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Original Research Article

Initial growth responses of five multipurpose tree species under moisture stressed environment, Northern Ethiopia: Implications for rehabilitation of degraded areas in the drylands

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Abstract

This study was conducted in Abergele, a degraded and moisture stressed dryland area. The objective of this study was to evaluate the initial growth response of five tree species namely *Leucaena enega, Faidherbia albida, Leucaena leucocephala, Moringa stenopetala,* and *Acacia enegal* with the ultimate goal of selecting best performing species for the restoration of the degraded forest area. Seedlings of these species were planted in the field in June 2010 in a randomized complete block design with three blocks. Data on survival, height and root collar diameter were recorded every three months. High growth response was recorded for *A. enegal, M. stenopetala*, and *L. palida* and were significantly (p<0.0039) different. Similarly, the growth response in root collar diameter also reviled that there was highly significant (p<0.001) difference among the species. High mean value of root collar diameter was recorded for *M. stenopetala* (5.61mm), *A. enegal* (2.86mm), while it was low in *F. albida* and *L. leucocepala* species (1.39mm and 1.69mm, respectively). The survival result also showed *F. albida* was higher (88.9%) followed by *M. stenopetala* (70.4%), *A. Senegal* (66.7%), and *L. palida* (63%), while survival of *L. leucocepala* was only 25.9%. Thus, the long dry season, which extended from seven to nine months in the study area, clearly explains the poor survival and growth response in some of the species. Generally, these findings may help forest managers to properly allocate species into the site that grow and adapt well. Further testing of provenances of the best performing species is recommended to select the most adaptable ones for such areas for future forest plantation establishment at wider scale; on which success of forest plantations depend.

Keywords: Dryland areas, Growth response, Multipurpose trees, Restoration, Survival

INTRODUCTION

Environmental degradation is proceeding at an unprecedented rate in many tropical regions, jeopardizing prospects for conservation of biological diversity and sustainable economic development of agricultural and forest resources (Lanly, 1982), resulting in scarcity of plant cover which is the first symptom of ecosystem degradation associated with increased soil erosion, decreases in water infiltration, plant nutrient availability, organic matter content and loss of microbial activity (Remigi et al., 2008).

Establishing forest plantation on degraded lands can play a key role in harmonizing long-term forest ecosystem rehabilitation or restoration goals with near-term socio-economic development objectives (Lamb, 1998). Forest plantations can contribute to restoring some of the floristic diversity on abandoned land (Newmaster et al., 2006, Aubin et al., 2008) and some plantations may have a surprisingly diverse understory (Keenan et al., 1997). Moreover, plantations can have, in the absence of management strategies aiming at eliminating naturally occurring woody understory species, a “catalytic” effect by facilitating the colonization of early and even late successional tree species and other floristic elements from the surrounding forest (Brockerhoff et al., 2008).

Forest plantations, using appropriate tree and shrub species, can play an important role in the tropical ecosystem rehabilitation (Founoune et al., 2002). The choice of plantation species is likely to greatly influence both the rate and trajectory of rehabilitation processes. Among species that may be considered suitable for a given degraded site, there may be considerable variations in their capacity to stabilize soils, increase soil organic matter and available soil nutrients (Sharma and Gupta, 1989).

In line to this, however, many reforestation projects fail due to inappropriate species choice, a consequence of inadequate knowledge about the potential of species and their growth and survival rates under different site conditions which is basic for the plantation success (Wuethrich 2007).

It is well understood that structural and physiological adaptations to drought determine the growth and survival of forest tree species in dry climates. Because, many plant growth characteristics and phenology of plants at different localities is influenced by environmental factors such temperature, moisture, and soil type (Dierig et al., 2005).

Moreover, successful seedling establishment and growth depends on the stored soil moisture to ensure survival into the next growing season (Warren et al., 2005), water stress commonly affects the growth, survival and distribution of trees (Kozlowski et al., 1991).

In arid and semi-arid ecosystems, water and nutrient availabilities are the main constraints on the growth and productivity of plants (Bréda et al., 2006). Specially, in drylands, water availability is a primary factor controlling plant growth processes and productivity (Li et al., 2007). In dry environments about 90% of the diameter growth in woody plants is attributed to water availability (Zahner, 1968).

Despite the unfavorable growth conditions for most plants in the arid and semi-arid areas, *Acacia* and *Moringa* species are appreciated in these areas because of their specific morphological and physiological attributes enabling them to cope with those conditions (Kasolo, 2010). The rare outstanding characteristics and adaptive responses to moisture stress and drought allow these species to produce a high biomass in extremely dry environments (Gaafar et al., 2006).

Generally, plant moisture and the onset of plant water stress caused by soil water deficits are recognized as the principal limiting factors controlling the growth and survival of forest trees (Tognetti et al., 1995). Therefore, the objective of this study was to evaluate the survival and growth response of five forest trees selected based on their suitability for moisture stressed environments, so that best performing species will be selected for the restoration of degraded forest areas. It is believed that, such information will be used as reference for the future development of forest plantations in similar site conditions contributing to their success. It will also ensure feasibility of dryland forest establishment as tree species selection based on their growth response and spatial arrangement is a key factor.

MATERIALS AND METHODS

Study site

The study was conducted in Abergele (Figure 1) one of the woredas in the Amhara Region of Ethiopia which lies between (13^0 20' N Lat, 38^0 58' E Long; elevation 1250m above sea level). Geographically, it has a very rugged topography of mountains, hills and gorges. The mean annual rainfall of the area is 375mm. The mean annual temperature is 32^0C. The natural vegetation is mainly scattered bushes and shrubs and acacia species.

Experimental design and layout

Five tree species namely *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. Senegal* were selected for this study. Species selection was based on the assumption that these tree species are compatible and potential to grow well in the study area, which is degraded and moisture stressed, and facilitate land rehabilitation and improving soil fertility. Seedlings with the same age of these species were planted in the field in June 2010 using a randomized complete block design with three blocks. Each block had five experimental plots, representing five species of twenty five seedlings each. The spacing between blocks and plots was 2m, plot size was 8mx8m, and the space between trees in a plot was 2m. In each plot, 25 trees were planted, and the nine inner seedlings were taken as a sample for data collection. After planting, the site was protected from grazing and human interferences for the duration of the study. Plantation plots were neither irrigated nor fertilized. Survival, height (from ground level to the tip of the plant) and root collar diameter (RCD) were recorded every 3 months from June 2010 up to June 2012.

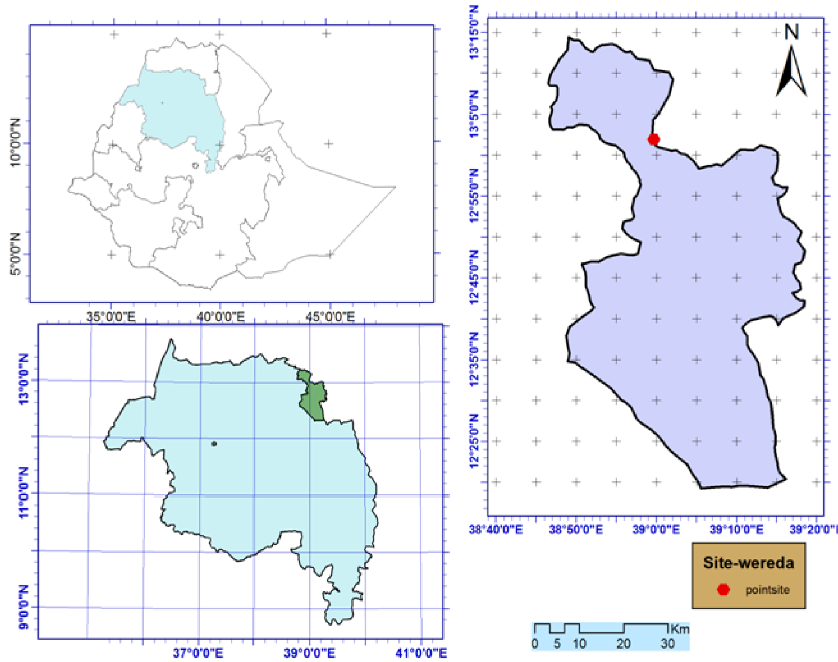

Figure 1. Map of Ethiopia, Amhara Region, and Abergele Wereda with location of the study area (red point).

Survival and growth rate calculations

Survival percentage of each species was calculated as the number of trees surviving by the end of the experiment divided by initial tree number times 100. The relative growth rates (RGRs) for both height and diameter for each species was calculated following the procedure by Ibrahim et al., (2003):

Height; RGR (%): $((H_1\text{-}H_o)/$ time in years) *100

Diameter; RGR (%): $((D_1\text{-}D_o)/$time in years)*100

Where: H_0 is the initial plant height in cm, and H_1 is the plant height in cm on any given observation date, D_0 and D_1 were the diameters in mm at the beginning and the end of each period.

Statistical analysis

Statistical analyses were performed to test the growth data of the selected tree species using One-way analysis of variance (ANOVA) procedures. Mean comparisons were made using the Tukey Honest Significant Difference (HSD) test at 0.05 significant levels. The JMP 5 package was used to perform all the statistical analysis.

RESULTS

Survival rate of the species

Survival data of the five species under the present investigation (Table 1) revealed that *F. albida* was higher (88.9%) followed by *M. stenopetala* (70.4%), *A. Senegal* (66.7%), and *L. palida* (63%), while survival of *L. leucocepala* was only 25.9%. (Figure 2)

Height and diameter growth

The analysis of variance of the height data recorded by the end of the experiment revealed that there were highly significant differences among the species ($p<0.0039$). *A. senegal, M. stenopetala* and *L. palida* were the species attained the highest mean values, while *F. albida* and *L. leucocepala* species had the lowest value (Table 1). Similarly, the root collar diameter data also reviled that there were highly significant ($p<0.001$) differences among the species. High mean value of root collar diameter was recorded in *M. stenopetala* (5.61mm), while it was low in *F. albida* and *L. leucocepala* species (1.39mm and 1.69mm, respectively). (Figure 3, 4)

Relative growth rate

The analysis of variance of relative height, and diameter growth rates for the selected species showed highly significant differences ($p<0.0071$ and $p<0.001$ respectively. The comparisons between the height and diameter RGR averages for the species showed that *A. senegal* had the highest average height RGR value followed by *M. stenopetala*, *L. palida, L.*

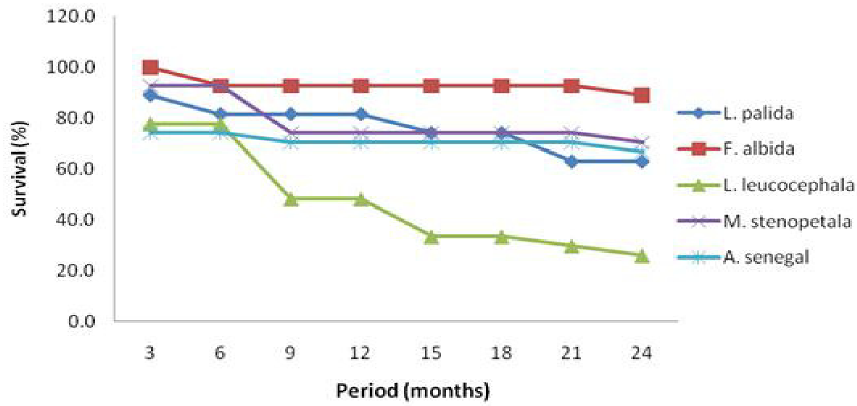

Figure 2. Survival (%) for *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. senegal* through sequential periods from June 2010 to June 2012.

Table 1. Mean height, diameter and survival rate of *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. senegal*.

Species	Height (cm)	RCD (mm)	Survival (%)
M. stenopetala	155.79±12.05a*	5.61±0.33a	70.4
A. senegal	163.56±12.38a	2.86±0.34b	66.7
L. palida	128.29±12.74ab	2.05±0.35bc	63.0
L. leucocepala	108.67±19.86b	1.69±0.55bc	25.9
F. albida	105.43±10.72b	1.39±0.29c	88.9

*Values followed by the same letters within each column are not significantly different at p<0.05 level according to Tukey Honest Significant Difference (HSD) test. Values are expressed as mean ± standard error. RCD=root collar diameter

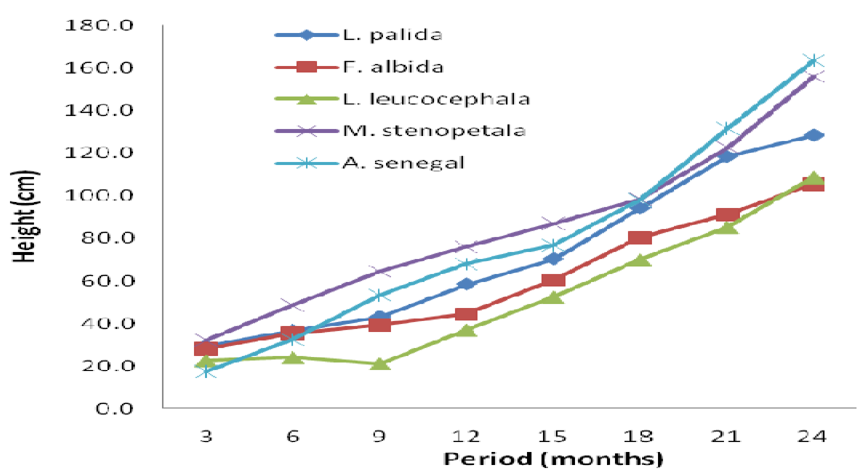

Figure 3. Growth of height (cm) for *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. senegal* through sequential periods from June 2010 to June 2012.

leucocepala, and *F. albida* (Table 2). The highest average diameter RGR was also attained by *M. stenopetala* followed by *A. senegal*, *L. palida*, *L. leucocepala*, and *F. albida* (Table 2).

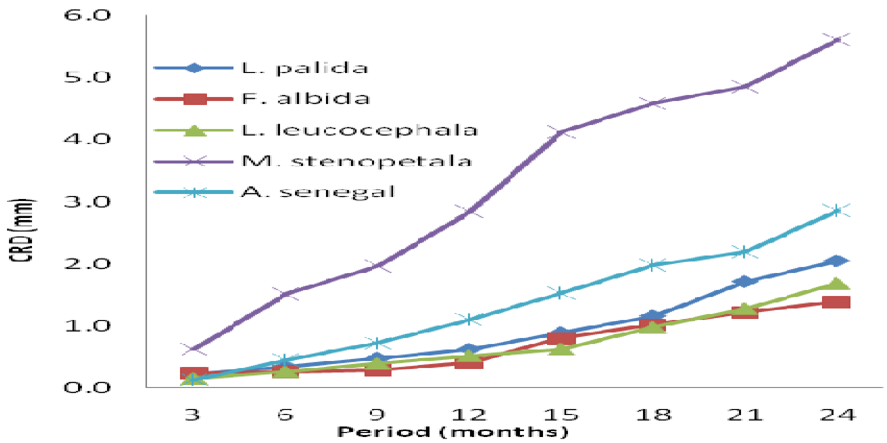

Figure 4. Growth of root collar diameter (mm) for *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. senegal* through sequential periods from June 2010 to June 2012.

Table 2. Height and diameter relative growth ratio (RGR) of *L. pallida, F. albida, L. leucocephala, M. stenopetala,* and *A. senegal* species at Abergele a lowland dry area.

Species	Height RGR (cm year⁻)	RCD RGR (mm year⁻)
F. albida	42.35±5.47b*	0.60±0.16c
A. senegal	71.18±6.36a	1.28±0.18b
L. leucocepala	43.33±10.70ab	0.90±0.30bc
L. palida	51.53±6.36ab	0.91±0.18bc
M. stenopetala	63.58±6.18ab	2.38±0.17a

*Means followed by the same letter are not significantly different at P≤0.05 as determined by Tukey Honest Significant Difference (HSD) test. Values are expressed as mean ± standard error. RGR; Relative growth rate.

DISCUSSION

The long dry season, which extended from seven to nine months in the study area, clearly explains the low survival of the *L. leucocepala* seedlings during this season. On the other hand, *F. albida*, *M. stenopetala*, *A. senegal* and *L. palida* were found to be highly resistance to moister stress in the study area.

Similar results have been reported by Raebild et al., (2003) that *F. albida* and *A. senegal* had higher survival than *A. tortilis* in hot, dry and moisture stressed area. According to Karachi and Lefofe (1997) *L. pallida* can also withstand several months of dry season where rainfall is highly seasonal. Yitebitu Moges (2004) also reported that *M. stenopetala* is quite drought resistant species which is similar to the observation of the present study.

In the present study, the mortality was subjectively attributable to abiotic factors such as drought and moisture stress during the initial growth from October to June, although biotic problems like termites were also experienced during the assessment period. Due to the long dry season, mainly *L. leucocepala* had showed a marked decrease from 77.8% to 25.9% in the specified period compared to the other species. This can be attributed to the moisture stress experienced, which as Kozlowski et al. (1991) also stated can affect the growth, survival and distribution of forest trees.

This finding also concurs with McKinnell (1990) who stated that *A. senegal* and *F. albida* are the most promising species in the hot, dry subtropics and tropics with high salt tolerance and high coppicing ability. In the present study, *M. stenopetala* was also performing best in survival in the study area. This is a good observation, where on top of its multiple use and contributions to household food security, its character of best adaptation to dryland areas is an added advantage. Yitebitu Moges (2004) also reported that *M. stenopetala* is quite drought resistant species, and does not have any specific soil requirements, except it does not grow on water logged or swampy soils.

Results on the growth response also showed that, *A. senegal, M. stenopetala*, and *L. palida* were higher than the other species. Thus, increase their importance for soil conservation in the area, since trees with fast growth habit can shorten establishment period and protect the soil form excessive soil erosion. Similarly, Raebild et al. (2003) also stated that apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment as tall trees usually being better adapted to the site than short trees.

It has been previously reported that *A. Senegal* the multipurpose tree has the additional benefit of being able to fix nitrogen, thus constituting an N input into the ecosystem (Cossalter, 1987) and this species could be used to improve soil characteristics through maintenance of soil organic matter or soil aggregation (Cossalter, 1987). *M. stenopetala* and *L. palida* also can play a great importance in the rehabilitation process especially during periods of drought or in areas where nutrient resources are not available.

Several similar studies also showed that fast growth of seedling is an important indicator in terms of determining the situation of growth response especially in the first growing period and it is commonly assumed that the early fast growth rates of tropical trees reflect productivity status of the trees (Baris and Ertenkin, 2010).

In contrast, poor survival and growth response was observed on *L. leucocepala* that might be explained as a response to the site condition and the long dry season with severe moisture stress especially during the initial seedling growth in the area. Soil and belowground competition are also other factors that influence the growth and survival rate of *L. leucocepala* (Casper and Jackson, 1997).

Other researchers also stated that slow establishment is considered to be a major limitation to the expanded use of *L. leucocepala.* Slow seedling growth makes this species to be more vulnerable to weed competition during the initial growing period (Ruaysoongnern et al., 1985) and growth response is low in dry environments (Brewbaker et al., 1985)

Despite its high survival, *F. albida* also had low growth response in this study. However, as this species is relatively drought resistant, it can grow slowly. Piotto et al. (2009) also stated that some species may show accelerated growth response after poor growth in the initial periods which emphasizes the need for continuous monitoring of growth and mortality in plantations and reforestation trials.

Implications for rehabilitation of degraded area in the drylands

Rehabilitation of degraded areas for environmental conservation and possible production has been the prime focus of the country's endeavor in reversing degradation trends. As one component to rehabilitation activities, was the incorporation of trees and shrubs into the system. This basically has enabled to stabilize the degraded landscape along with physical soil and water conservation measures. The provision of animal fodder and amenities was also another multiple use of incorporating trees and shrubs in land rehabilitation. And these days there is an increasing interest in conserving not only the soil but also carbon, where trees and shrubs in the system are getting better values.

On the contrary, not all rehabilitation efforts involving trees and shrubs were successful to the level they are expected. This, on top of the moisture stressed environment, failure in the selection of most adaptable species to the prevailing conditions was one of the bottlenecks. Only few studies have addressed the question of which species show the best natural potential for adaptability. This needs selection of tree species that have developed mechanisms to efficiently exploit the environmental conditions found in such degraded areas, particularly the low moisture and fertility of most soils.

The preliminary results from this study will then serve as an input in the decision making of selecting species for rehabilitation of degraded areas of similar field conditions in the country. This is believed to increase the likelihood of success of rehabilitation interventions as known well adapted species will be incorporated to the system. Moreover, this will ensure not only the conservation of soil being eroded, increase success of regenerating native species, but also the provision of ecosystem services for the local communities as the productivity of rehabilitated areas will be enhanced.

REFERENCES

Aubin I, Messier C, Bouchard A (2008). Can plantations develop understory biological and physical attributes of naturally regenerated forests? Biol. Conserv. 141: 2461-2476.

Baris H and Ertenkin M (2010). Growth models in investigating oriental beech (*Fagus orientalis Lipsky*). Romanian Biotechnological Letters 16: 5850-5857.

Bréda N, Huc R, Granier A, Dreyer E (2006). Temperate forest trees and stands under severe drought: a review of ecophysiological responses, adaptation processes and long-term consequences. Ann. For. Sci. 63: 625-644.

Brewbaker J, Hegde L, Hutton N, Jones EM, Lowry RJ, Moog JB van den Beldt R (1985). *Leucaena* - Forage Production and Use. NFTA, Hawaii. Pp: 39.

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J (2008). Plantation forests and biodiversity: oxymoron or opportunity? Biodivers. Conserv. 17: 925-951.

Casper B, Jackson RB (1997). Plant competition underground, Annu. Rev. Ecol. Syst. 28: 545-570.

Cossalter C (1987). Introduction of Australian *acacias* into dry, tropical West Africa. Forest Ecology and Management 16: 367-389.

Dierig DA, Adama NR, Mackey BE, Dahlquist GH, Coffelt TA (2005). Temperature and elevation effects on plant growth, development, and seed production of two Lesquerella species. Industrial Crops and Products. Pp: 17-25.

Founoune H, Duponnois R, Ba AM, El Bouami F (2002). Influence of the dual arbuscular endomycorrhizal/ectomycorrhizal symbiosis on the growth of *Acacia holosericea (A. Cunn. Ex G. Don)* in glasshouse conditions. Annals of Forest Sciences 59: 93-98.
Gaafar AM, Salih AA, Luukkanen O, Fadl MA, Kaarakka V (2006). Improving the traditional Acacia senegal-crop system in Sudan: the effect of tree density on water use, gum production and crop yields. Agrof. Syst. 66: 1-11.
Ibrahim M, Aref LI, El-Juhany, Said SH (2003). Comparison of the growth and biomass production of six acacia species in Riyadh, Saudi Arabia after 4 years of irrigated cultivation. Journal of Arid Environments 54: 783-792.
Karachi M, Lefofe BM (1997). The performance of *Leucaena spp*. at Morale, Botswana. LEUCNET News 4: 11-12.
Kasolo J (2010). Phytochemicals and uses of *Moringa oleifera* leaves in Ugandan rural communities. Journal of medicinal plant research 4 (9): 753.
Keenan R, Lamb D, Woldring O, Irvine T, Jensen R (1997). Restoration of plant biodiversity beneath tropical tree plantations in Northern Australia. For. Ecol. Manage. 99: 117-131.
Kozlowski TT, Kramer PJ and Pallardy SG (1991). The physiological ecology of woody plants. Academic Press, Toronto. Pp: 657.
Lamb D (1998). Large scale ecological restoration of degraded tropical forestlands: the potential role of timber plantations. Rest. Ecol. 6: 271-279.
Lanly JP (1982). Tropical Forest Resources. FAO For. Pap. 30. FAO, Rome. Pp:106.
Li JB, Chen FH, Cook ER, Gou XH, Zhang YX. 2007. Drought reconstruction for north central China from tree rings: The value of the Palmer drought severity index, Int. J. Climatol. 27: 903-909.
McKinnell F (1990). Species trail on alkaline soils in Indonesia. Forestry Newsletter 10:1-3.
Newmaster SG, Bell FW, Roosenboom CR, Cole HA, Towill WD (2006). Restoration of floral diversity through plantations on abandoned agricultural land. Can. J. For. Res. 36:1218-1235.
Piotto D, Craven D, Montagnini F, Alice F (2009). Silvicultural and economic aspects of pure andmixed native tree species plantations on degraded pasture lands in humid Costa Rica. New Forests 39: 369-385.
Raebild A, Graudal L and Rehman SK (2003). Evaluation of a provenance trial with *Acacia albida, A. senegal* and *A. tortilis* at Dagar Kotli, Pakistan. Trial no. 21 in the arid zone series. Results and Documentation No. 26.
Remigi P, Faye A, Kane A, Deruaz M (2008). The exotic legume tree species Acacia holosericea alters microbial soil functionalities and the structure of the arbuscular mycorrhizal community. Applied and Environmental Microbiology 74: 1485-1493.
Ruaysoongnern S, Shelton HM and Edwards DG (1985). Effect of pot size on growth of Leucaena leucocephala cv. Cunningham. Leucaena Research Reports 6:11-13.
Sharma BD and Gupta IC (1989). Effect of trees cover on soil fertility in western Rajasthan. Indian For. 115: 348-354.
Tognetti R, Johnson JD, Michelozzi M (1995). The response of European beech (Fagus sylvatica L.) seedlings from two Italian populations to drought and recovery. Trees 9: 348-354.
Warren JM, Meinzer FC, Brooks JR, Domec JC (2005). Vertical stratification of soil water storage and release dynamics in Pacific Northwest coniferous forests. Agric. For. Meteorol. 130: 39-58.
Wuethrich B (2007). Biodiversity: reconstructing Brazil’s Atlantic rainforest. Science 315:1070-1072.
Yitebitu M (2004). Recommended Agroforestry/Multipurpose Trees for Borana Lowlands/Midlands and their Production Techniques. Sub-report, No. 4.
Zahner R (1968). Water deficits and growth of trees. In: Kozlowski, T.T. (Ed.), water deficits and plant growth II, Academic Press New York. Pp. 191-254.