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Predicting field performance of five irrigated tree species using seedling quality assessment in Burkina Faso, West Africa

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Abstract

Five exotic tree species (*Acacia angustissima* (Mil.) Kuntze, *Acacia mangium* Wild, *Gliricidia sepium* (Jacq.) Alp., *Leucaena* hybrid (LxL), and *Leucaena leucocephala* (Lam.) de Wit) were investigated to determine whether parameters of nursery seedling stock quality could be used to predict their field performance in a plantation irrigated with treated waste-water to produce fodder and wood. Plants were grown in the nursery in two contrasting rooting substrates (ordinary nursery soil and sand), predicted to have different effects on resource allocation. Three categories of morphological indicators were measured, i.e. plant dimensions (height, diameter, root length), plant weights (shoot, root and whole plant weights) and indices (sturdiness quotient 'SQ', shoot:root dry weight ratio 'SRR' and Dickson's quality index 'DQI'). In the nursery, all species performed better in the ordinary nursery soil for all growth parameters except root length. Thus ordinary nursery substrate appeared superior to sand in terms of plant quality. However, a follow up at plantation phase revealed that only some morphological attributes or ratios were suitable to predict field performance for the five tested species in irrigated plantation. In addition, the effect of the substrate observed at the nursery stage had disappeared 12 months after out planting due to the availability of water and nutrients provided by the treated waste water used for the irrigation. The results showed that root collar diameter and DQI appeared to be the most appropriate indicators to predict the outplanting performance of the five tested species in a short-rotation irrigated plantation in semi-arid Burkina Faso. The former measure is simpler and non-destructive.

Keywords: Irrigation, seedling quality, substrate, waste-water

Introduction

In the semi-arid zone, most plant production systems are geared to producing plants which are capable of surviving in a hostile arid climate (Mackay 1996; Zida et al. 2008). Thus, nursery plants are frequently water stressed and then weaned under shade to "harden them off" before transporting them to the field because in drier parts of the tropics such as semi-arid West Africa, drought is the major environmental factor determining the establishment and growth of seedlings (Engelbrecht et al. 2005). In an effort to improve outplanting performance, a variety of seedling quality assessment methods has been developed, based on seedling morphological attributes, such as shoot height, root collar diameter, height to diameter ratio, and root to shoot ratio (Deans et al. 1989; Dey and Parker 1997; Jacobs et al. 2005; Zida et al. 2008). However, despite advances in seedling quality testing and prediction of field performance, no single test has proved suitable across a multitude of species and conditions (Davis and Jacobs 2005), indicating that seedling attributes need to be determined at the species level and take into account specific environmental and management conditions (Zida et al. 2008).

Seedlings destined for irrigated sites probably require different management in the nursery compared to those for non-irrigated plantations because they will experience less water stress, although they will still experience post-transplant shock (Oliet et al. 2002). Consequently, the tendency to favor low shoot:root ratios (large root systems) promoting subsequent rapid root growth may appear unnecessary and undesirable for irrigated conditions. However, overcoming post-transplant shock is only possible if new root elongation takes place shortly after transplanting the seedlings (Oliet et al. 2002). Such growth and production of new roots are affected by water availability as well as the balance between shoot and root (Becker et al. 1987; Rose et al. 1993). While there are several reports of indices developed for harsh conditions (Deans et al. 1989; Bayley and Kietzka 1996; Rawat and Singh 2000; Villar-Salvador et al. 2004; Davis and Jacobs 2005) little information describing the desirable attributes of tree seedlings for irrigated systems in arid climates is available (Zida et al. 2008). In short rotation applications, the emphasis needs to be focused on producing seedlings which have the capacity to immediately begin rapid shoot growth following outplanting. Consequently, nursery regimes geared to produce such plant types need to be developed.

Therefore, this paper examines the influence of substrate on the morphology of planting stock of five exotic tree species for irrigated conditions and their performance in the field. Two contrasting substrates were used because of the evident effect of this factor on resource allocation, and the tendency of plant species to allocate more resources to the development of root systems on poor soils such as sand (Balisky et al. 1995; Osmont et al. 2007; Semchenko et al. 2007). The selected species are fast growing and can produce both wood and fodder, which are both in high demand in urban and peri-urban areas of Burkina Faso. Short-rotation plantations, irrigated with treated waste-water, are one option to help meet this demand.

Materials and methods

Study site

Plants were grown in a nursery in the open courtyard of Département Productions Forestières (DPF) of Institut de l'Environnement et de Recherches Agricoles (INERA) in Ouagadougou, Burkina Faso, West Africa (12^{o}22' N and 1^{o}30' W and at an altitude of 306 m.a.s.l). The rainfall at the site is unimodal with a mean annual rainfall of 804 mm, and a rainy season between May and September. The mean annual temperature is 28^{o}C with a minimum of 22^{o}C and a maximum of 35^{o}C. The plantation was established in a plot 500 m from the DPF courtyard thus experiencing the same climatic conditions as in the nursery site.

Experimental design

Nursery phase

A factorial experiment was designed to test the effects of species and substrate on seedling morphological attributes and indices of five exotic species as indicators of their future performance in short-rotation irrigated plantations to produce fodder and wood. Thus, two factors were investigated:

1. Five species: *Acacia angustissima* (Mil.) Kuntze, *Acacia mangium* Wild, *Gliricidia sepium* (Jacq.) Alp., *Leucaena* hybrid (LxL), and *Leucaena leucocephala* (Lam.) de Wit

2. Two substrates: pure sand and normal nursery substrate in Burkina Faso (a mixture of arable soil, sand and manure in the proportions of 2v:1v:1v) (Table 1).

The experiment was laid out in eight blocks or replicates, with a split plot design. Tree species was the main plot and substrate was the sub plot, with four plants within the sub plot. Thus each block contained 5 (species) x 2 (substrates) x 4 (plants) = 40 pots.

Seeds were pre-treated according to the recommendations of the supplier (Agro-forester Tropical Seeds of Holualoa, Hawaii, USA) and pre-germinated for one week and then transplanted into poly bags of 25 cm height and 7 cm diameter (962 cm^3) at the end of June 2005. All treatments were watered twice a day with tap water using a watering can. No fungicide or pesticide was used in the present experiment. At the end of the nursery phase in September 2005, i.e. after 2.5 months, half of the seedlings were destructively harvested to evaluate for their morphological attributes and the remaining half was used for the plantation.

Plantation phase

As in the nursery, the design was a split plot design with species factor attributed to the main plot treatment and the substrate used in the nursery to the sub plot. Plants were planted in three blocks or replicates, and there were 2 plants for each substrate in the sub plot. Thus each block contained 5 (species) x 2 (substrates) x 2 (plants) = 20 pots. Plants were carefully removed from their pots and planted out with 1 m intervals in a row and 2 m between rows. A 4 m space was allowed between blocks. The plants were watered every three days with treated waste-water from the University of Ouagadougou in

Burkina Faso. The plants were watered until saturation, when water remained on the soil surface around the plants. The water had been treated through a succession of basins starting with a homogenizing basin, followed by an anaerobic basin, an aerobic basin and a distribution basin. The treated water had the following properties: temperature 30.1°C, conductivity 259 µS m^{-1}, dissolved O_2 1.9 mg l^{-1}, pH 7.7, *Escherichia coli* 13000 Colony Forming Units (cfu) l^{-1}, Thermotolerant coliforms (TTC) 85000 cfu, Fecal streptococcus (FS) 7000 cfu, Biochemical Oxygen Demand-Five-Day (DOB5) 10 mg l^{-1}, Chemical Oxygen Demand (COD) 46 mg l^{-1} , Suspended Particulate Matter (SPM) 28 mg l^{-1}, total P 1.4 mg l^{-1}, PO_4^{3-} 0.7 mg l^{-1}, NH_4^+ 3.8 mg l^{-1} and NO_3^-. 1.5 mg l^{-1}.

Data collection and handling

Nursery phase

In September 2005 half of the seedlings were harvested and their height, root collar diameter (rcd) and tap root length (from the ground or root collar level to the tip of the main and longest root) were measured. They were then divided into shoots and roots, and the roots were washed. All components were then dried to constant weight at 60°C for 48 h. The following seedling quality and performance attributes were then assessed: shoot:root dry weight ratio (SRR), sturdiness quotient (SQ) (height (cm)/rcd (mm)), and Dickson's Quality Index (DQI) (Deans et al. 1989), which was calculated as follows (Eq.1):

$$\text{Quality index} = \frac{\text{Seedling dry weight (g)}}{\dfrac{\text{Height (cm)}}{\text{Root collar diameter (mm)}} + \dfrac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}} \qquad \text{Eq.1}$$

Plantation phase

Twelve months after out-planting (14.5-month old plants), the height and diameter at 1.30 m (dbh) of the trees were measured, and half the plants were carefully uprooted and separated into leaves, wood and roots. The roots were then washed, and all plant components were dried as before. For this phase, only SRR was calculated.

Data analysis

Data from the nursery and plantation phases were tested for homogeneity of variances before being subjected to general analysis of variance (ANOVA) using GenStat Release 8.11 (Rothamsted Experimental Station) software package. When the *F*-test was significant, treatment means were separated using the least significant difference (*LSD*) method at 5% probability. Correlation analyses were also used to establish relationships between plant performance at nursery and plantation phases.

Results

Nursery phase

The survival rates ranged from 86% for *A. angustissima* to 100% for *L. leucocephala* and from 96% for sand to 97% for nursery substrate.

Plant dimensions

There were, significant species x substrate interactions and significant main effects of species and substrate for plant height ($P<0.001$), rcd ($P<0.001$), and tap root length ($P<0.01$) (Table 2). All species grown on ordinary nursery substrate were taller and had greater root collar diameters than their counterparts grown in sand, while root length was usually not significantly different within a species, or, in the case of *L.* hybrid was significantly longer in sand (Table 3). Despite the differences in growth between nursery substrate and sand, the ranking of the performance of plants in both substrates tended to be similar, except for *A. angustissima* which in terms of height growth performed much better in nursery substrate than in sand (Table 3).

Plant weights

Shoot, root and total dry weights also showed significant species x substrate interactions as well as significant main effects of these two factors (all $P<0.001$) (Tables 2 and 4). When grown in sand, shoot weights did not differ between species, but when grown in nursery substrate, significant differences were present, with *L. leucocephala* and *G. sepium* being the heaviest and the two acacia species the lightest. Root weights did differ between species in both substrates, and were least for the acacias.

Seedling quality and performance attributes

As for the previous parameters, analysis of the indices revealed significant species x substrate interactions, as well as significant main effects (all $P<0.001$) (Tables 2 and 5).

All species had significantly higher SQ's in nursery substrate than their counterparts in sand, except for *A. mangium*. Overall, *A. angustissima* had the highest values and *G. sepium* the lowest. In terms of shoot: root ratio, all species had higher values in nursery substrate than in sand, except for *L. leucocephala*, and the acacias had the highest shoot:root ratios. Dickson's quality index was higher in nursery substrate, with *G. sepium* and *L. leucocephala* being superior to the rest. Within a substrate, trends in DQI between species were the reverse of those in SQ and SRR, as expected by their mathematical relationships.

Plantation phase

Twelve months after out-planting, survival rates ranged from 50% for *A. angustissima* to 100% for *L. leucocephala* and from 80% for plants originating from sand substrate to 83% for those from nursery substrate. By this time, some species exceeded 5 m in height.

Analysis of the data from the plantation phase revealed no significant interaction between factors for effects on plant dimensions, weights of plant components or shoot:root ratio, and no effect of substrate used in the nursery. Species was the only factor that exerted a significant effect on all variables (all $P<0.05$ at least) except for leaf weight (Table 6). The two leucaena species were the tallest, and they, together with *G. sepium* were overall the best performing species in terms of weight, height and dbh (Table 7). The small acacias had the highest shoot:root ratios, while *Leucaena* hybrid had the lowest.

Leaf biomass that could be used as fodder ranged from 0.18 t ha^{-1} for *A. angustissima* to 0.29 t ha^{-1} for *L.* hybrid while wood production (stem biomass) which could be used as fuel ranged from 0.42 t ha^{-1} for *A. angustissima* to 0.98 t ha^{-1} for *G. sepium* (Table 7).

Relationships between plant performance at nursery and plantation phases

Several measures of growth in the nursery were significantly correlated with subsequent growth in the plantation (Table 8). SQ was not significantly correlated with any aspect of plant growth, whereas DQI was significantly correlated with a number of plant parameters. However, a number of simple measures of plant growth in the nursery were also significantly correlated with plantation performance. In particular, root collar diameter in the nursery, a quick and easy non-destructive measure, was as well, or better correlated with future plant performance as DQI. Relationships between total plant dry weight in the plantation and nursery DQI and rcd are shown in Figure 1. With the exception of *L.* hybrid, grown in sand, a common expression describes the growth of all species in both substrates.

Discussion

Despite the differences in growth in the nursery between nursery substrate and sand, the ranking of performance of the species in both substrates tended to be similar, with the two leucaenas performing best, followed by gliricidia, and the two acacia species performing worst. Although plant shoots and roots weighed less, were shorter, and had smaller rcd when grown in sand (Table 3, 4), root length tended to be greater in sand than in nursery substrate, indicating that plants responded to this nutrient-poor substrate by producing a more finely divided root system, providing a greater surface area for uptake of nutrients (Balisky et al. 1995; Osmont et al. 2007; Semchenko et al. 2007). Both acacias performed relatively poorly in sand in terms of shoot growth, and their root systems appear to have been less adaptable to this substrate (Table 3, 4) than those of the other species. Although survival in the nursery was generally good, the poor-growing *A. angustissima* had the lowest survival rate.

However, despite the observations in the nursery of the importance of rooting medium to plant growth, after 12 months' growth in the field, all effects of nursery substrate were lost. South et al. (2005) also reported that on easy-to regenerate sites, some factors which affect nursery growth may not affect seedling survival and growth at plantation phase. The irrigation and the nutrients contained in the waste-water may have contributed to improved growth conditions for the tested species. Many other factors may come into play (Tomlinson et al., 1996; Lindqvist and Ong, 2005) so that final success comes from a combination of nursery practice and field practice.

DQI, which is the most complex formula for assessing seedling quality, and which incorporates both measures of SQ and SRR was a useful predictor of plantation performance. However, other more straightforward measures were equally good predictors of future seedling performance and easier to determine (Table 8). A simple non-destructive measure of root collar diameter for instance, was as good as DQI, which involves numerous destructive measures for its determination.

SQ and SRR showed similar trends for species and substrate factors which were opposite to the trend of DQI (Table 5) as also observed by Deans et al. (1989), and reflecting the mathematical relationships between these different indices. The morphological attributes (low growth values in acacias) did not appear to be in accordance with good quality indices (low values SQ and SRR and high values of DQI) for non-irrigated systems. However, it is not easy to draw a consistent conclusion taking all quality indices together, indicating the difficulty of establishing criteria for early selection as also reported by previous workers (Mattsson 1996; Court-Picon et al. 2004). The difficulty in finding a good indicator based on morphological attributes suggests a need for integrated approaches and ecophysiological evaluations in correlating seedling vigor with field performance (Mattsson 1996; Davis and Jacobs 2005). Such approaches might also be associated with modeling because effective integration of both physiological and morphological parameters into future models may further benefit seedling quality evaluation (Gazal et al. 2004; Davis and Jacobs 2005; Landqvist and Ong 2005).

In general, the two leucaenas and *G. sepium* appeared to be the best seedlings for non-irrigated systems in line with the interpretation of others who have worked on such systems (Deans et al. 1989; Bayley and Kietzka 1996; Rawat and Singh 2000; Villar-Salvador et al. 2004; Davis and Jacobs 2005). As low shoot:root ratios (large root systems) with subsequent rapid root growth may appear unnecessary and undesirable for irrigated conditions, the two acacias might be considered as the best for irrigated systems followed by the two leucaenas and *G. sepium*. At nursery and plantation stages, the two acacias displayed the highest SRR values followed by the two leucaenas (Tables 5 and 7).

However, although nursery SRR was significantly and positively correlated with plantation SRR, it was not significantly correlated with other parameters of shoot growth, thus it was not a good predictor of plant growth after 12 months in irrigated conditions, whereas DQI was a useful predictor. The effects of combining different species in these analyses may be masking the effects of different nursery management practices. Nursery root collar diameter was an effective predictor of future performance in the plantation, confirming the observations of Mattsson (1996), Rawat and Singh (2000), Davis and Jacobs (2005) and is a simple non-destructive measure, especially compared with DQI.

Despite the difficulties of defining morphological attributes which can predict field performance, studies on seedling quality have an important practical application because failure of many reforestation projects in dry areas like Burkina Faso is primarily due to planting of poor quality seedling stocks and poor environmental and soil conditions. In such situations, careful selection and planting of only viable and vigorous seedlings is crucial to ensure high survival and performance in the field. Thus, a simple and reliable nursery grading practice is urgently needed to improve the income generated by plantations particularly for irrigated systems where more financial resources have been invested.

Plantations of 14.5 month gave fodder production ranging from 0.18 t ha^{-1} to 0.31 t ha^{-1} while fuelwood production was between 0.42 t ha^{-1} and 0.98 t ha^{-1} for the five tested species (Table 7). These figures are lower than the values reporting by previous workers (Mullen and Gutteridge 2002; Chirwa et al., 2003; Kwesiga et al. 2003; Odenyo et al.

2003; Kimaro et al. 2007). This may due to differences in plantation age, soil type, management practices, etc. Despite the fact, the two acacias allocated more resources to their above ground part in comparison with the below ground part, they have produced less biomass than the two leucaena and *G. sepium* (Table 7). Therefore, the three latter species may also be recommended for irrigated plantation because of the higher biomass produced in comparison with the two acacias. However, the two acacia may also have an advantage in the long run because exporting less nutrients in a production system where the above ground harvested part (leaves and wood) is taking away from the plot leaving only the root system that decay to improve soil carbon and N status (Kimaro et al. 2007).

Although these results demonstrate the benefits of using waste-water for plantations, health issues must be considered. The use of waste water for production of materials which enter the food chain requires very careful evaluation due to the possibility of introducing heavy metals and other contaminants. Thus continued analysis of waste water, soils and plant materials must be built in to irrigation systems which rely on waste-water.

Conclusion

The present investigation revealed that not all morphological attributes or ratios are suitable for predicting field performance for a given system and environmental conditions. In an irrigated plantation, the effects of the substrate observed at the nursery stage disappeared by 12 months after outplanting due to the availability of water and nutrients provided by the irrigation using treated waste water. For such irrigated systems, plant root collar diameter and DQI seem to be the most appropriate indicators to predict the outplanting performance of *Acacia angustissima, Acacia mangium*, *Gliricidia sepium, Leucaena* hybrid, and *Leucaena leucocephala* in semi-arid Burkina Faso (Figure 1).

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Table 1: Physico-chemical properties of sand and nursery ordinary substrate used in the nursery to produce seedlings of the five exotic species in Burkina Faso, West Africa

	Sand	Nursery substrate
Clay (%)	1.96	7.84
Silt (%)	9.8	7.85
Sand (%)	88.24	84.31
Organic matter (%)	0.517	1.259
Carbon (%)	0.3	0.73
Nitrogen (%)	0.035	0.099
C/N	9	7
Total phosphorus (ppm)	29	392
Available phosphorus (mg kg^{-1})	0.76	128
Total potassium (ppm)	140	973
Calcium (Ca^{++})	1.42	1.78
Magnesium (Mg^{++})	0.18	0.78
Potassium (K^{+})	0.04	1.21
Sodium (Na^{+})	0.04	0.09
Exchangeable bases (S)	1.68	3.86
Cation exchange capacity (T) meq/100g	2.7	5.7
Saturation rate (S/T) %	62	68
pH water	6.64	6.09
pH KCl	5.23	5.48

Table 2: Degrees of freedom (d.f.) and mean square output from analysis of variance for morphological variables and quality indices of 2.5-month old seedlings of five exotic tree species during the nursery phase in Burkina Faso, West Africa

Source of variation	d.f.	Height	Root collar diameter	Tap root length	Shoot dry weight	Root dry weight	Total dry weight	SQ	Shoot:root ratio	DQI
Species	4	1897.99***	150.634***	4348.50***	39.150***	11.837***	93.274***	615.907***	91.959***	2.134***
Substrate	1	49566.94***	454.341***	1278.4***	512.661***	50.757***	886.040***	434.478***	164.745***	6.980***
Species x substrate	4	1036.97***	4.6379***	513.9**	17.597***	4.830***	38.876***	62.569***	9.951***	0.547***
Residual	291	55.37	0.607	115.5	1.244	0.223	2.439	2.197	1.407	0.0299

, * Significant at 0.01 and 0.001 probability levels determined using *F-test*. SQ = sturdiness quotient, DQI = Dickson's Quality Index

Table 3: Mean height (cm), root collar diameter (rcd) (mm) and tap root length (cm) of 2.5-month old seedlings of five exotic species grown in normal nursery substrate or sand in the nursery in Burkina Faso, West Africa

	Height		rcd		Tap root length	
Species	Nursery substrate	Sand	Nursery substrate	Sand	Nursery substrate	Sand
Acacia angustissima	42.07e	8.96a	2.90c	0.94a	16.04ab	13.26a
Acacia mangium	23.53c	9.02a	2.95c	1.10a	20.77bc	22.81cd
Gliricidia sepium	30.44d	12.23ab	6.55g	4.33d	25.05cde	29.19ef
Leucaena hybrid	41.83e	12.60ab	5.28e	2.49b	26.62de	39.48h
Leucaena leucocephala	44.97e	15.57b	5.98f	2.88c	32.78fg	36.49gh
LSD 5%	3.66		0.38		5.29	

Means followed by the same letter are not significantly different at $P \leq 0.05$ as determined by ANOVA and Fisher's *F*-test

Table 4: Mean shoot, root and total dry weights (g) of 2.5-month old seedlings of five exotic species grown in normal nursery substrate or sand in the nursery in Burkina Faso, West Africa

	Shoot weight		Root weight		Total weight	
Species	Nursery substrate	Sand	Nursery substrate	Sand	Nursery substrate	Sand
Acacia angustissima	1.59c	0.09a	0.34c	0.03a	1.94c	0.12a
Acacia mangium	1.49c	0.13ab	0.30c	0.05ab	1.79c	0.18a
Gliricidia sepium	4.02e	0.59ab	1.28d	0.44c	5.30e	1.02b
Leucaena hybrid	3.22d	0.44ab	1.27d	0.28bc	4.49d	0.72ab
Leucaena leucocephala	4.23e	0.66ab	1.94e	0.35c	6.17f	1.01b
LSD 5%	0.55		0.23		0.77	

Means followed by the same letter are not significantly different at $P \leq 0.05$ as determined by ANOVA and Fisher's *F*-test

Table 5: Planting stock quality assessed by sturdiness quotient (SQ), shoot:root ratio (SRR), and Dickson's quality index (DQI) of 2.5-month old seedlings of five exotic species grown in normal nursery substrate or sand in Burkina Faso, West Africa

	SQ		SRR		DQI	
Species	Nursery substrate	Sand	Nursery substrate	Sand	Nursery substrate	Sand
Acacia angustissima	14.80g	9.58f	5.30g	3.86f	0.10bc	0.01a
Acacia mangium	8.06de	8.32e	5.39g	3.01de	0.14c	0.02ab
Gliricidia sepium	4.68b	2.86a	3.38ef	1.44a	0.68f	0.24d
Leucaena hybrid	7.86de	5.11bc	2.65cd	1.58a	0.43e	0.11c
Leucaena leucocephala	7.58d	5.43c	2.33bc	1.99ab	0.64f	0.14c
LSD 5%	0.72		0.58		0.08	

Means followed by the same letter are not significantly different at $P \leq 0.05$ as determined by ANOVA and Fisher's *F*-test

Table 6: Plantation growth of five exotic species grown in Burkina Faso, West Africa: degrees of freedom (d.f.) and mean square output from analysis of variance for morphological variables and indices 12 months after planting out from a nursery where seedlings had been propagated in normal nursery substrate or sand.

Source of variation	d.f.	Height	DBH	Leaf weight	Stem weight	Root weight	Plant weight	Shoot:root ratio
Species	4	11.812***	10.499*	0.0797	3.8313**	0.186***	6.752*	30.31**
Substrate	1	0.376	0.726	0.353	3.765	0.1023	8.155	4.665
Species x substrate	4	0.751	3.749	0.086	0.609	0.027	1.314	3.539
Residual	37	0.594	2.954	0.103	0.958	0.029	2.011	6.918

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels determined by *F*-test

Table 7: Mean height, dbh, weight of plant components and shoot:root ratio of five exotic species in Burkina Faso, West Africa, after 12 months in irrigated plantation

Species	Height (m)	DBH (cm)	Leaf weight (kg)	Stem weight (kg)	Root weight (kg)	Plant weight (kg)	Shoot:root ratio
Acacia angustissima	3.33ab	3.92a	0.35a (0.18)	0.81a (0.42)	0.12a	1.28a	9.61b
Acacia mangium	3.04a	4.43a	0.44a (0.23)	0.84a (0.43)	0.12a	1.38a	10.21b
Gliricidia sepium	3.79b	4.51ab	0.48a (0.25)	1.90b (0.98)	0.32b	2.70b	8.21ab
Leucaena hybrid	5.25c	6.01c	0.58a (0.29)	1.76b (0.89)	0.39b	2.70b	6.32a
Leucaena leucocephala	5.02c	5.87bc	0.47a (0.24)	1.89b (0.97)	0.34b	2.70b	7.41a
LSD 5%	0.64	1.42	n.s.	0.81	0.14	1.17	2.18

Means followed by the same letter are not significantly different at $P \leq 0.05$ as determined by ANOVA and Fisher's *F*-test. Leaf and stem weight data in parentheses are expressed in tonnes ha^{-1}

Table 8: Pearson's correlation coefficients between plant performance at nursery (N) and plantation (P) phases of five exotic tree species in Burkina Faso, West Africa. Significant correlations between parameters measured in the nursery and plantation are emboldened

	N - rcd	N - ht	N -rt leng	N - sht wt	N - rt wt	N - tot wt	N - SQ	N - SRR	N - DQI
N - rcd	1.0000								
N - ht	0.6873	1.0000							
N -rt leng	0.3159	-0.0586	1.0000						
N - sht wt	0.9018	0.8431	0.1012	1.0000					
N - rt wt	0.9009	0.7670	0.2979	0.9464	1.0000				
N - tot wt	0.9113	0.8315	0.1589	0.9958	0.9721	1.0000			
N - SQ	-0.3454	0.4065	-0.6731	-0.0226	-0.1699	-0.0638	1.0000		
N - SRR	-0.2160	0.2818	-0.8040	0.0558	-0.2163	-0.0209	0.7518	1.0000	
N - DQI	0.9604	0.6552	0.2702	0.9416	0.9473	0.9532	-0.3206	-0.2071	1.0000
P - dbh	0.3959	0.2307	**0.7153**	0.3446	0.5225	0.3992	-0.4328	-0.4999	0.3875
P - ht	0.4577	0.3226	**0.8119**	0.3807	0.5430	0.4317	-0.3645	-0.5994	0.4320
P- tot dwt	**0.8435**	0.5144	**0.6554**	**0.7240**	**0.7639**	**0.7435**	-0.4615	-0.3816	**0.8056**
P - lf wt	0.5867	0.5304	0.4401	0.5325	0.4880	0.5262	-0.1729	0.0057	0.4767
P - stem dwt	**0.8659**	0.4947	**0.6475**	**0.7415**	**0.7929**	**0.7644**	-0.4952	-0.4206	**0.8458**
P - rt dwt	**0.7780**	0.4514	**0.7340**	**0.6430**	**0.7053**	**0.6682**	-0.4795	-0.4936	**0.7381**
P - SRR	-0.3949	-0.1317	**-0.7254**	-0.2429	-0.4658	-0.3092	0.4737	**0.8518**	-0.3823

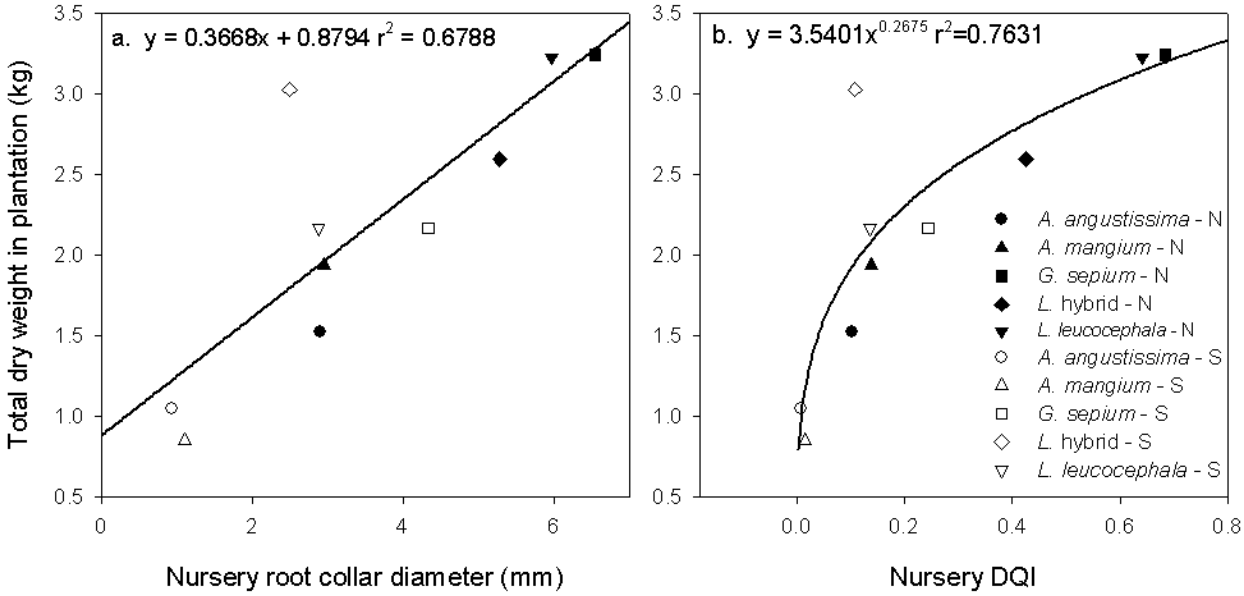
$n = 10$

$p \leq 0.05$ when coefficient ≥ 0.6319, $p \leq 0.01$ when coefficient ≥ 0.7646

rcd = root collar diameter, ht = height, rt leng = length of tap root, sht wt = shoot dry weight, rt wt = root dry weight, tot wt = total weight, SQ = sturdiness quotient, SRR = shoot: root ratio, DQI = Dickson's Quality Index, dbh = diameter at breast height

Caption for Figures

Fig. 1: Relationship between total plant dry weight of five exotic tree species after 12 months growth in irrigated plantation and (a) root collar diameter and (b) Dickson's Quality Index after 2.5 months in the nursery in normal nursery substrate (N) or sand (S)



a. y = 0.3668x + 0.8794 r2 = 0.6788
Total dry weight in plantation (kg)
Nursery root collar diameter (mm)
b. y = 3.5401x0.2675 r2=0.7631
Nursery DQI
A. angustissima - N
A. mangium - N
G. sepium - N
L. hybrid - N
L. leucocephala - N
A. angustissima - S
A. mangium - S
G. sepium - S
L. hybrid - S
L. leucocephala - S