and osmotic manipulation. Shaltout et al. (2009) (*Emex spinosa*); Young et al. (2011) (Oak trees); Gonzalez-Rodriguez et al. (2010) (*Acacia rigidula, Forestiera augustifolia and Prosopis laevigata*) observed that photosystem adjustments, stomatal regulation and adjustment of water potentials were responsible for the drought resistance of the species.

The results are not consistent with the findings of Martinez-Berdja and Valverde (2008) on Cactus species (*Mammilaria pectinifera, Obregonia denegrii* and *Coryhantha wedermanii*) whose growth performance remained either unchanged or reduced in the control (100% field capacity) as compared to other treatments since cactus species are drought adapted species. Root/shoot ratio and root mass fraction were significantly influenced by the soil moisture levels ($P \leq 0.001$). The results indicates that in the nursery, the greater root/shoot ratio of *A. ferruginea* in all the treatments indicates that this species realocates more sinks to the root for proper establishment where there is less competition for light resource. It may also be a genetic factor for this species. This in contrast to root/shoot ratios of *E. Grandis* which was less than 1.0 which is an indication that more biomass was in the shoot than roots which may related to the genetic make-up of the plant. This species might require other addition treatment to develop a better root system while *A. ferruginea* might require only the best irrigation practice to do so.The preceding analysis is significant for the North West Region of Cameroon where afforestation/reforestation endeavours are either on-going or planned, as well as debates on whether or not to replace the existing *Eucalyptus* forests with other species at water catchment areas.

The current study revealed that leaf area, dry biomass of shoot and number of leaves are phenotypic expressions of water use efficiency. The results are similar to water-use efficiencies recorded by Andah et al. (2003) in Gwangneung catchment for *Quercus* (8.9±1.8 to 10.3±4.4 gC/L) and *Carpinus* sp. (7.7±1.5 to 9.5±4.5 gC/L). The amount of water used by *Eucalyptus* plantation is a relevant ecological question worldwide because in regions where short rotations of 7 - 10 years of *Eucalyptus* are preferred, potential risk of water and nutrient deficiencies and unsustainable production have been reported (Whitehead and Beadle, 2004; Zahid and Nawaz, 2009).Water-use efficiencies indicated that a prodigal water use through high rate of transpiration may be indicative of a species' poor potential to produce biomass as observed in *E. excelsa*.

Whitehead & Beadle, 2004; Ripullone *et al*., 2009; Zahid and Nawaz, 2009 pointed out that the higher rate of transpiration, the lower the water-use efficiencies in a seedling. The significantly higher rate of transpiration of *Erythrina excelsa* can be attributed to its significantly larger surface area of the leaves. The rate of evapotranspiration for the seedlings was about doubled the rate of transpiration. This is in line with Ripullone et al. (2009); Zahid and Nawaz (2009); Zhang et al. (2003) who observed that the transpiration rates of many tropical seedlings were less than the evapotranspiration rates. The ecological implication is that deforested ecosystem loss more water through evaporation than those occupied by trees.

CONCLUSION

This study shows that best height, collar diameter, leaf number, root development and biomass accumulation increments oftree seedlings are achieved when there is adequate moisture (50-100% soil moisture field capacity).*Albizia ferruginea* seedlings had better water-use efficiency in the nursery than *E. grandis* and *E. excelsa* seedlings.This, together with better root development makes *A. ferruginea* a better species for the afforestation of water catchments in the Northwest region of Cameroon to replace *Eucalyptus* species. A long term field study is necessary to determine the ecological attributes of these species at maturation and the effect of spacing for the early closed canopy development.

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