Growth Characteristics, Biomass and Chlorophyll Fluorescence Variation of Garhwal Himalaya’s Fodder and Fuel Wood Tree Species at the Nursery Stage

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Fodder and fuel wood deficiency in the Himalayan region is well recognized. Rural inhabitants are exploiting these forest resources for their livelihood for generations which leads to severe deforestation. The aim of this study was to identify the fast growing fodder and fuel wood tree species of Garhwal Himalayas at nursery stage with wider relevance and great potential for extensive afforestation programmes. Seed of Bauhinia purpurea L., Bauhinia retusa Roxb., Bauhinia variegate L., Celtis australis L., Ficus nemoralis Wall., Ficus roxburghii Wall., Grewia optiva Drummond, Leucaena leucocephala (Lam.) de Wit, Melia azedarach L., Ougeinia oojieinensis (Roxb.) Hochr., Quercus leucotrichophora A. Camus, Terminalia alata Heyne ex Roth. and Toona ciliate M. Roem. were collected from the superior trees and seedlings were raised. After one year and one month of establishment at the nursery, the growth characteristics, biomass and chlorophyll fluorescence (dark-adopted Fv/Fm) of each species were also recorded. G. optiva had shown the highest growth in terms of height, basal diameter increment and number of branches, while production of leaves was more on O. oojieinensis. Biomass and chlorophyll fluorescence (maximum quantum yield or photochemical efficiency of PSII) was found highest in Q. leucotrichophora which indicates photosynthetically this species was most active among the studied fodder and fuel wood tree species. The information in this communication could be utilized for developing various conservation and sustainable strategies in the Garhwal Himalayas to mitigate the scarcity of fodder and fuel wood production.

Keywords: Scarcity; Fodder and Fuel Wood Species; Screening; Growth; Biomass; Chlorophyll Fluorescence

Introduction

The rural population of the Himalayan region have been exploiting forest resources for their livelihood for generations. The excessive and uncontrolled use of fodder and fuel wood has ended up with severe deforestation. In Garhwal Himalaya, about 77.4% of the total human population is rural (Anonymous, 1991). Several hilly regions of Garhwal Himalayas, the rural inhabitants, mostly women’s are use to spend about 60 percent of their daytime for collection of fodder and fuel wood, and for this purpose they often travel 5 - 10 km distances per day. The foliage of tree forms is the key source of green fodder during dry months as the major areas is rain fed and no green fodder is grown in agricultural fields (Husen & Nautiyal, 2004). Moreover, for rural inhabitants due to poor connectivity with the urban areas, the alternative sources of fuel wood are not easily accessible consequently making the population to totally depend on wood resources (Bhatt et al., 2004); and it is evident that most of this demand is met from the adjoining forests almost uninterrupted (Shah, 1982; Khosshoo, 1987), and biomass (i.e. fuelwood and fodder) extraction is the major reason for such depletions (Singh, 1998). Most of the fodder and fuel wood tree species of Garhwal Himalayas are under stress because of unplanned or unscientific lopping (Husen & Nautiyal, 2004). It has been remembered that the improvement and preservation of life in the third world will largely depend on the presences of forest and also availability of fuel wood (Perschel, 1991). Therefore, to meet this critical requirement of fodder and fuel wood tree species, and to reduce the pressure on natural forests stand, there is a strong need to screen the fast growing fodder and fuel wood tree species in hilly regions of Garhwal Himalayas.

Growth characteristics and photosynthetic efficiency or chlorophyll fluorescence have been used to select high-quality seedlings or clones for a particular environment (Husen et al., 2004a; Husen, 2009). Chlorophyll fluorescence is a useful physiological test to detect perturbation of leaf metabolism and growth of seedling because it is a noninvasive, nondestructive and rapid procedure (Barbagallo et al., 2003). The chlorophyll fluorescence rises rapidly from a ground state (Fo) when all electron acceptors are fully oxidized, to a maximum fluorescence level (Fm) when electron acceptors are highly reduced and unable to accept and transfer electrons. Chlorophyll fluorescence then decreased slowly to a steady state (Fv) as photo-chemistry and CO2 assimilation increased (Krause & Weis, 1991). The ratio of maximum variable fluorescence Fv/Fm (where, Fv = Fm − Fo) is linearly correlated with the quantum yield of net photosynthesis (Krause & Somersalo, 1989) and thus may be a good measure of seedling vigour (Husen, 2009). Chlorophyll fluorescence has also been used as a diagnostic tool to study the various envi-
Environmental stresses (Ashraf et al., 2004; Yin et al., 2005; Husen, 2010), genotypic variation (Janssen et al., 1995; Husen, 2009), altitudinal variation (Husen et al., 2004a) and species specific diurnal changes (Husen et al., 2004b). Therefore, chlorophyll fluorescence is a sound method to diagnose seedling stock quality (Mohammed et al., 1995; Barbagallo et al., 2003; Husen, 2009). There is no report available on screening of fast growing indigenous fodder and fuel wood species growing at nursery stage, considering the growth, biomass and physiological characteristic features. Therefore, this research paper focuses extensive attention on these parameters to identify the best and fast growing fodder and fuel wood tree species of Garhwal Himalayas with wider relevance and great potential for afforestation programmes.

Material and Methods

Experimental Site

The experiments were conducted at the Plant Physiology nursery of New Forest campus, Forest Research Institute (FRI), Dehra Dun, Uttarakhand (UK), India. The FRI campus is located in Doon Valley and is surrounded by Western Lesser Himalayan ranges in the North and Shiwalik ranges in the South. This campus covers an area of 4.45 km², and lies at an elevation of 640 m above mean sea level. It is situated on North Latitude 30°20′40″ and East Longitude 77°52′12″ on the northern limit of the Oriental region.

Plant Materials

For quality planting material, the seeds of Bauhinia purpurea L., Bauhinia retusa Roxb., Bauhinia variegata L., Celtis australis L., Ficus negoralis Wall., Ficus roxburghii Wall., Grewia optiva Drummond, Leucaena leucocephala (Lam.) de Wit, Melia azedarach L., Ougeinia ooeijensis (Roxb.) Hochr., Quercus leuotrichophora A. Camus, Terminalia alata Heyne ex Roth. and Toona ciliate M. Roem. were collected from the phenotypically superior trees in different localities under research forest/plantation/agroforestry areas of Garhwal regions, Uttarakanchal, India. The superiority percentage was calculated following Wright (1976) as: $S = \left( \frac{C}{A} \times 100 \right) - 100$; where, S is superiority percentages, C is value for Candidate Plus Tree’s and is stand for average value of five comparison trees. The details of the selected superior tree species from which seeds were collected are mentioned in Table 1.

Nursery Development and Experimental Design

Nursery was developed to identify and screen fast growing fodder and fuel wood tree species at New Forest campus, FRI, Dehra Dun, UK, India. Seeds obtained from the superior tree were carefully examined for disease free status and shown in plastic tray for germination. When seeds were germinated; these were transplanted to the polybags in mid June, 2002. The polybags were filled with the mixture of soil, sand and farm-yard manure in the 2:1:1 ratio and the total weight of the medium was 1.50 kg. The planting medium had 0.120, 0.024 and 0.31 percent nitrogen, phosphorous and potassium respectively. These polybags with plantlets were acclimatized in green house. The upper portion of the green house was covered with green plastic shade, while the other parts remained open. Following 2 months of acclimatization all polybags were shifted to an open environment prevailing at New Forest campus. These plantlets were maintained carefully by regular watering and weeding. Complete protection was provided against diseases and insects by foliar spray with insecticides and fungicides, as and when required. The completely randomized factorial design (CRD) was used for this experimentation. Five replications with ten seedlings ($5 \times 10 = 50$ seedling per species) were used.

Growth and Biomass Studies

After one year and one month (July, 2003) observation on growth namely height (cm) was measured from the ground line of polybags up to the tip of each species. Similarly, the ground line basal diameter (mm), number of leaves (in number) and

Table 1.

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>Detail characteristics of phenotypically superior fodder and fuel wood trees species.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species name</td>
<td>Height (in meter)</td>
</tr>
<tr>
<td>Bauhinia purpurea L.</td>
<td>13.10</td>
</tr>
<tr>
<td>Bauhinia variegata L.</td>
<td>12.62</td>
</tr>
<tr>
<td>Bauhinia retusa Roxb.</td>
<td>10.10</td>
</tr>
<tr>
<td>Celtis australis L.</td>
<td>16.52</td>
</tr>
<tr>
<td>Ficus negoralis Wall.</td>
<td>8.30</td>
</tr>
<tr>
<td>Ficus roxburghii Wall.</td>
<td>11.60</td>
</tr>
<tr>
<td>Grewia optiva Drummond</td>
<td>9.60</td>
</tr>
<tr>
<td>Leucaena leucocephala (Lam.) de Wit</td>
<td>14.28</td>
</tr>
<tr>
<td>Melia azedarach L.</td>
<td>16.00</td>
</tr>
<tr>
<td>Quercus leuotrichophora A. Camus</td>
<td>19.30</td>
</tr>
<tr>
<td>Ougeinia ooeijensis (Roxb.) Hochr.</td>
<td>10.44</td>
</tr>
<tr>
<td>Terminalia alata Heyne ex Roth</td>
<td>27.50</td>
</tr>
<tr>
<td>Toona ciliate M. Roem</td>
<td>21.50</td>
</tr>
</tbody>
</table>
number of branch (in number) were recorded. Thereafter, at the same time the destructive sampling were performed for biomass (the total dry weight of each seedling in gm). Total dry mass or dry weight of each seedling was obtained after placing the root, stem and leaves in an oven at 70°C for 48 h.

**Chlorophyll Fluorescence Measurements**

The chlorophyll fluorescence of each species were recorded during 10:00 to 11:00 hrs on cloud free conditions over a period of 2 days with the help of portable Hansatech Plant Efficiency Analyser (Hansatech, King’s Lynn, England) in first week of July, 2003 (Table 2). For chlorophyll fluorescence, data was analyzed taking three replication of each species. Approximately, the 5th leaf from top was darkened with leaf clips for twenty minutes before the measurement. Then values of Fv/Fm (chlorophyll fluorescence) at ambient temperature were noted (Husen, 2009).

**Statistical Analysis**

Statistical analysis was carried out with the Statistical Package for Social Sciences (SPSS) software package version 6.1.3. A fixed-effects model was used for statistical analyses. The data recorded on the growth, i.e. height, the ground line basal diameter, number of leaves, number of branches and biomass were subjected to one-way analysis of variance (ANOVA) to test the significant variation among the different fodder and fuel wood species. In the ANOVA, the mean values of each replication of each species contained five plants (3 × 5), therefore, 15 seedlings were measured from each species. As mentioned previously that the chlorophyll fluorescence, such as it might be due to low temperature (Hardacre & Greer, 1989), low irradiance (Janssen et al., 1990; Singh et al., 2006). Similar observations have also been examined in many other species by several investigators (Salazar, 1989; Bindroo et al., 1990; Singh et al., 2006).

Chlorophyll fluorescence study exhibited significant variation in photochemical efficiency in PS II as it was recorded as Fv/Fm ratio on fully developed leaves in sunny days. *Q. leucotrichophora* was found to be photosynthetically most efficient species while *B. variegat* was exhibited least Fv/Fm ratio (Figure 6). The extent of chlorophyll fluorescence variation in selected fodder and fuel wood tree species was probably due to the specific liking of individual species or environmental conditions. Several explanation have been given for variation in chlorophyll fluorescence, such as it might be due to low temperature (Hardacre & Greer, 1989), low irradiance (Janssen et al., 1995) and/or other environmental conditions (Parker & Mohamed, 2000; Husen et al., 2004a, 2004b) were observed by several researchers. It was interesting to note that both total biomass and chlorophyll fluorescence was higher in *Q. leuco-

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**Table 2.** Meteorological data during chlorophyll fluorescence (Fv/Fm) measurements.

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>Rainfall (mm)</th>
<th>Evaporation (mm)</th>
<th>Bright sunshine (hrs)</th>
<th>Mean wind velocity (Km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Min.</td>
<td>Mean</td>
<td>719</td>
<td>1419</td>
<td></td>
</tr>
<tr>
<td>July 28, 2003</td>
<td>34.1</td>
<td>24.9</td>
<td>27.9</td>
<td>92</td>
<td>78</td>
<td>1.6</td>
</tr>
<tr>
<td>July 29, 2003</td>
<td>32.0</td>
<td>23.0</td>
<td>26.6</td>
<td>95</td>
<td>70</td>
<td>22.8</td>
</tr>
</tbody>
</table>

**Table 3.** Analysis of variance for height, basal diameter, number of leaves, number of branches, dry mass and chlorophyll fluorescence.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Height</td>
</tr>
<tr>
<td>Species</td>
<td>12</td>
<td>3195.68*</td>
</tr>
<tr>
<td>Error</td>
<td>52</td>
<td>3.23</td>
</tr>
</tbody>
</table>

Note: *reflect significant at the p ≤ 0.01
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**Figure 1.** Variation in height (in cm) of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate, Br = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.

**Figure 2.** Variation in basal diameter (in mm) of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate, Br = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.

**Figure 3.** Variation in number of branches of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate, Br = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.

**Figure 4.** Variation in number of leaves of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate, Br = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.

**Figure 5.** Variation in total dry mass (in gm) of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate, Br = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.

**Figure 6.** Variation in chlorophyll fluorescence (Fv/Fm) of fodder and fuel wood tree species (Bp = Bauhinia purpurea, Bv = Bauhinia variegate Bv = Bauhinia retusa, Ca = Celtis australis, Fn = Ficus nemoralis, Fr = Ficus roxburghii, Go = Grewia optiva, Li = Leucaena leucocephala, Ma = Melia azedarach, Ql = Quercus leucotrichophora, Oo = Ougeinia oojeinensis, Ta = Terminalia alata and Tc = Toona ciliate). Values followed by the same letter indicate no significant differences at p < 0.05 level according to Tukey’s test. Each value represents the mean ± SE of five replicates.
trichophora; which is supported by more carbon assimilation. Physiological characterization (chlorophyll fluorescence) has been used more in stock quality assessment (Mohammed et al., 1995; Husen, 2009) because this test is noninvasive, nondestructive and rapid (Vidaver et al., 1989). However, in this finding Q. leucotrichophora was photosynthetically most active plants while G. optiva exhibited maximum growth in terms of height and basal diameter at the nursery stage. Hence, selection for plantation of Q. leucotrichophora and G. optiva around agricultural fields in different agroforestry systems of Garhwal Himalaya for rapid growth and higher biomass production can be advantageous. In addition, Q. leucotrichophora and G. optiva also recommended as a fast growing fodder and fuel wood tree species for Garhwal Himalayas which leads with wider relevance and great potential for extensive afforestation programmes.

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REFERENCES