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Evaluation of Seedlings of Three Woody Species under Four Soil Moisture Capacities

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Authors' contributions

This work was carried out in collaboration between all authors. Author Egbe E. Andrew designed the study, performed the statistical analysis, wrote the protocol, and author FEY did the study and wrote the first draft of the manuscript and author EEA managed literature searches and drew the figures. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To evaluate the growth performance, their rates of transpiration and water-use efficiencies under different moisture levels.
Study Design: A randomised complete design of three tree species, four treatments and three replicates.
Place and Duration of Study: Screen house of the University of Buea from January to June 2012.
Methodology: 144 uniform seedlings of *Markhmia tomentosa*, *Funtumia africana* and *Prunus africana* were treated to four soil moisture capacities (12.5, 25, 50 and 100%) determined gravimetrically and water supplied to the seedlings three times per week after pre-transplanting. The collar diameter, height and number of leaves were measured non-destructively every fortnight. The seedling biomass, leaf area, mass fractions, number of first order lateral roots, root/shoot ratio, specific leaf area, shoot and root lengths were determined six months after pre-transplanting. The seedlings' rates of transpiration, evapotranspiration and water-use efficiencies were determined gravimetrically.
Results: The growth trends with respect to collar diameter, height and the number of leaves showed significant variations at P = 0.05. The effects of the soil moisture capacities on the growth performances were significantly different at P< 0.001. *Markhmia tomentosa* seedlings supplied with 25% soil moisture showed maximum leaf number (42) and leaf area (10712.8 cm^2) while those with 50% treatment had collar diameter and

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root/shoot ratio of 17.8 cm and 2.8 respectively. *Funtumia africana* seedlings at 50% soil moisture capacity showed maximum height (88.6 cm) and total biomass (60.3g). *Prunus africana* seedlings had the least growth performance. Markhmia seedlings had the maximum rate of transpiration (12.69 $gH_2O/s/m^2$) and evapotranspiration (14.20 $gH_2O/s/m^2$). *Funtumia* seedlings gave the best water-use efficiency (176.5 ml/g). The poor performance observed in *P. africana* seedlings was as result of low elevation (≤ 450 above sea level).

Conclusion: *Funtumia africana* had the best water use efficiency while *Markhmia tomentosa* had the best root development. These two species would be suitable for the afforestation/reforestation of water catchment in humid areas of Cameroon.

Keywords: Growth characteristics; soil moisture capacity; tree seedlings; transpiration; evapotranspiration; water-use efficiency.

1. INTRODUCTION

Trees and water are inseparable and the former is well known for its regulating function in water catchment areas [1]. Growth, biomass allocation, rate of transpiration and water use efficiency of trees provide important clues on which tree species are suitable for the afforestation of water catchment areas [2]. In catchment areas, there are distinct spatial differences in climatic, edaphic factors and land use [3]. Among these parameters, the vegetation type plays a crucial role because trees with poor water use efficiency and high transpiration rate would deplete the water resource [2]. Yet, trees are seriously threatened by forest exploitation; habitat loss and fragmentation; invasive species introduction; land cover change as a consequence of demographic explosions and the quest for arable land [4,5,6].

Remedies so far include ratifying recommendations of conferences such as the Montreal Conference of Parties Meeting of the UN Framework Convention on Climate Change (UNFCCC) in late 2005. So far, the conference point on Clean Development Mechanism-afforestation reforestation (CDM-AR) projects have received growing attention in mitigating climate change and water resource depletion by avoiding unnecessary deforestation and encouraging reforestation and afforestation [7,8,9,10]. There are tremendous efforts in Cameroon to afforest or reforest many areas as a management strategy to combat desertification and climate change. Suitable tree species that can be used to protect water catchment areas have not been elucidated in Cameroon. In addition, anthropogenic activities have often degraded these water catchment areas. For example, key water catchment habitats and watershed ecosystems have been destroyed by successive waves of cultural activities such as slash/burn agriculture, bushfire, pesticides, and other industrial chemicals in some localities in the North West region of Cameroon [11]. Equally, vegetation has often been burnt or cleared, exposing the soils and streams to the full strength of solar radiation and erosion in this region [12]. These anthropogenic influences are manifest through active stream and gully erosion affecting water courses in the water catchment areas, damaging landscape eco-structures and water catchment processes that manage flows, yields, reliability and quality of water resources [2]. The impact of the mismanagement of tree-water relationship in Cameroon presents adverse effects on local livelihood. This includes the time to search for good quality water and conflict of ownership [11]. This suggests that research to identify indigenous trees which are capable of protecting water catchment areas would further add impetus to the current drive on afforestation/reforestation of water catchment areas in Cameroon.

A management option by a comprehensive afforestation and reforestation would provide advantageous solutions to land and water degradation, by also providing answers to shortages of food, fuel, income, animal fodder and building material [13]. Suitable practices in afforestation of tropical areas would reverse the large-scale species extinction expected in these areas in the near future [14,15]. The trees for afforestation/reforestation of water catchments can be selected based on growth performance, rate of transpiration, biomass allocation and water use efficiency [16].

The adoption of good strategies in water catchment management is therefore indispensable, yet requires significant research [2]. In the North West and West Regions of Cameroon, *Eucalyptus species* are extensively used in afforestation and reforestation, yet it has been shown that these species have increased water-use (lower Transpiration Coefficient) which may lead to desertification and lower the ground water-table [17]. Therefore, for effective afforestation and reforestation in water catchment areas, it is important to elucidate the water requirements of target tree species so as to obtain clues to select suitable tree species for water catchment protection [2]. This study compared the effect of different soil moisture levels on the early growth performance, rate of transpiration and water use efficiencies of three tree seedlings (*Markhmia tomentosa*, *Funtumia africana* and *Prunus africana*) and to assess their suitability for reforestation/afforestation of water catchment areas in the humid zones in Cameroon.

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, University of Buea. This area is located in the Southwest Region of Cameroon between latitude 3º57^1 to 4º27^{1}N and longitude 8º58^1 to 9º25^{1}E. Buea is located on the eastern slope of Mount Cameroon. It has a mean annual rainfall of about 2800 mm, received mostly between June and September [18,2]. The mean annual temperature, mean relative humidity and sunshine are 280, 86% and 900 to 12000 hours per annum respectively [2]. Buea is mountainous with thick evergreen forest vegetation at the lower elevations 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 Cameroon Development Cooperation (CDC) [2].

2.2 Study Species

Funtumia africana (Benth.) Stapf is an Apocynaceae that can reach 30m in height with a straight, cylindrical trunk and a narrow tree crown [19]. It is also common in forest regrowth. It is a native tree of Angola, Cameroon, Ivory Coast, Democratic Republic of Congo, Gabon, Kenya, Liberia, Mozambique, Nigeria, Sierra Leone, Tanzania, Togo and Uganda [19]. The flowers are yellow-white with fragrant dense cymes. The tree is used for timber and has other cultural importance such as drum making [20]. It is also used in erosion control, fuel wood, apiculture, production of gum or resin, treatment of urinary incontinence and burns, adherent for poisoned arrows, soil fertility improver of the surrounding and extraction of alkaloids such as funtumine and funtumidine that are hypotensive [19].

Prunus africana (Hook. f.) Kalkman is a Rosaceae that attains a height of 30 m with a straight bole and simple, alternately arranged leaves [21]. It is restricted to montane and Afromontane forest habitats in Africa and parts of U.S.A [19]. Biophysically, its best growth is limited between 900-3400 m altitudes, 890-2600 mm mean annual rainfall and 18-26°c mean annual temperature [19]. The flowers are small, creamy white and fragrant. Flowering of *Prunus africana* occurs between November and February [19]. The plant is used for timber, apiculture, erosion control, fuelwood and soil improver through mulching. The bark extracts contain phytosterols (β- Sitosterol, β-sitostenone) used to treat benign prostate hyperplasia (BPH) [19].

Markhmia tomentosa (Benth.) K. Schum. is a Bignoniaceae that attains a height of 15 m with a straight often branched bole and compound bipinnate leaves [19]. It is widely distributed through savannah forests in West and Central Africa extending southward to Angola [21]. Biophysically, it is limited between 400-1000m altitudes. The tree produces large yellow flowers in long terminal racemes. Its peak of flowering in Cameroon is between March and May. It is used as an ornamental, in tanning, timber; treatment of skin diseases, sores and scabies; oedema of the legs and elephantiasis, and rheumatic pain. Tannins and astringents have been extracted from its leaves [19].

2.3 Methodologies

2.3.1 Growth performance of the seedlings of the three tree species under four soil moisture capacities

Seeds of *Funtumia africana, Markhmia tomentosa* and *Prunus africana* were collected from local stands in the North West region of Cameroon. The seeds were sown in 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 analysed top soil had the following chemical properties (Table 1).

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

All the pre-transplanted seedlings were hardened for four weeks to acclimatize them before application of the various treatments. Soil moisture levels (25, 50,100 and 200ml) were determined as 12.5, 25, 50 and 100% of the soil moisture at field capacity. The soil moisture capacity was gravimetrically determined. Five pots used in the experiment were filled with the topsoil and these pots were watered to saturation and allowed to stand for at least three hours to allow 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 105^0C to 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. One hundred and forty-four seedlings were treated to the different soil moisture levels. The experiment was a completely randomized design in three replicates and the seedlings were placed in a screen house. The pots were watered three times weekly with the various volumes of water (25, 50, 100 and 200 ml) [22]. The water levels of 12.5, 25, 50 and 100% of the soil field capacity mimicked the soil water potential levels recorded in tropical regions in the dry season, after the rainy season and during the rainy season [23].

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 and this was measured with an electronic veneer calliper (Shenzhen® G02022615) to the nearest 0.1 mm. The height was measured from a point at the soil surface to tip of terminal bud with a metre rule to the nearest 0.1 cm. 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 first order lateral roots counted. The length of tap root was measured with a metre 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 70ºC and dry weight recorded. Leaf area was measured with a leaf area meter (Orsenigo 121TM35) to the nearest 1.0 cm^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 [24].

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

Thirty-six potted seedlings at six months were selected from the three tree species and the pots were watered to saturation, allowed to drain completely of gravitational water for three hours. Six of the 12 pots with seedlings for each species were covered with black polythene bags from the bottom of each pot to the soil surface of the pots to prevent evaporation of water from the soil surface. In the other six 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 4 pm) 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.

The rate of transpiration and evapotranspiration for each square meter of leaves of species were calculated from equation (1).

$$\xi = \left| \left\{ \mathrm{Wi} - \mathrm{Wf} \big/ \mathrm{Tf} - \mathrm{Ti} \right\} \times \frac{\mathrm{TLA}}{10{,}000} \right| \quad (1)$$

Where, ξ = 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, Tf respectively. TLA= Total leaf area of the seedling. The constant 10,000 was the conversion factor used to change the leaf area measured in cm^2 to m^2.

Changes in masses were plotted against time and the line of best fit was obtained. The gradient of the slope was calculated and this gave the transpiration rate.

Water-use efficiency was calculated as volume (ml) of water needed to produce 1g of biomass. This was calculated using the equation (2) [25].

$$\mathrm{WUE} = 1/\ (\mathrm{TDB}/\mathrm{TW}) \quad (2)$$

Where, WUE = Water use efficiency of the tree seedlings, TDB = Total dry biomass (g) and TW = Total water used (ml) in the experiment and this was 9.6 litres in six months, only for seedlings supplied with 200 ml soil moisture level.

2.4 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 14.0 to test the effects of the different treatments on plant growth parameters, 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.

3. RESULTS

3.1 The Effects of Soil Moisture Capacities on the Patterns of Growth in Heights, Collar Diameters and Leaf Number

The growth trends with respect to heights, collar diameter and the number of leaves showed that there were significant variations at P = 0.05 between the species and treatments. Seedlings supplied with 50 and 100% soil moisture capacities showed sharp increases in the growth pattern of heights for all the tree species from the 10^{th} week after treatment application (Fig. 1). *Funtumia africana* and *Markhmia tomentosa* seedlings showed a sharp increase in collar diameter from 8 weeks after treatment application while the growth pattern of collar diameter of *Prunus africana* remained constant regardless of the treatment and time factor in the course of the study (Fig. 2). *Markhmia tomentosa* and *Funtumia africana* seedlings showed marked increase in the number of leaves from the 4^{th} and 6^{th} weeks respectively after treatment application in all the treatments (Fig. 3).

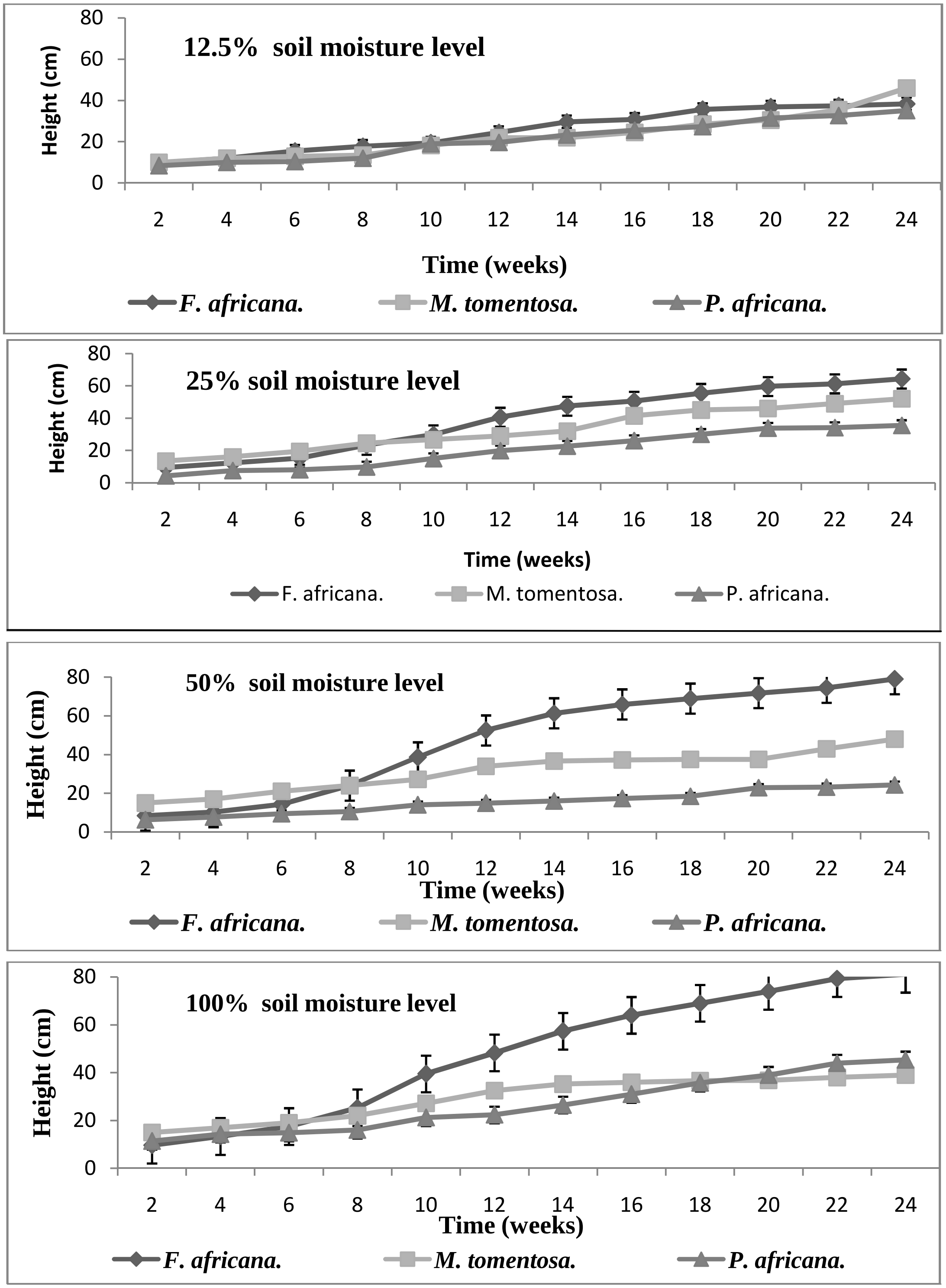

Fig. 1. Growth patterns of heights of the seedlings of three tree species supplied with four soil moisture capacities

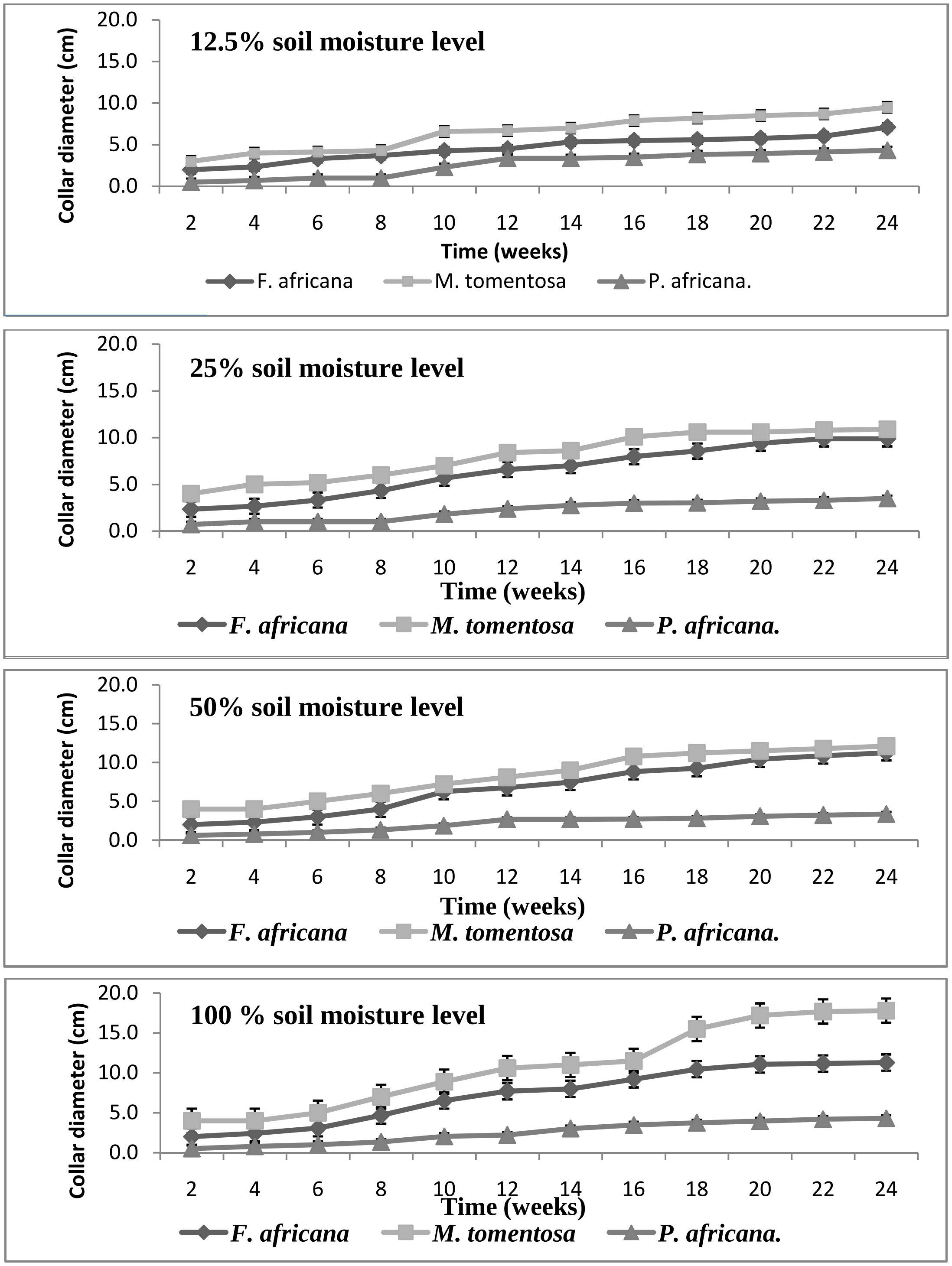

Fig. 2. Growth patterns of collar diameter of the seedlings of three tree species under four moisture capacities

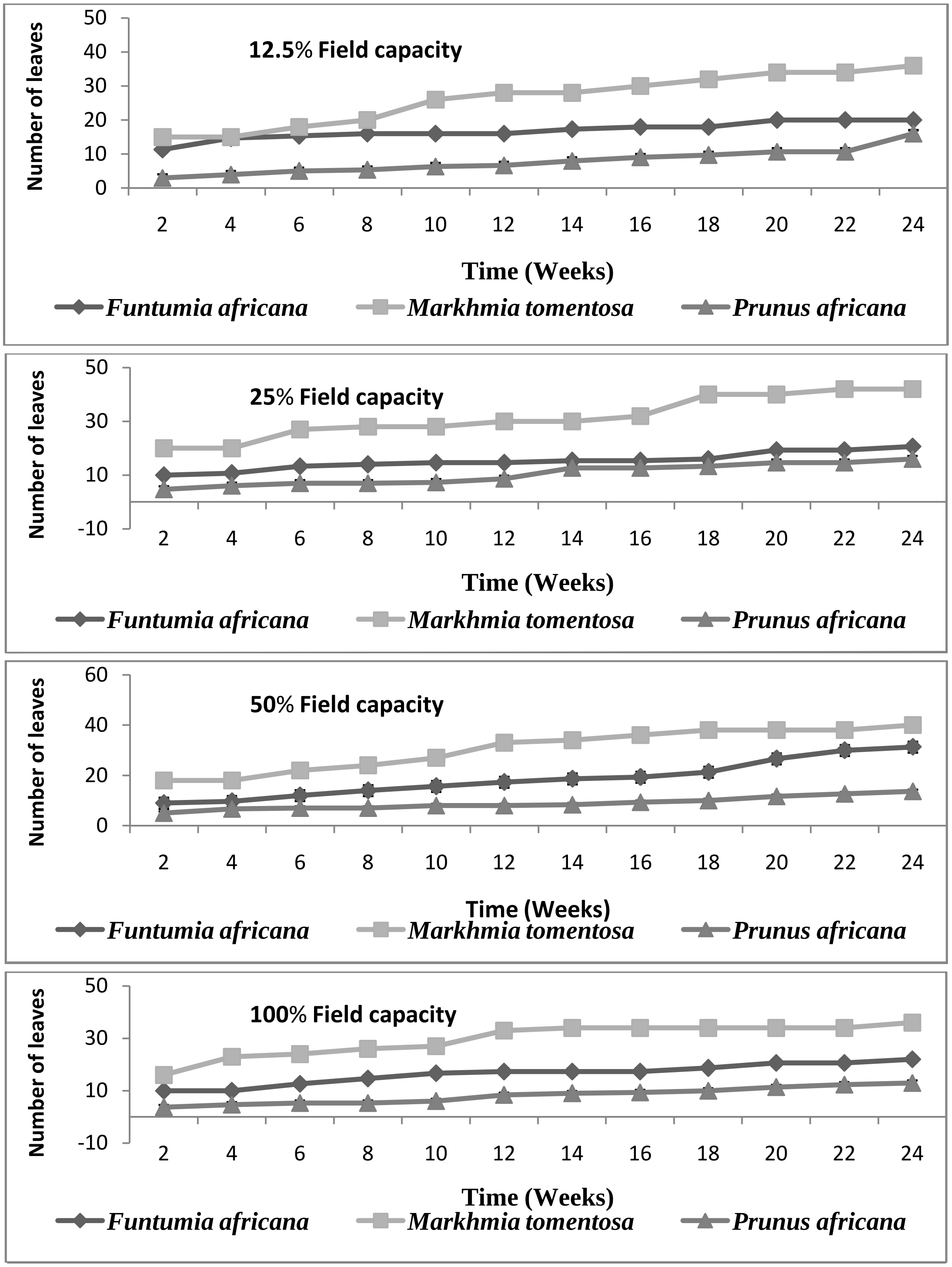

Fig. 3. Growth patterns of the number of leaves of the seedlings of three tree species under four soil moisture capacities

3.2 The Effects of Soil Moisture Capacities on Morphological Characters of Seedlings of the Three Tree Species

The effects of the treatments on the heights and number of leaves of the species were significant different at $P \leq 0.001$ (Table 2). The 50, 25 and 100% soil moisture levels recorded the highest heights (88.6, 62.0 and 55.7cm) for *F. africana*, *M. tomentosa* and *P. africana* seedlings respectively. The least heights for *F. africana* and *M. tomentosa* were 49.0 and 46.7cm and these were observed in seedlings supplied with 12.5% soil moisture capacity. The least height for *P. africana* seedlings was 31.1cm recorded in seedlings supplied with 50% soil moisture capacity.

The effects of the treatments on the collar diameter of the species were significantly different at $P \leq 0.001$ (Table 2). The seedlings of species treated with 100% soil moisture level or at field capacity recorded the highest collar diameters of 17.8, 11.3 and 4.3cm for *Markhmia tomentosa*, *Funtumia africana* and *Prunus africana* respectively. The *F. africana* and *M. tomentosa* seedlings treated with 12.5% soil moisture capacity gave the least collar diameters of 7.9 and 9.5 cm respectively while in the *Prunus africana* seedlings treated with 50% soil moisture capacity recorded the least collar diameter of 3.4 cm.

The highest number of leaves for *Funtumia africana* and *Markhmia tomentosa* seedlings were 31 and 42 and these were recorded in the seedlings supplied with 50 and 25% soil moisture levels respectively. The least number of leaves (13) for *Prunus africana* was recorded in seedlings treated to the 100% soil moisture level (Table 2).

The effects of the treatments on the leaf area and specific area showed significant variations at $P \leq 0.02$ (Table 2). The largest leaf areas (5213.0, 10712.8 and 369.7 cm^2 for *F. africana*, *M. tomentosa* and *P. africana* seedlings) were observed in the 50, 25 and 100% soil moisture capacities respectively. Their least leaf areas (912.7, 3233.1 and 116.0 cm^2 for *F. africana*, *M. tomentosa* and *P. africana* seedlings) were recorded in 12.5, 100 and 12.5% soil moisture capacities respectively. The leaf area ratio was highly significantly different for all the tree species. The highest leaf area ratios for *Markhmia tomentosa* and *Prunus africana* seedlings were 267.1 and 107.6 cm^2/g and this was noted in seedlings supplied with 25% soil moisture capacities while the highest leaf area ratio for *Funtumia africana* seedlings was 86.5 cm^2/g recorded in seedlings supplied with 50% soil moisture capacity. The least leaf area ratios for *F. africana* and *P. africana* seedlings were 58.7 and 94.9 cm^2/g respectively and was observed in the 12.5% soil moisture capacity. The least leaf area ratio for *M. tomentosa* seedlings was 76.6 cm^2/g recorded in the 100% soil moisture capacity. The highest specific leaf areas for *F. africana* and *M. tomentosa* were 271.4 and 1015.5 and these were observed in seedlings supplied with 50% soil moisture capacity. The seedlings of *Prunus africana* that were treated to 100% soil moisture capacity had the highest specific leaf area (2353.1 cm^2/g). The least specific leaf area (167.3, 306.9 and 327.8 cm^2/g for *F. africana*, *M. tomentosa* and *P. africana* seedlings) were recorded in the 12.5, 12.5 and 50% soil moisture field capacities respectively.

Table 2. Means of morphological characters of the seedlings of three tree species under four soil moisture capacities

Species	Treatments (% SFC)	Mean height (cm)	Mean collar diameter (cm)	Mean leaf number	Mean total leaf area (cm^2)	Mean number of first order lateral roots	Mean Length of the main root (cm)	Leaf area ratio (cm^2/g)	Specific shoot length (cm/g)	Specific root length (cm/g)	Specific leaf area (cm^2/g)
F. africana	12.5	49.0	7.1	20	913	6	17.4	58.7	8.7	3.9	167.3
	25	72.4	9.9	21	1997	11	17.1	64.8	6.1	1.9	205.1
	50	88.6	11.3	31	5213	15	17.3	86.5	3.6	1.1	271.4
	100	82.4	11.3	22	3276	13	27.3	60.3	4.1	1.4	214.6
M. tomentosa	12.5	46.7	9.5	36	3331	6	15.2	120.4	6.8	1.5	306.9
	25	62.0	10.9	42	10713	11	36.5	267.1	6.1	2.1	858.4
	50	49.7	12.1	40	6313	8	49.0	137.4	4.8	1.7	1015.5
	100	49.6	17.8	36	3233	11	41.2	76.6	4.9	1.6	481.8
p. africana	12.5	36.8	4.3	16	116	5	23.8	94.9	60.4	59.3	476.0
	25	41.9	3.5	16	176	5	22.3	107.6	44.9	46.2	758.9
	50	31.1	3.4	14	137	4	20.9	99.5	50.2	59.0	327.8
	100	55.7	4.3	13	370	8	23.9	143.1	36.8	30.7	2353.1
	Mean	54.5	9.5	27	3352	11	26	125.0	16.4	13.6	666.9
	LSD (0.05)	7.0	1.4	4	524	3	7.1	41.6	22.9	23.0	1108.7
	FPr.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.85	0.47	0.05

Where LSD=Least square difference, %SFC= Percentage soil moisture of its field capacity and FPr is the variance probability

3.3 The Effects of Soil Moisture Capacities on Biomass Parameters on the Tree Seedlings

The effects of treatments on the biomass parameters of seedlings were highly significant ($P \leq 0.001$) (Table 3). The seedlings of *Funtumia africana* treated with 50% soil moisture capacity had the highest leaf biomass (19.3 g), stem biomass (24.7g), total biomass (60.3 g). The species with the highest root biomass (29.3 g) was noted with *Markhmia tomentosa* seedlings. The least leaf biomass (0.2 g), stem biomass (0.6 g), root biomass (0.3 g) and total biomass (1.1g) were observed with *Prunus africana* seedlings treated with 12.5% soil moisture capacity. The leaf mass fraction and root shoot ratio were highly significantly different with respect to treatments while the shoot and root mass fractions for the seedlings did not show significant differences.

The root biomass of *Markhmia tomentosa* seedlings was greater than the shoot biomass and therefore the root/shoot ratios were greater than 1.0 (Table 3). The seedlings of *F. africana* supplied with 100% soil moisture capacity also allocated more biomass to the roots than the shoots. The seedlings of *Funtumia africana* and *Markhmia tomentosa* supplied with 12.5% soil moisture level recorded the highest leaf mass fraction (0.4 g/g). The seedlings of *M. tomentosa* and *P. africana* supplied with 50% soil moisture capacity and seedlings of *P. africana* treated with 100% soil moisture capacity had the least leaf mass fraction of 0.1 g/g. The seedlings of *M. tomentosa* supplied with 50% soil moisture capacity recorded the highest root/shoot ratio (2.8 g/g) while seedlings of *Prunus africana* treated with 25% soil moisture capacity recorded the least root/shoot ratio of 0.4 g/g (Table 3).

3.4 Evaluation of the Rate of Transpiration, Evapotranspiration and Water Use Efficiencies of the Species Seedlings of the Three Tree Species

The mean temperature, light intensity and relative humidity during this experiment were 29.9ºC, 275000 lux and 64% respectively. The minimum temperature (24ºC), light intensity (73000 lux) and relative humidity (56%) were also recorded. The maximum temperature (33.5ºC), light intensity (497000 lux) and relative humidity (71%) were noted. Rate of transpiration calculated for *F. africana* was 2.29 $gH_2O/s/m^2$, *M. tomentosa*(12.69 $gH_2O/s/m^2$) and *P. africana* (0.51 $gH_2O/s/m^2$) were significantly different ($P = 0.03$) for the different species (Fig. 4a). The rates of evapotranspiration recorded with *F. Africana* was 10.76 $gH_2O/s/m^2$, *M. Tomentosa* (14.2 $gH_2O/s/m^2$) and *P. africana* (0.73 $gH_2O/s/m^2$) were significantly different for the different species (Fig. 4b). Water-use efficiencies were significantly different ($P \leq 0.001$) with values of 176.5, 227.5 and 3692.3 ml/g recorded for *F. africana*, *M. tomentosa and P. africana* respectively (Fig. 4c).

Table 3. Means of biomass characters of the seedlings of three tree species under four soil moisture capacities

Species	Treatments (%SFC)	Mean leaf biomass (g)	Mean stem biomass (g)	Mean root biomass (g)	Total biomass (g)	Leaf mass fraction (g/g)	Shoot mass fraction (g/g)	Root mass fraction (g/g)	Root shoot ratio (g/g)
F.africana	12.5	5.5	5.6	4.5	15.6	0.4	0.4	0.3	0.8
	25	9.7	11.9	9.1	30.8	0.3	0.4	0.3	0.8
	50	19.3	24.7	16.3	60.3	0.3	0.4	0.3	0.7
	100	15.3	20.0	19.1	54.4	0.3	0.4	0.4	1.0
M.tomentosa	12.5	10.9	6.9	9.9	27.7	0.4	0.2	0.4	1.4
	25	12.5	10.1	17.5	40.1	0.3	0.3	0.4	1.7
	50	6.2	10.4	29.3	46.0	0.1	0.2	0.6	2.8
	100	6.7	10.1	25.4	42.2	0.2	0.2	0.6	2.5
P.africana	12.5	0.2	0.6	0.3	1.1	0.2	0.5	0.3	0.6
	25	0.3	1.1	0.5	1.9	0.1	0.6	0.3	0.4
	50	0.5	0.7	0.4	1.6	0.3	0.4	0.2	0.5
	100	0.3	1.5	0.8	2.6	0.1	0.6	0.3	0.5
	Mean	7.3	8.6	11.1	27.0	0.3	0.4	0.4	1.1
	LSD	0.4	0.4	0.1	0.7	0.1	0.1	0.03	0.1
	FPr.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Where LSD=Least square difference, %SFC= Percentage soil moisture of its field capacity and FPr. is the variance probability

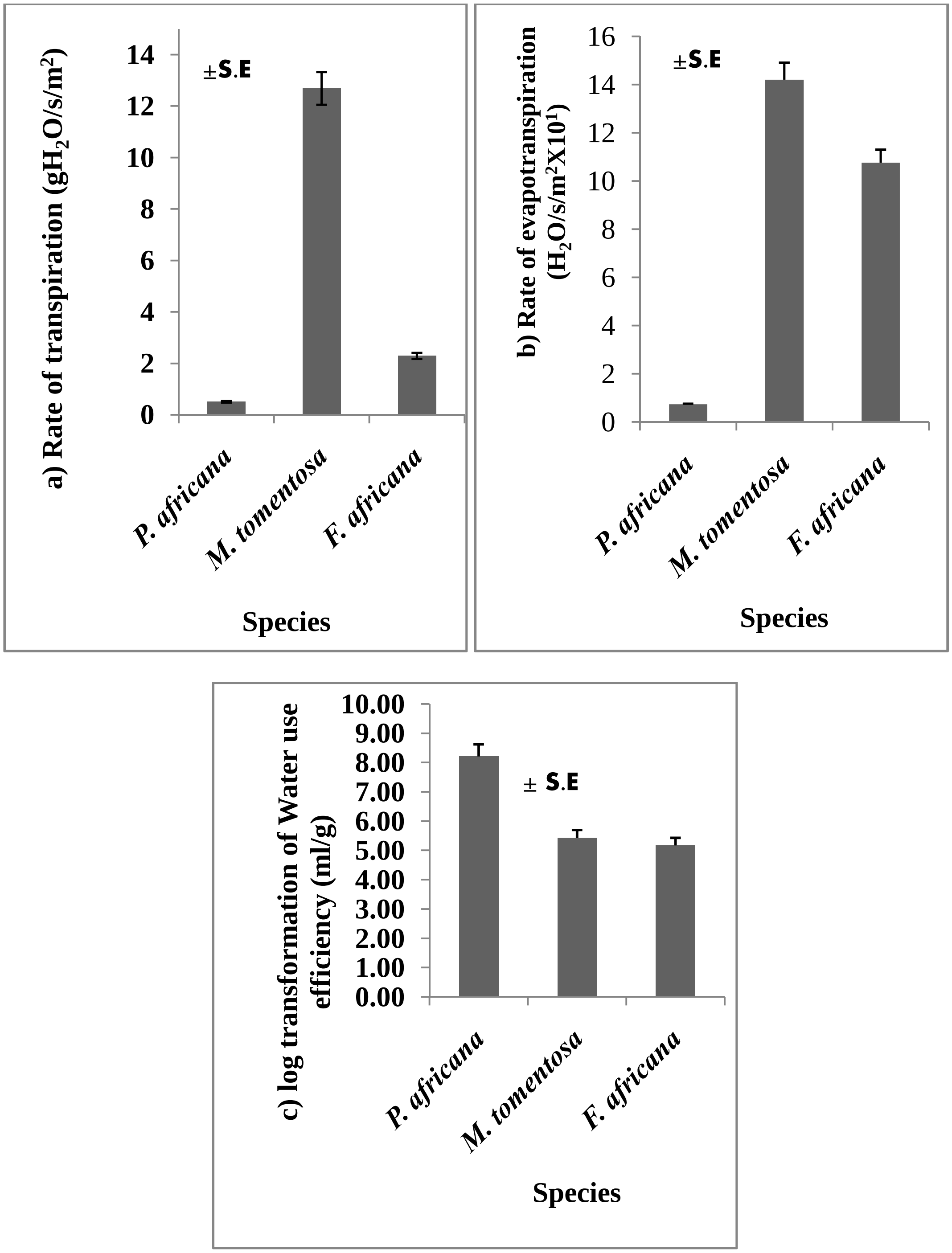

Fig. 4.a. Rate of transpiration, b. rate of evapotranspiration and c. the water use efficiencies of the various studied tree species seedlings
S.E= Standard error

4. DISCUSSION

Soil moisture availability and plant water-use efficiency are important drivers of both vegetation cover and water-table dynamics in water catchment areas [26]. The enhanced growth performance in leaf area, plant height, collar diameter, leaf number, number of main lateral roots and biomass allocation as well as the calculated parameters recorded in higher soil moisture capacities confirmed the varied importance of water to plants. These importance include medium to dissolve nutrients for absorption, transport of food, metabolite and raw material for photosynthesis that are phenotypically expressed in the morphological parameters. Conversely, the soil water stress can reduce the net rate of photosynthesis, biomass assimilation hence, poor growth performance and decreased leaf area [3]. A comparison of tree seedlings for afforestation of water catchment areas under different moisture levels is especially important in the context of water 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 environment. The early growth performances with respect to heights and collar diameters have important ecological implications in seedling establishment in the field [2]. The seedlings with 50 and 100% soil moisture had adequate water for the various biochemical processes taking place in the plants such as photosynthesis and respiration. The dependency of the tree seedlings on high water availability suggested that the three species at the early growth stage have a high water requirement for growth [27].

These results are consistent with the findings of [28,26,2] who reported enhanced higher growth of these parameters in many tropical tree seedlings grown in soil moisture levels between 50-100% compared to those growing under water stress conditions. Similar results with tree species showing improved growth performance in the wet season as compared to the dry season in tropical tree seedlings has been reported [29]. In this light, some authors remarked that tree seedlings in wet plots showed enhanced growth compared to those grown in drought plots [30,31]. These findings all re-iterated the fact that water is essential for plant growth and development.

The poor growth performance of *P. africana* can be attributed to the fact that it is a high altitude plant (900-3400 m) that requires a moderate mean daily temperatures of 18-26^{o}c [19]. This explanation suggests that plant growth integrates environment and physiology to achieve its morpho-ecological functioning. The physiology of trees is controlled by biochemical, physiological as well as leaf anatomical features expressed through the morphological adjustments of the parameters. The well-developed roots of *Markhmia tomentosa* corroborates to a research finding that attributed drought resistant in *Eucalyptus sp*. to deep rooting ability [32]. The results are not consistent with the findings of [23] on Cactus species (*Mammilaria pectinifera, Obregonia denegrii* and *Coryhanthawedermanii*) whose growth performance remained either unchanged or reduced in the control (100% soil moisture level) as compared to other treatments since cactus species are drought adapted species. According to [31], the greater root/shoot ratio of *M. tomentosa.* In all the treatments indicates that this species reallocates more biomass 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 is in contrast to root/shoot ratios of *F. africana* which was less than 1.0 which is an indication that more biomass was in the shoot than roots. This species might require other addition treatment to develop a better root system while *Prunus africana* might require the best irrigation practice and climate related to altitude to do so. The preceding analysis is significant for the afforestation/reforestation endeavours in Cameroon at water catchment areas to replace the existing Eucalyptus forest.

Current studies have shown that leaf area, biomass and number of leaves can be morphological expressions of water use efficiency [27]. The water-use efficiencies of the tree seedlings are similar to results recorded in three tropical tree seedlings for *Albizia ferruginea* (1173 ml/g), *Eucalyptus grandis* (2388 ml/g) and *Erythrina excelsa*(2349 ml/g) [2]. *Eucalyptus* plantations establishment in water catchment areas have important ecological importance related to their short rotations of 7-10 years as this possess potential risk of water and nutrient deficiencies in this water catchment areas [17]. Studies on water-use efficiencies indicate that an extravagant water use through high rate of transpiration may be indicative of a species' poor potential to produce biomass as observed in *Erythrina excelsa* [33]. The higher water use efficiency of *Funtumia africana* and *Markhmia tomentosa* corroborates with the finding that the lower the rate of transpiration, the higher the water-use efficiencies in a seedling [33,31,17]. The significantly higher rate of transpiration of *Markhmia tomentosa* can be attributed to its significantly higher leaf area. This observation suggests that there is a wide variation in the morpho-genetic potentials of tree seedlings that can be exploited to rehabilitate degraded water catchment areas in Cameroon. The rate of evapotranspiration for the seedlings was significantly higher than the rate of transpiration. This is in line with some authors who observed that the transpiration rates of many tropical seedlings were less than the evapotranspiration rates [31,17,34]. The ecological implication is that deforested ecosystem loss more water through evaporation from exposed soil than areas occupied by trees [5,17].

5. CONCLUSION

This study shows that best height, collar diameter, leaf number, root development and biomass accumulation increments of tree seedlings are achieved when there is adequate moisture (50-100% soil moisture capacities). *Funtumia africana* seedlings had better water-use efficiency in the nursery than *Markhmia tomentosa* and *Prunus africana* seedlings. This, together with better root development makes *F. africana* and *M. tomentosa* better species for the reforestation/afforestation of water catchment areas in Cameroon to replace *Eucalyptus* species. A long term field study would be necessary to determine the ecological attributes of these species at maturation and the effect of tree density in a water catchment area. *Prunus africana* is a montane species and should be evaluated for water catchments at elevations of at least 900 m above sea level as its potential physiological attribute can be exploited.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Brook BW, Sodhi NS, Bradshaw CJA. Synergies among extinction drivers under global change. Trends in Ecol. and Evol. 2008;23(8):453-460.
2. Egbe EA, Forkwa EY, Mokake ES, Ngane EB. Early growth, biomass allocation and water use efficiency of three species of tropical tree seedlings at four moisture level. Glob. Adv. Res. Jr. of Agric. Sci. 2013;2(2):047-058.
3. Norman A, McGinnity P, O'Hea B. Factors influencing the downstream transport of sediment in the Lough Feeagh catchment, Burrishoole, co. Mayo, Ireland. Freshwater Biological Association. Freshwater Forum. 2005;23:126-138.
4. Malcom JR. Global warming and extinctions of endemic species from biodiversity hotspots. Conserv. Biol. 2006;20:538-548.

5. Wright SG, Muller HC. The future of tropical forest species. Biotropica. 2006;38(3):287-301.
6. Ministry of Forests and Wildlife (MINFOF), Food and Agricultural Organization (FAO). Evaluation of national forest resources of Cameroon, 2003–2004. MINFOF and FAO, Yaoundé, Cameroon; 2005.
7. Laurance WF. A new initiative to use carbon trading for tropical forest conservation. Biotropica. 2007;39(1):20-24.
8. Gullison RE, Frumhoff PC, Canadell JG, Field CB, Nepstad DC, Hayhoe K. Tropical forests and climate policy. Sci. 2007;316:985-986.
9. Mollicone D, Achard F, Federici S, Eva HD, Grassi G, Belward A, Raes F, Seufert G, Stibig HJ, Matteucci G, Schulze ED. An incentive mechanism for reducing emissions from conversion of intact and non-intact forests. Climatic Change. 2007;83(4):477-493.
10. Tavoni M, Sohngen B, Bosetti V. Forestry and the carbon market response to stabilize climate. Energy Policy. 2007;35(11):5346-5353.
11. Ndenecho EN. NGO input and stakeholder participation in natural resource management: Example of north west Cameroon. International NGO J. 2009;4:050-056.
12. Margulis S. Causes of deforestation of the Brazilian Amazon. World Bank workings paper No 22, Washington D.C; 2005.
13. Ndenecho EN. Sustaining mountain environments and rural livelihoods in Bamenda Highlands, Unique Printers, Bamenda; 2006.
14. Da Silva JMC, Tabarelli M. Tree species impoverishment and the future flora of the Atlantic forest of northeast Brazil, Nature. 2000;404:72-74.
15. Sodhi NS, Koh LP, Brook BW, Ngonh PKL. Southeast Asian biodiversity: An impending disaster. Trends Ecol. Evol. 2004;19:654-659.
16. Cregg BM. Improving drought tolerance of trees: Theoretical and practical Considerations. Acta Hort. 2004;630:147-158.
17. Zahid MD, Nawaz A. Comparative water use efficiency of *Eucalyptus camaldulensis* and *Dalbergia sisso.* Int. J. Agric. Biol. 2009;4:540-544.
18. Egbe EA, Tabot PT. Carbon sequestration in eight woody non timber species and their economic potentials in south western Cameroon. Appl. Ecol. Environ. Res. 2011;9: 369 -385.
19. Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A. Agroforestry database: A tree reference and selection guide. 2009;4.0. Accessed 16 December 2013. Available: http://www.worldagroforestry.org/af/treedb/.
20. Omino EA, Kokwaro JO. Ethnobotany of apocynaceae species in Kenya. J. of Ethnopharm. 1993;40(3):167-180.
21. Simpson GM. Plant systematic. Elsevier Academic Press; 2006.
22. Masinde WP, Stutzel H, Agong GS, Fricke S. Plant growth water relations and transpiration of two species of African nightshade (*Solanum villosum* Mill. ssp. miniatum (Bernh.exwilld.) Edmonds and *S. Sarrachoides* Sendtn.) under water-limited conditions. Scientia Horticulturae; 2006;11:154-159.
23. Martinez-Berdeja A, Valverde T. Growth response of three Cacti species to radiation and soil moisture: An experimental test of the mechanism behind the nurse effect. J. Arid Environ. 2008;72:1766-1774.
24. Bloor JMG, Grub PJ. Growth and mortality in high and low light: trends among15 shade-tolerant tropical rain forest tree species. J. Ecol. 2003;91:77-85.
25. Jones HG. What is water use efficiency? In: Water use efficiency in plant biology, edited by Bacon M A, Blackwell Publishing, Oxford; 2004.

26. González-Rodríguez H, Cantú-Silva I, Ramírez-Lozano RG, Gómez- Meza MV, Sauceda JI, Maiti RK. Characterization of xylem water potential in ten native plants of north-eastern Mexico. Plant Stress Manage. 2010;1:219-224.
27. Bunker DE, Carson WP. Drought stress and tropical forest woody seedlings: Effect on community structure and composition. J. Ecol. 2005;93:794-806.
28. Cernusak LA, Aranda J, Marshall JD, Winter K. Large variation in whole-plant water-use efficiency among tropical tree species. New Physiologist. 2007;173:294-305.
29. Siam AMJ, Radoglou KM, Noitsakis B, Smiris P. Physiological and growth responses of three Mediterranean oak species to different water availability regimes. J. Arid Environ. 2008;72:583-592.
30. Engelbrecht BMJ, Herz HM. Evaluation of different methods to estimate under storey light conditions in tropical forests. J. Trop. Ecol. 2001;17:207-224.
31. Ripullone F, Borghetti M, Raddi S, Vicinelli E, Baraldi R, Guerrieri MR et al. Physiological and structural changes in response to altered precipitation regimes in a Mediterranean Macchia ecosystem. Trees Struct. Funct. 2009;23:823-834.
32. Otieno DO, Schmidt MWT, Adiku S, Tenhunen J. Physiological and morphological responses to water stress in two *Acacia spp.* from contrasting habitats. Tree Physiol. 2005;25:361-371.
33. Whitehead D, Beadle CL. Physiological regulation of productivity and water use in Eucalyptus. For Ecol. Manage. 2004;10:1016-1034.
34. Zhang L, Vertessy R, Walker G, Gilfedder M, Hairsine P. Agroforestation in catchment context: understanding the impacts on water yield and salinity. Industry report. Climatic 1/07, eWater CRC, Melbourne, Australia; 2003.

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