DENDROBIOLOGY
2006, vol. 56, 37–43

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Acclimation of acacia hybrid (*Acacia mangium* × *Acacia auriculiformis*) vegetative propagules to soil water deficits

Received: 20 April 2006, Accepted: 21 July 2006

Abstract: The aim of the present work was to investigate the acclimation potential of acacia hybrid (*Acacia mangium* Willd × *Acacia auriculiformis* A.Cunn.ex Benth) vegetative propagules to soil water stress in the nursery of Institute of Forestry and Environmental Sciences, Chittagong University. Acacia hybrid showed significant decrease in total plant biomass in two months water-stressed conditions. Allocation of assimilates to root growth relative to shoot found to be an important acclimation mechanism. Leaf area ratio (LAR) increased under water-stressed plants with simultaneous increase in specific leaf area (SLA) but almost no change in leaf weight ratio (LWR). Significant increase in LAR with limited water supply by increasing SLA was likely to be an important acclimation potential since this relative increase in leaf area compensated, at least partially, for a lower photosynthesis under water-stressed conditions as was evident from decreased mean total biomass under water-stressed regimes.

Additional key words: Rooted cuttings, biomass, leaf area ratio, leaf weight ratio, specific leaf area, water deficits

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Introduction

Due to periodic drought shortage of soil-moisture is common in Bangladesh. Plantations commence with outbreak of monsoonal rain in May and continue usually up to August. The propagules get very short growing season followed by a period of five-six months with less than 100 mm rainfall per month. Hence the planted propagules experience gradual decline in soil moisture as dry season progresses. This is very crucial for survivorship and growth of planted seedlings. About 20 to 50 percent of tree seedlings planted every year are reported to die during following dry months (Hassan, 1987). To avoid plantation failure, facts on responses of tree seedlings/propagules to varied soil-water availability is important in choosing right species for raising plantation on a particular site. Although many workers have reported the influence of soil water deficits on plant growth and physiology (Ackerson and Herbert 1977, Osonubi, 1985, Bachelard, 1986, Gollan, et al., 1986, Seiler and Cazell, 1990, Metcalfe et al., 1989, Khalil and Grace, 1992 and Mohiuddin, 1992) there have been a few studies on the impact of soil water deficits to forest tree seedlings especially in Bangladesh. Acclimation mode of specific species to soil drying is thus important from plantation management point of view. While general pattern of responses to water stress is similar in many plants, there are important differences in responses of stomatal (Ludlow, 1980) and developmental (Angus and Moncur, 1977) processes. A species originated in dry climate may differ from those of wet climate in mode of acclimation to water stress. The present study was an attempt to simulate water regimes that might occur in nature particularly in dry months of the year that are crucial for survival and growth of planted propagules in plantations and to investigate mode of acclimation of acacia hybrid (*A. mangium* Willd X *A. auriculiformis* A. Cunn. ex Benth), one of the most popular plantation species of Bangladesh under water deficits.

Materials and methods

The experiment was carried out at the permanent nursery of Institute of Forestry and Environmental Sciences, University of Chittagong, Chitagong, Bangladesh (Fig. 1). The nursery site enjoys a tropical monsoon climate characterized by hot, humid summer and cool, dry winter. The average monthly mean temperature varied between 21.8°C to 29.2°C maximum and between 15°C to 26°C minimum. Relative humidity was generally the lowest (64%) in February and highest (95%) in June-July-August and September. However the mean maximum & minimum temperature, total monthly rainfall and mean humidity (at 12 A.M.) of Chittagong region for the experimental period is shown in Figure 2. Six weeks old stecklings (rooted stem cuttings) of acacia hybrid *(A. mangium* Willd × *A. auriculiformis* A. Cunn. ex Benth) were transplanted on 1st week of October into black polythene tubes (15 cm in diameter and 63 cm in length) which were filled up-to 60 cm with forest top soil. The soil used in the nursery was moderately coarse to fine textured. It has a grey to olive grey; sandy loams

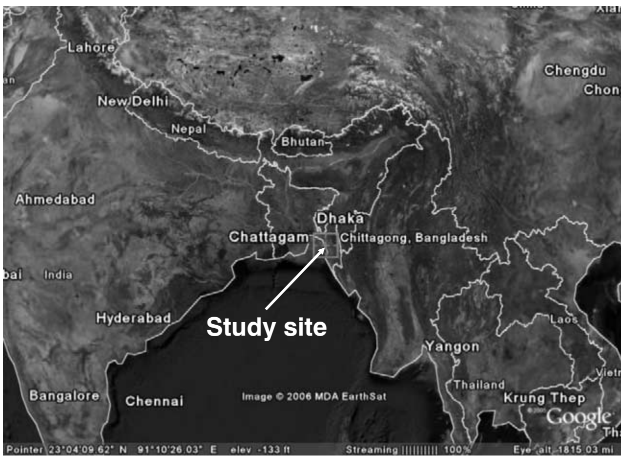

Fig. 1. Study area (Source Google Earth) [Downloaded at 27.03.06]

sub soil with moderate coarse and medium angular blocky structure. The planted growth-tubes (containing a single plant in each) were assigned to four watering regimes: daily (W_0), 3-day interval (W_3), 7-day interval (W_7), and 15-day interval (W_{15}) in three completely randomised blocks. Multi-plant plots (fourteen plants per plot) were used. As such, there were 42 rooted stem cuttings per watering regime. The plants were watered every alternate day for 60 days to allow them to establish. Then the watering treatments commenced and continued for four consecutive 15-day cycles totalling the treatment period of 60 days. For the soil water parameter at the time of harvesting soil moisture content at three different layers (0–18; 18–36 and 36–54 cm.) of growth tubes were measured. Soil samples were collected from each layer of soil column in five replications after separating each layer by a sharp knife. In the measurement fresh and oven dry (at 70°C for 72 hours) weight of the soil samples were recorded and then moisture content was calculated by the formula (fresh weight – Dry weight)/ Dry weight and expressed as g g^{-1}. At the end of 60 days of watering treatments seedlings were harvested, shoot length and leaf area was measured. Leaf area of each plant was measured by grid-plate method. Then root, leaf and shoot samples of each plant were dried in an oven at 70°C for 48 hours and then dry weights were recorded. From these data, specific shoot weight (SSW, shoot dry weight/shoot length), leaf area ratio (LAR, leaf area/total plant dry weight), leaf weight ratio (LWR, leaf dry weight/total plant dry weight), specific leaf area (SLA, leaf area/leaf weight), shoot weight ratio (SWR, shoot dry weight/total plant dry weight), root weight ratio (RWR, root dry weight/total plant dry weight) and root to shoot ratio (R/S, root dry

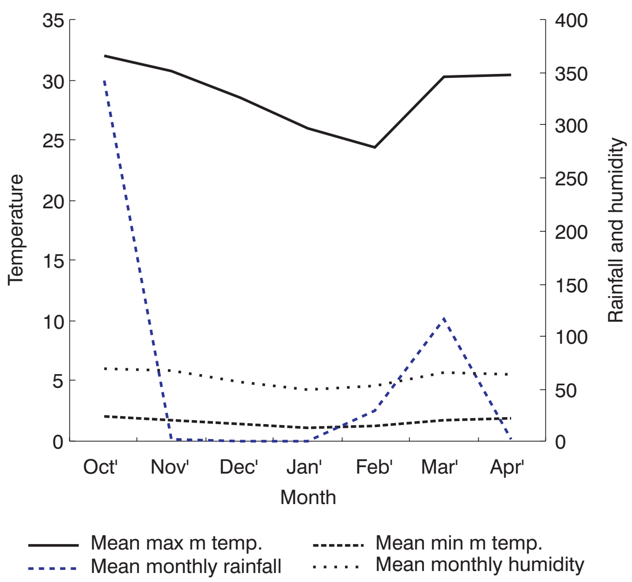

Fig. 2. Mean monthly Temperature (°C), Rainfall (mm), and Humidity (%) for the study period

weight/shoot {leaf+stem} dry weight) were derived following Briggs et al. 1920. Treatment differences were explored by two way analysis of variance and least significant difference test following Freese (1967), Zaman et al. (1982) and Dawkins (1975). Finally the results were computed using Microsoft Excel computer program.

Results and Discussion

Soil water content was significantly reduced due to the watering regimes. In case of W_{15} at the depth of 18 cm it was found lowest (0.12g g^{-1}) and at 54 cm depth of W_0 it was found highest (0.45 g g^{-1}). However the reduction was highest at the top layer (0–18 cm) followed by middle (18–36 cm) and bottom (36–54 cm) layer (Fig 3). Reduction in watering frequencies significantly decreased growth variables of acacia hybrid except height growth (Fig. 4–16). However maximum (82.2 cm) plant height growth was recorded in W_0 and following a gradual decreasing trend the minimum (65.0 cm) was found in W_{15} (Fig. 4). No significant difference for daily and 3-day interval regimes was found. Maximum (41.9 g) plant dry weight was recorded for W_0 and the minimum (24.6 g) was recorded from W_{15} (Fig. 5). The same patterns of responses were observed for leaf (Fig. 7), shoot (Fig. 6) and root dry weights (Fig. 8). Total phyllode area was not significantly affected by watering regimes with reduction in watering frequencies (Fig. 9). SSW was found highest (156.58 mg cm^{-1}) in W_3 and lowest (90.5 mg cm^{-1}) in W_{15}. But between daily and 3-day interval watering regimes was not significant. Shoot weight ratio (SWR) and root weight ratio (RWR) were not significantly affected by watering regimes (Fig. 13 and 14). Specific leaf area (SLA), Leaf area ratio (LAR) and Root to shoot ratio significantly increased with reduction in watering frequencies (Fig. 10, 12 and 16) with no significant increase in leaf weight ratio (LWR) (Fig. 15). Highest (0.281) root shoot ratio was recorded in W_{15} where as the lowest (0.244) was found with W_3.

The decreased total plant dry weight was accompanied by decreased root, shoot and leaf dry weights. The

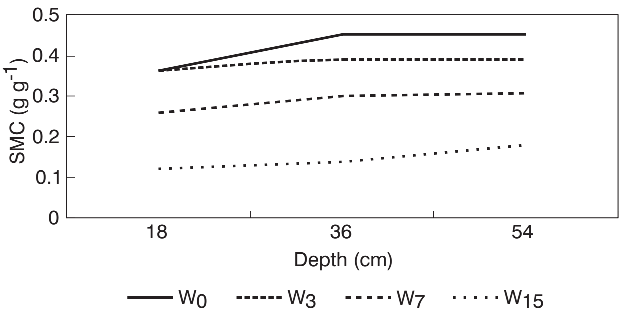

Fig. 3. Soil moisture content (SMC) at various depths after harvesting

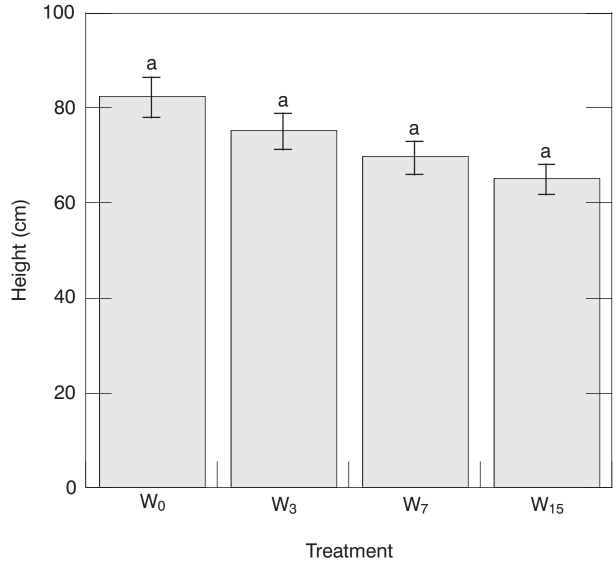

Fig. 4. Plant height in different watering regimes

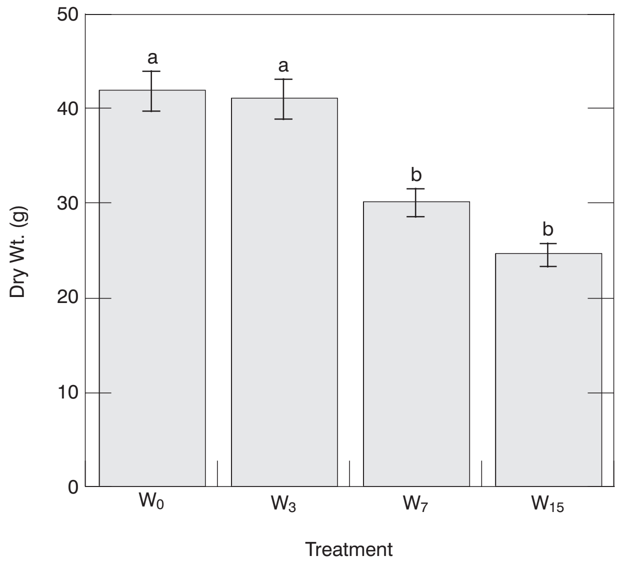

Fig. 5. Plant dry weight in different watering regimes

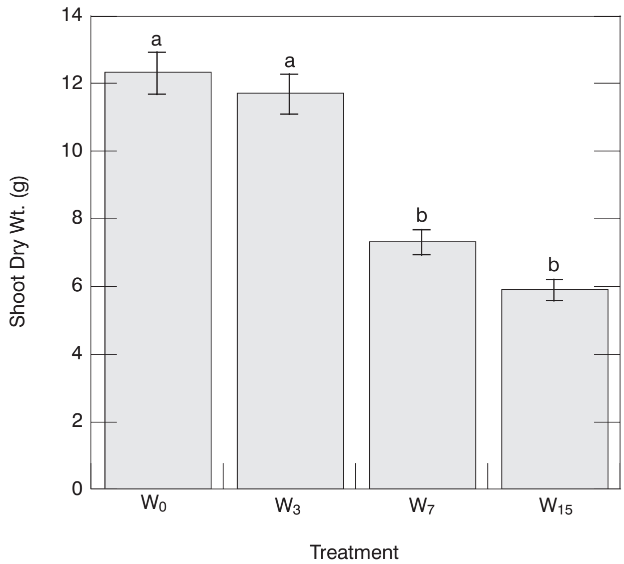

Fig. 6. Shoot dry weight in different watering regimes

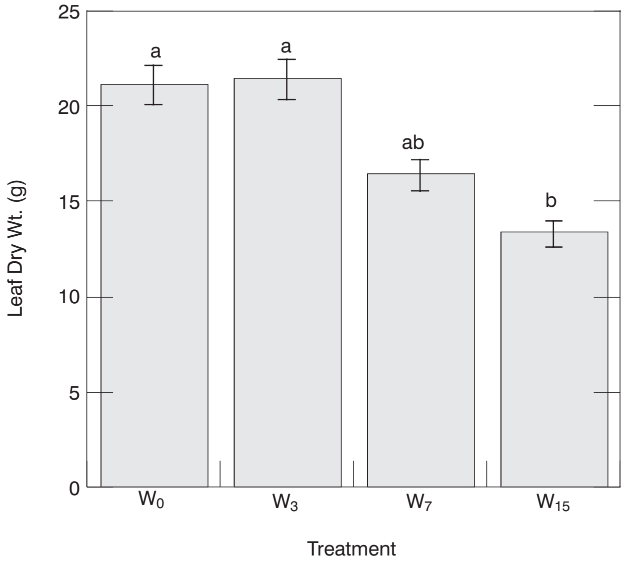

Fig. 7. Leaf dry weight in different watering regimes

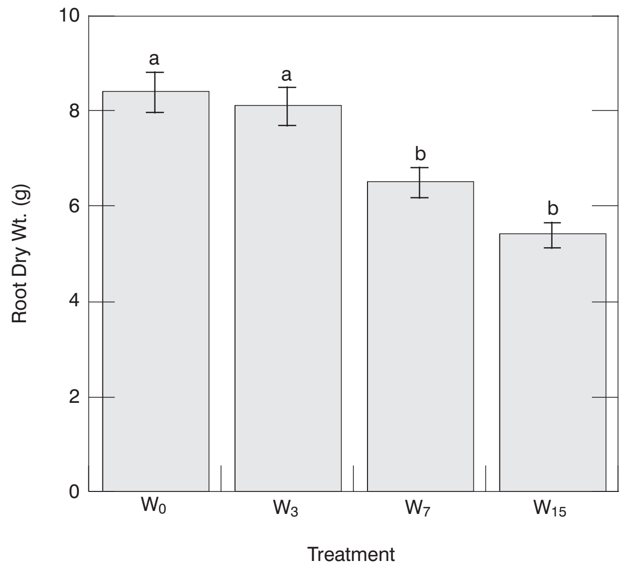

Fig. 8. Root dry weight in different watering regimes

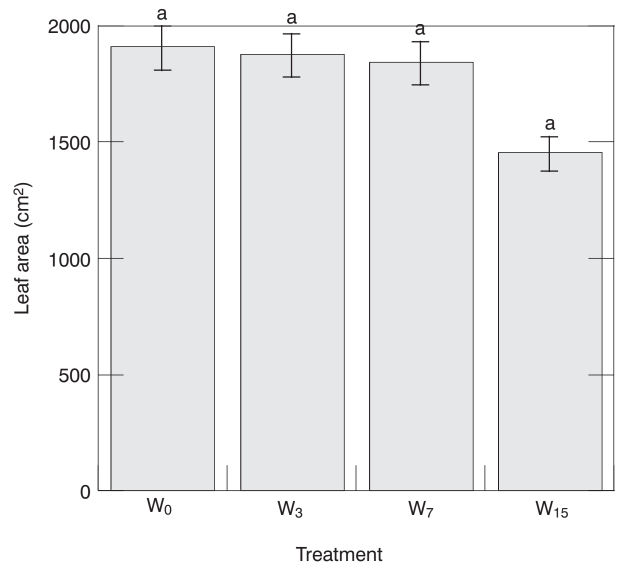

Fig. 9. Leaf area in different watering regimes

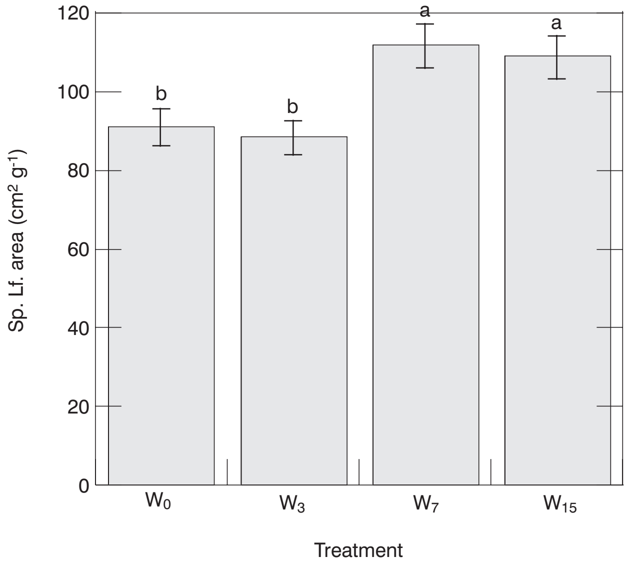

Fig. 10. Specific Leaf area in different watering regimes

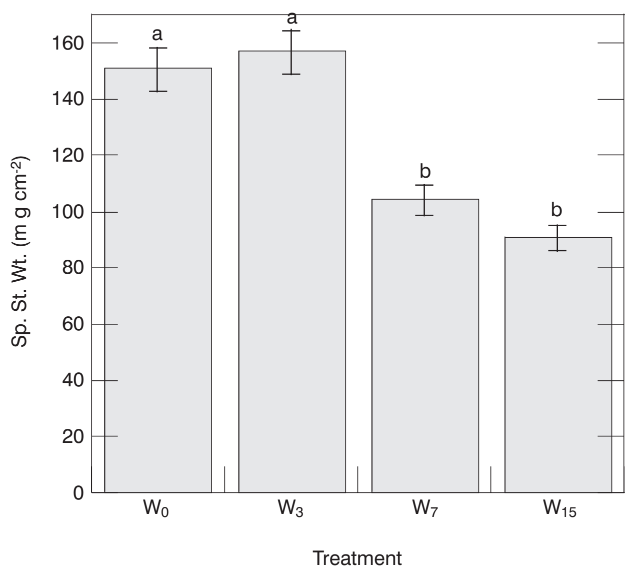

Fig. 11. Specific shoot weight in different watering regimes

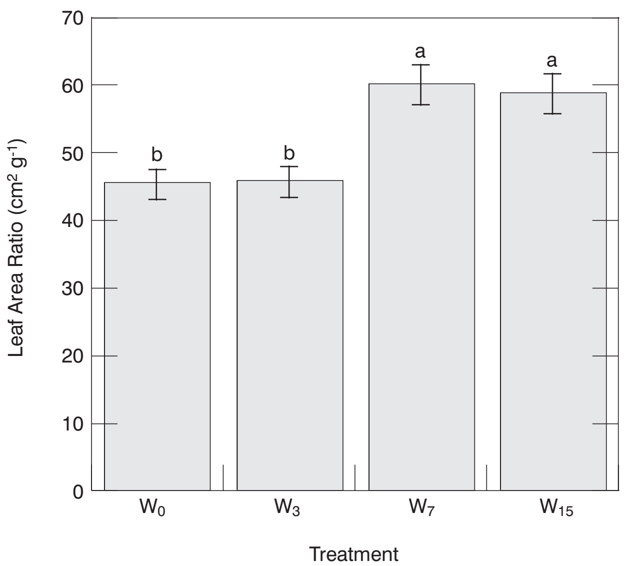

Fig. 12. Leaf area ratio in different watering regimes

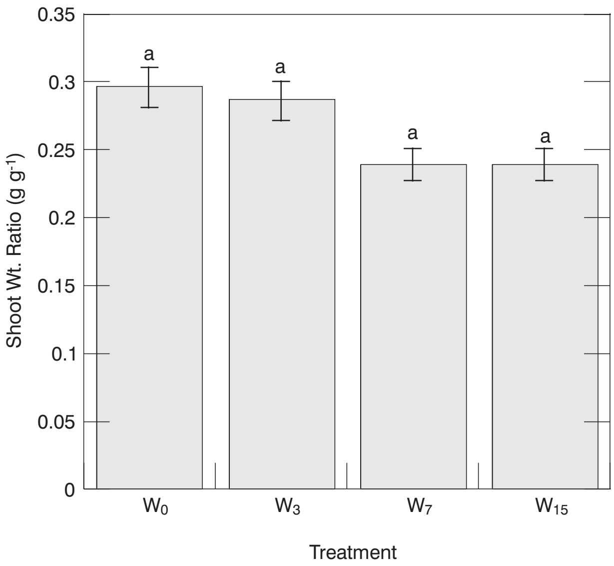

Fig. 13. Shoot weight ratio in different watering regimes

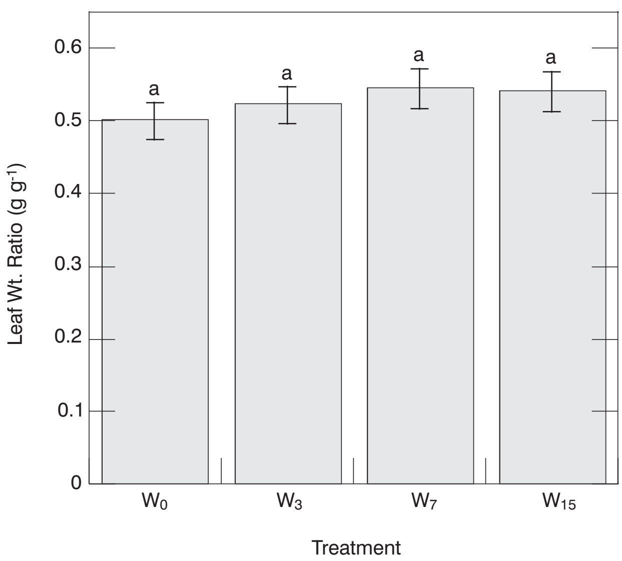

Fig. 15. Leaf weight ratio in different watering regimes

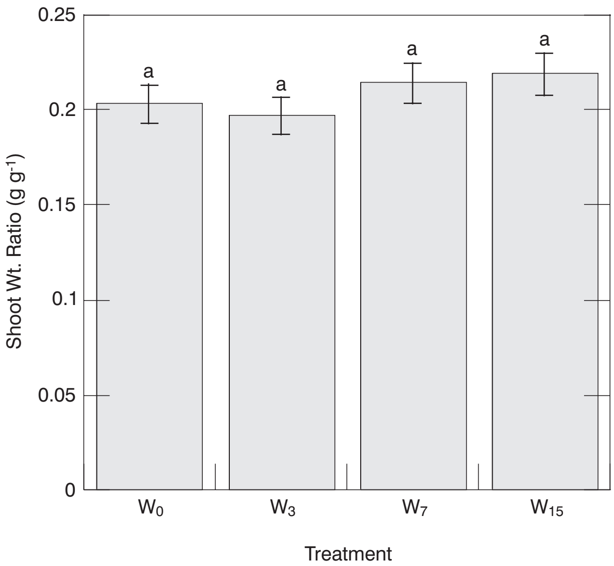

Fig. 14. Root weight ratio in different watering regimes

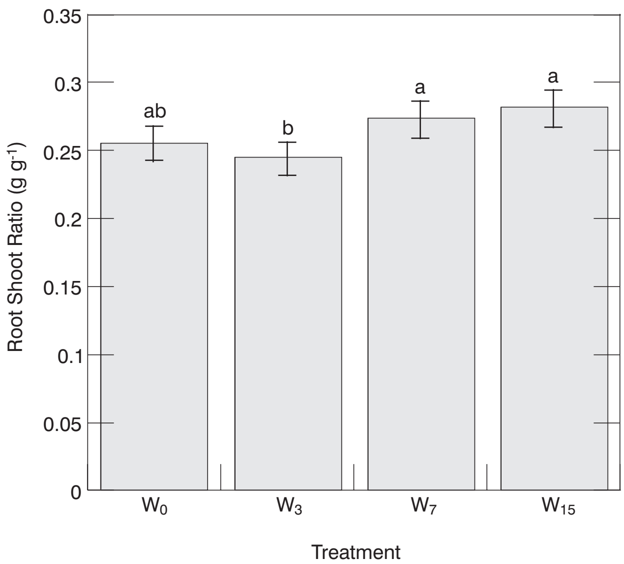

Fig. 16. Root shoot ratio (dry weight) in different watering regimes

result is in agreement with the findings of Mohiuddin (1992), who reported significant reduction of total biomass production with limited water supply in poplar. Biomass production in plants is directly related with photosynthesis. In water-stressed plants, the initial reduction of photosynthesis as well as less biomass production is thought to be associated with the decline of leaf water potential (Ackerson and Herbert 1977). The decline of leaf water potential reduces the photosynthetic capacity of chloroplasts to fix carbon dioxide (Matthews and Boyer 1984) finally limits the biomass production.

Leaf area per plant was not significantly affected with water stress. This result is not in agreement of common observation that water stress affects leaf growth (Srinivas-Rao and Bhatt 1988). Reduced leaf water potential, resulting from limited water supply, can decrease net photosynthesis, so leaf growth is inhibited, as reported in sorghum (Shearman et al. 1972). Closure of stomata, in response to limited soil water supply, inhibits carbon dioxide exchange with the result that reduced supplies of assimilates are available for allocation to the growing leaves, and as a result, leaf growth is adversely affected, as reported for wheat (Masle and Passioura 1987). In contrast, some plants acclimate to soil drying by increasing the concentration of solutes in the symplast, turgor can be maintained at low tissue water potentials, as low water potential enables water to continue to be extracted from dry soil. The turgor allows cell expansion (Turner 1986) to be continued in leaf with no significant decrease in total leaf area. It seems that acacia hybrid might have maintained turgor in the cells of expanding leaves. This might be the reason of no significant leaf area change per plant in acacia hybrid by water stress.

Though plant height was not significantly affected by water stress, specific shoot weight (SSW) significantly decreased with reduction in watering frequencies. It means that the shoot length with fewer materials was produced in water-stressed conditions. This might be due to decreased photosynthesis in plants growing under limited water supply. Soil drying induces stomatal closure before any change in leaf water status occurs (Gollan et al. 1986). Several experiments have shown a strong correlation between stomatal conductance and net photosynthesis (Downton et al. 1988). During water stress, a close correlation between photosynthesis and stomatal conductance has been reported for many tree seedlings, e.g., *Eucalyptus globulus* (Metcalfe et al. 1989) and red spruce (Seiler and Cazell 1990).

LAR increased in water-stressed plants with almost no change in leaf weight ratio (LWR). Such an increase in SLA in water-stressed plants was reported for some *Eucalyptus* species (Bachelard 1986) and for poplar (Mohiuddin 1992). Increased SLA means plants growing under water-stressed conditions produced thinner leaves. In other words, the same leaf area was produced with less material. This might be related to leaf development and limited carbon dioxide fixation rates under water-stressed conditions (Michael et al. 1988).

Root to shoot ratio significantly increased with limited water supply. It is reported that mechanism of acclimation to soil drying involves a shift in the allocation of assimilates from shoot to root. Soil drying stimulates root growth and proliferation deep into the soil profile (Molyneux and Davies, 1983). Such structural changes in rooting are generally correlated with a reduction in shoot growth (Kramer 1983) resulting in an increase in root growth in absolute terms (Khalil and Grace 1992) or relative to shoot growth (Osonubi and Fasehun 1987). However, extreme soil drying ultimately reduces root growth (Seiler and Cazell 1990).

Conclusion

The results suggest that Acacia hybrid can acclimate to drying of soil with significant decrease in total biomass in water-stressed conditions. Significant increase in leaf area ratio in acacia hybrid with limited water supply by increasing specific leaf area seems to be an important acclimation potential since this relative increase in leaf area will compensate, at least partially, for a lower biomass production under water-stressed conditions. Acacia hybrid has excellent potential to be one of the best plantation species in Bangladesh due to its wider use and added genetic quality compared to *A. auriculiformis* and *A. mangium*. The result of the present study also adds another criterion to make it popular for large scale plantation and detailed field level research.

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