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Screening of Fuel, Fodder and Timber Agroforestry Tree Species for Drought Tolerance

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Abstract

This paper describes the findings of study conducted in northwestern Indian Himalayas to select drought tolerant agroforestry tree species suitable for stress sites. The findings indicated that summer drought from April to June for 25, 50 and 75 days during first and second year after transplanting, adversely but differentially affected growth and physiological attributes of five tree species namely, *Grewia optiva, Morus alba, Dalbergia sissoo, Acacia catechu* and *Populus deltoides*. Plant height, collar diameter and leaf biomass were less in water stressed plants compared to unstressed plants within each tree species and within each drought level. In general, 75 days of drought exerted more pronounced effect on the performance of tree species. The minimum adverse effect of summer drought was seen on *M. alba* and *D. sissoo*, while the maximum on *G. optiva* and *P. deltoides*. Xylem water potential was significantly higher in unstressed plants compared to water stressed plants of all the five tree species. Reduction in photosynthesis under drought over control was least in *M. alba* and *D. sissoo*.

Introduction

Water is one of the most critical constraints, which restricts establishment as well as subsequent growth potential of tree species. Water stress at any phenophase can be deleterious, affecting almost every aspect of growth and physiological functioning of plants (Hennessey and Lorenzi, 1988; Thakur *et al*, 1998; Uprety *et al*, 1999; Thakur *et al*, 2000). The need for afforestation, especially under rainfed conditions and for stress sites is increasing rapidly world over due to the massive deforestation and lack of forest wealth for fuel wood, fodder and timber. The success of these plantations depends on the ability of tree seedlings to establish under water stress conditions (Zwiazek and Blake, 1990; Thakur *et al*, 2000). Desiccation poses great threats to the survival of newly transplanted seedlings. The responses and behaviour of any tree species to first and second summer droughts immediately after outplanting will be indicators for success and / or failure of afforestration programme. The numerous physiological responses of plant to water deficits generally vary with the severity as well as the duration of water stress (Rose *et al*, 1993; Thakur *et al*, 1998; Correia *et al*, 2001; Weigh, 2001). Nursery grown tree seedlings usually experience a great change in environmental conditions when they are outplanted; and unless they are adapted to this change, establishment process will be jeopardised. Practically no information is available on the ability of important agroforestry tree species to cope with the drought conditions, especially during the first two summer droughts after transplanting. This study is an effort to delineate relative drought tolerance as well as impact of two successive summer droughts on *Grewia optiva*, *Morus alba*, *Dalbergia sissoo*, *Acacia catechu*, and *Populus deltoides*; important fuel-fodder and timber agroforestry tree species.

Materials and Methods

The study site is the transitional zone between sub-temperate and sub-tropical with an elevation of 1200 m amsl in the northwestern Indian Himalayas. The area receives an annual rainfall of 1150 mm, most of which is received during the months from July to September. April, May and June are the hottest months with temperature varying between 29^{o} - 37^{o}C. One year old seedlings of five multipurpose agroforestry tree species, namely *Grewia optiva*, *Morus alba* M-5, *Dalbergia sissoo*, *Acacia catechu* and *Populus deltoides* were planted in the last week of June 2001 in the field as square planting with row x row and plant x plant spacing of 80 cm. Plot size was 20 x 9 m and design was RBD factorial with three replications (16 plants per replication).

Withholding watering for 75 days from April to June during 2002 and 2003 imposed summer drought. The calculated amount of water, one evening before creating water stress, was given by the ridge and furrow method based on cumulative pan evaporation (CPE). Thereafter, plants were left unwatered for 75 days, however, the parallel watered plots for each tree species were maintained to serve as control. Soil moisture in unstressed and stressed plots ranged between 14.30-15.22%, whereas between 4.22-4.59% in stressed plots on 75^{th} day of stress. The temperature ranged between 25-36^{0}C and relative humidity 52-37% from April to June; the experimentation period. Observations for water potential, photosynthesis, transpiration, drought tolerance efficiency, injury index and mean daily productivity were made on 75^{th} day after stress treatments. Pressure chamber technique was used to determine leaf water potential for which a method of Scholander *et al.* (1965) was followed.. Photosynthesis (mol m^{-2} s^{-1}) was measured every 25^{th} day with the help of CI-301 Portable Photosynthesis System (CID INC. USA). Four leaves were randomly selected from stressed and unstressed plant within each tree species and data recorded with pre-programmed photosynthesis system between 10:00-12:30 hrs. Each value is a mean of three replications and each replication a mean of 4 readings. Transpiration rate (m mol m^{-2} s^{-1}) was also measured with CI-301 system. Injury index for stressed and control plants was calculated by adopting the method as described by Gebre and Kuhns (1991). Drought tolerance efficiency was calculated on the basis of the following formula:

$$\text{DTE (\%)} = \frac{\text{Above ground biomass (leaf + wood) under stress}}{\text{Above ground biomass (leaf + wood) under control}} \times 100$$

Mean daily productivity (g /tree /day) for stressed and unstressed plants within each species was calculated as shoot + root dry weight (75^{th} day) - shoot + root dry weight (on day of treatment) divided by total number of days. Data were statistically tested using the technique of analysis of variance (Gomez and Gomez 1984).

Results and Discussion

Dry spell from April to June (summer drought) during first and second year after transplanting significantly influenced water potential (Ψ) within each of the five multipurpose tree species tested for drought tolerance. Stress period up to 75 days drastically reduced water potential in all the five tree species with more reduction during the first drought period after transplanting. *G. optiva* followed by *P. deltoides* exhibited least water potential, whereas *M. alba* and *D. sissoo* registered a maximum water potential in comparison to other stressed species. The critical differences for Ψ within each species were statistically significant. The variation in water potential among the tree species at the advent of drought stress, indeed, is the intrinsic abilities of tree species to respond as well as adjust to the changing internal water status (Zwiazek and Blake, 1999; Thakur *et al*., 2000). *M. alba* and *D. sissoo* were observed to maintain significantly higher water potential in comparison to *A. catechu, P. deltoides* and *G. optiva.* This helped *M. alba* and *D. sissoo* to undergo least irreversible changes during drought period mainly via maintaining lower drought injury index and higher hydration of tissues. Better metabolic activities in plants capable of maintaining higher water potential have been reported for various tree species (Choi, 1992, Thakur *et al*., 1998; 2000).

Photosynthesis and amount of water transpired are the other indicators of drought tolerance. Drought period for 75 days during first and second year after transplanting reduced rate of photosynthesis in all the five tree species. Reduction relative to control (unstressed) plants was significantly higher during first summer drought than the second summer drought. Maximum reduction in photosynthesis was observed in *P. deltoides* where rate declined from 20.20 mol m^{-2} s^{-1} to 7.41 mol m^{-2} s^{-1} up to 75 days of stress (Table 1). This was followed by *G. optiva* with 46% inhibition over control. A minimum inhibition in photosynthetic rate was observed for *M. alba* and *D. sissoo*. Stressed plants of all the five MPTs transpired lower amount of water in comparison to unstressed plants during both the summer droughts. Transpiration rate did not reveal marked inergeneric variation, especially during the first summer drought after transplanting. Stressed plants of *M. alba* and *D. sissoo* transpired higher amount of water in comparison to *P.deltoides, A. catechu* and *G. optiva* during second summer drought. Higher rate of transpiration is not desirable under stress conditions since this reflects open state of stomata. This situation, however, will certainly result in greater gaseous exchange ensuring higher photosynthesis. During the present study this has been found to be true since higher rate of transpiration in *M. alba* and *D. sissoo* corresponds to higher rate of photosynthesis. This is probably the reason that these two tree species have exhibited better drought tolerance than the remaining species.

Drought tolerance efficiency is based on the ability of an individual tree species to produce maximum above ground biomass (leaf + wood) under stress compare to unstressed control. The data in figure 1 show comparatively higher drought tolerance efficiency in *M. alba* and *D. sissoo* than *G. optiva, A. catechu* and *P. deltoides* during first and second summer droughts after transplanting. Ability to maintaining higher water potential and photosynthetic rate in these species seems to help them cope with the drought conditions in a better manner. The first summer drought up to 75 days caused greater irreversible damage to all the five species experiencing significantly higher drought injury than that during the second drought after transplanting (Fig. 1). *G. optiva* and *P. deltoides* exhibited 61% drought injury while *M. alba, D. sissoo* and *A. catechu* recorded 26, 32 and 30% drought injury, respectively during first summer drought (Fig. 2). The damage due to second drought period of 75 days, however, was significantly less in all the MPTs, with minimum injury in *Morus* and *Dalbergia*.

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Mean daily productivity (g tree^{-1} day^{-1}) was calculated to look into the cumulative effect of summer drought on synthetic processes. The estimated productivity was significantly higher in unstressed plants compared to water stressed plants. Stressed plants of *M alba* accumulated higher biomass per tree per day than the remaining tree species during both the summer droughts after transplanting. This was followed by *D. sissoo.* The pattern of mean daily productivity was almost similar during both the summer droughts. Mean daily productivity, indeed, is the net and cumulative effect of all the vital metabolic and physiological processes that regulate performance and production at the advent of drought. Significantly higher mean daily productivity in *M alba* and *D. sissoo* than *A. catechu, G. optiva* and *P. deltoides* under similar conditions of water stress, reflects better drought tolerance of *M. alba* and *D. sissoo.*

Conclusions

Higher water potential (better osmotic adjustment) in *M. alba* and *D. sissoo* appears to be the result of maintenance of higher photosynthetic rate. The less injury index in *M. alba* and *D. sissoo* during the summer drought reflects maintenance of equilibrium in favor of synthetic processes. The plants of these tree species have tolerated drought periods with minimum changes at physiological and metabolic levels. This is important and desirable. The findings suggest better drought tolerance of *M. alba* and *D. sissoo* in comparison to *A. catechu, G optiva* and *P. deltoides.* The plantation of *M. alba* and *D. sissoo* may be preferred at dry sites for better success.

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