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The Early Growth Stages of Six Forest Plantation Species Affected by Soil Water Deficit

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ABSTRACT. Seeds and three month old seedlings of Eucalyptus camaldulensis Dehnhardt, Eucalyptus tereticornis Ewart, Eucalyptus citriodora Hook. Mitch., Acacia nilotica (L.) Delile, (Dassanayake and Fosberg, 1981) Acacia senegal (Linn.). Willd. and Casuarina equisitifolia Forst. (Pearson and Brown, 1981) were subjected to seven soil water deficit levels i.e. 0, −5.1, −6.5, −8.0, −10.0, −12.0, −15.0 bars in a randomized block design with three replicates in green house.

Both germination percentage and rate of germination were significantly different between species and soil water deficit levels. All the species germinated below the level of −10.0 bars, except Casuarina equisitifolia, whereas Acacia senegal and Acacia nilotica managed to germinate even above −10.0 bars.

The differences in percentage survival of seedlings with substrate moisture too were significant. As in seed germination, all seedlings survived below the deficit level of −10.0 bars and E. camaldulensis, E. citriodora, A.nilotica and A. senegal succeeded even under the highest water deficiency. Transpiration rate was also reduced significantly with the reduction of moisture.

After five months, total height and leaf number were significantly different between species and moisture levels, while diameter varied only with moisture levels. The weight of plant components was also affected by the water deficit level.

Under the tested water deficit levels, A. senegal followed by A. nilotica and E. camaldulensis have shown promise and E. tereticornis occupies a central position in the ranking of species performance. But E. citriodora and Casuarina equisitifollia did not prove successful.

INTRODUCTION

In the face of rapid deforestation, increase of forest cover is an absolute necessity. Since the land available for this purpose is located mostly in the dry zone of Sri Lanka, for optimum vegetative cover, it is vital to introduce more drought resistent species.

Since drought resistance is a plant characteristic, which starts from the seed stage (Kozlowski, 1968a), a seed germination trial together with a seedling trial is necessary for an accurate selection.

Water content of the soil is a very important factor in seed germination and the amount of hydration required to bring about seed germination varies widely among plant species (Crafts, 1968).

Further, water stress affects water uptake, seed germination, root pressure, transpiration, photosynthesis and other processes (Kramer, 1983). Height growth as well as the number of leaves and their rate of expansion also reduced under soil water deficit (Kozlowski, 1968b).

Hence, the efficiency in seed germination and some major factors such as transpiration, height and leaf number which demonstrate growth rate, of some common plantation species; *E. camaldulensis, E. tereticornis, E. citriodora, A. nilotica, A. senegal* and *Casuarina equisitifolia* were assessed. Seven moisture deficit levels, *i.e.* 0, −5.1, −6.5, −8.0, −10.0, −12.0, −15.0 bars were exercised to select more suitable species for dry zone reforestation, where an annual rainfall of less than 75" which varies from place to place between 40" and 75" with a rain free period extending from June to September (Alwis and Eriyagama, 1969) makes soil water deficit one of the main factors to be contend with.

MATERIALS AND METHODS

Seeds of the following six species and three month old seedlings of the same were used (Uniform in size).

Eucalyptus camaldulensis	*Acacia nilotica*
Eucalyptus tereticornis	*Acacia senegal*
Eucalyptus citriodora	*Casuarina equisitifolia*

For the germination trial, polytene tubes (lay flat 10"x 15") were filled with the medium of sand:soil (2:1) and 20 g of NPK blue pellet fertilizer.

A pressure membrane apparatus (tensiometer) was used to obtain the seven treatment soil water deficit levels, *i.e.* 0, −5.1, −6.5, −8.0, −10.0, −12.0, −15.0 bars. Four seeds were placed in each tube amounting to 112 seeds per species, using randomized block design with 04 replicates. Germination of each seed was observed and the germinated seeds were counted over a period of 21 days from the commencement of experiment. The radical emergence up to 1 mm was considered germinated, and the percentage germinated within 14 days was also counted for the rate of germination.

Three month old seedlings were used in a randomized block design with three replicates for the seedling trial and were transplanted into similar tubes, containing same media as in seed germination. Those plants were watered well in the green house until they recovered from transplanting shock. When the seedlings started normal growth, watering was withheld and plants were divided into seven groups (03 pots per spp.), for the moisture deficit to be controlled at testing levels. A set of tubes without plants were also maintained at above moisture levels.

At 48 hour intervals, all the pots were weighed and the lost moisture replenished to maintain their respective water deficit level. The evaporation loss of plant-less tubes, was deducted from the evapo-transpiration loss of planted tubes, to obtain the transpiration loss at each deficit level as suggested by Rawat *et. al.*, (1985).

Percentage survival, total height, diameter at collar level and leaf number of plants were recorded bi-weekly.

Five months after the initiation of the experiment, the plants were uprooted and weighed componentwise, to obtain fresh and dry weight of leaf, stem and root. Root growth was photographed to exhibit the variation of growth under different soil water deficit levels.

RESULTS AND DISCUSSION

Germination percentage over a period of 21 days and the rate of germination differed significantly between the six species and the seven moisture levels (Table 1). Only *Acacia* species germinated above the moisture tension of −10.0 bar proving its low moisture requirement for germination. This is consistent with the existing literature which categorizes both *A. nilotica* and *A. senegal* as suitable for arid zones (Kaul, 1989). Although the three *Eucalyptus* species succeeded in reaching their threshold values below the tension of −8.0 bars, *Casuarina equisitifolia* demanded zero tension for seed germination (Table 1).

On average, germination rate of all the species was delayed by soil water deficit.

Statistically significant differences were observed ($p<0.05$) in percentage survival of seedlings with substrate moisture. Seedlings of all the species showed 100% survival below the tension of −12.0 bars, whereas *E. camaldulensis, E. citriodora, A. nilotica and A. senegal* succeeded even at −15.0 bars. *E. tereticornis* showed 50% survival at −15.0 bars, but *Casuarina equisitifolia* failed completely, as observed by Kaul (1989), the failure of seedling establishment of *C. equisitifolia* under low moisture conditions.

The estimation of transpiration loss per 48 hours which was the difference of evapo-transpiration of tubes with plants and the evaporation of plant-less tubes; is slightly underestimated, since the increase in weight due to the growth of plant has not been taken into consideration. However it assessed the comparative growth response and transpiration trends of the plants maintained at different moisture deficit levels. It revealed a decreasing pattern starting with the highest rate of water loss under zero tension, leaving −15.0 bars to restrict all species for their minimum transpiration (Figure 1). This is further reinforced by the findings of Kramer (1983), where the water deficiency affected water uptake, transpiration, photosynthesis and other processes.

Complying with other parameters, maximum height and diameter increments coupled with the lowest level of soil water deficit (Figure 2 & 4). At the lowest moisture level, die back of shoot tips occurred in *A. nilotica* but initiated new axillary buds. Although *A. senegal* seemed disfavoured in height increments at higher tension levels (Figure 2),

Table 1. The percentage seed germination and the rate of germination of the six species.

	Water deficit level (bars)	Percentage germination	Rate of germination
Eucalyptus camaldulensis	- 15.0	0.0	0.0
	- 12.0	0.0	0.0
	- 10.0	0.0	0.0
	- 8.0	18.75	18.75
	- 6.5	18.75	18.75
	- 5.1	18.75	12.50
	0.0	25.00	25.00
Eucalyptus tereticornis	- 15.0	0.0	0.0
	- 12.0	0.0	0.0
	- 10.0	0.0	0.0
	- 8.0	18.75	18.75
	- 6.5	18.75	12.50
	- 5.1	50.00	50.00
	- 0.0	37.50	37.50
Eucalyptus citriodora	- 15.0	0.0	0.0
	- 12.0	0.0	0.0
	- 10.0	0.0	0.0
	- 8.0	6.25	6.25
	- 6.5	12.50	12.50
	- 5.1	18.75	18.75
	- 0.0	43.75	37.50
Casuarina equisitifolia	- 15.0	0.0	0.0
	- 12.0	0.0	0.0
	- 10.0	0.0	0.0
	- 8.0	0.0	0.0
	- 6.5	0.0	0.0
	- 5.1	0.0	0.0
	0.0	18.75	18.75
Acacia senegal	- 15.0	12.50	6.25
	- 12.0	12.50	12.50
	- 10.0	25.00	25.00
	- 8.0	43.75	43.75
	- 6.5	31.25	25.00
	- 5.1	37.50	37.50
	0.0	62.50	56.25
Acacia nilotica	- 15.0	6.25	6.25
	- 12.0	12.50	6.25
	- 10.0	25.00	20.00
	- 8.0	37.50	31.25
	- 6.5	43.75	43.75
	- 5.1	50.00	50.00
	0.0	55.25	55.25

Percentage germination and rate of germination were significantly different between species and moisture levels at $p < 0.05$.

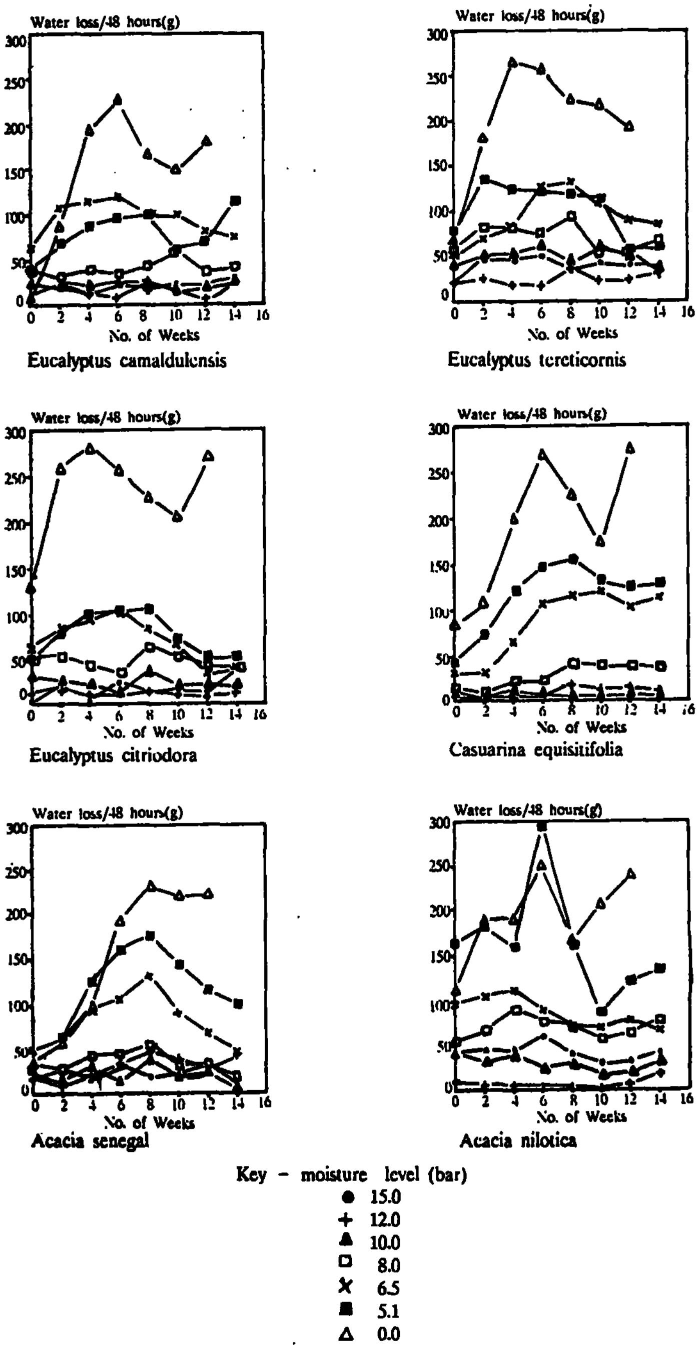

Figure 1. Variation of moisture loss in transpiration per 48 hours under seven moisture stress levels.

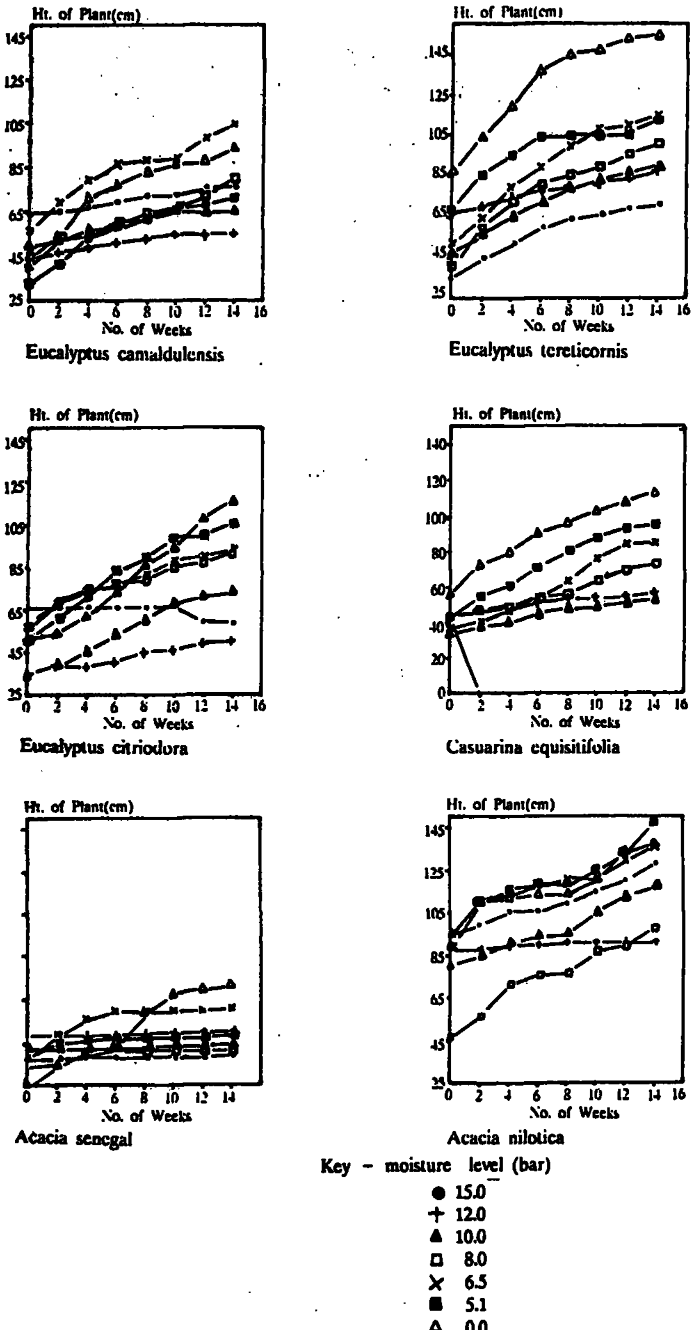

Figure 2. Variation of mean stem height under seven moisture stress levels.

it exhibited a well branching pattern, whereas *Eucalyptus* species and *Casuarina* were more or less rapid in main axis elongation. These results lend evidence to the study of Kozlowski (1968), that low availability of water retards height increments and the radial growth of tree species. But diameter at all moisture levels exhibited a smooth increasing pattern with time, which was rapid and prominent below −6.5 bars for all species (Figure 3). It is also pertinent to mention that *A. senegal* developed a thick corky bark as an adaptation to dry conditions.

Generally the leaf number increased with moisture availability (Figure 4), suggesting that leaf number is reduced under severe water stress (Zahner, 1968). Two *Acacia* species showed marked reduction above the deficit level of −10.0 bars (Figure 4), modifying the plant to reduce transpiration surface.

This rapid growth in height, diameter and leaf number under low deficit levels (Figure 2, 3 and 4) is vital, in order to avoid mortality at early stages and to acquire speedy growth during the rainy season of the dry zone, which is limited only for several months before the commencement of the rain-free period.

The percentage moisture content of shoot was significantly different between species and moisture levels (Table 2). The two *Acacia* species, *E. camaldulensis* and *Casuarina equisitifolia* had lower percentage of moisture in the stem at all deficit levels. It is of paramount importance to identify, especially in wood production, forest plantation species with greater proportion of plant material, to which the stem of the plant contributes immensely. The findings of Kozlowski (1968) also revealed the affected development of wood producing cells under water stress.

Differences of fresh weight of leaves between species and moisture levels were significant. The relatively higher values of *A. senegal* and *A. nilotica* (Table 2) prove their ability to conserve moisture in withstanding soil water deficit. Some anatomical changes in favour of retaining more water in leaf tissues under severe water stress have been reported by Zahner (1968).

Morphologically, root development exhibited a remarkable relationship with moisture stress, providing large root systems (Ref. Photos - Figure 5) at lower deficit levels, where similar logical

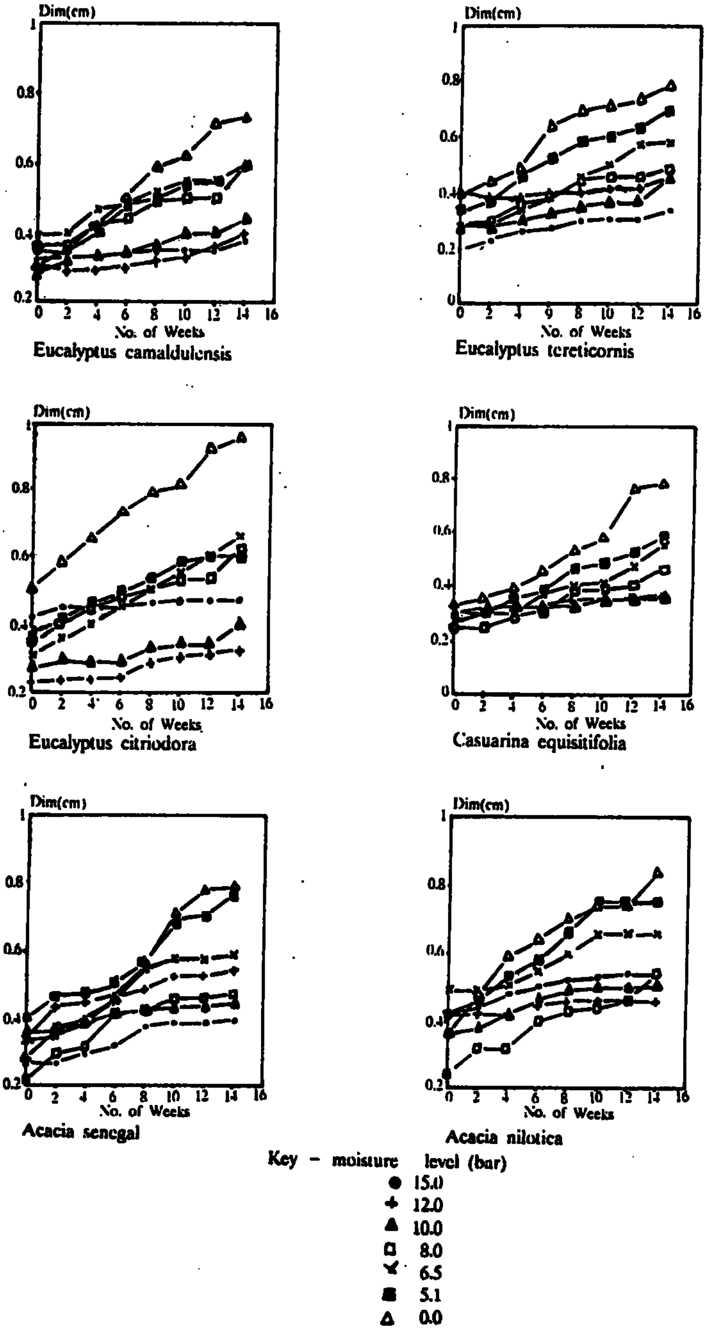

Figure 3. Variation of mean stem diameter under seven moisture stress levels.

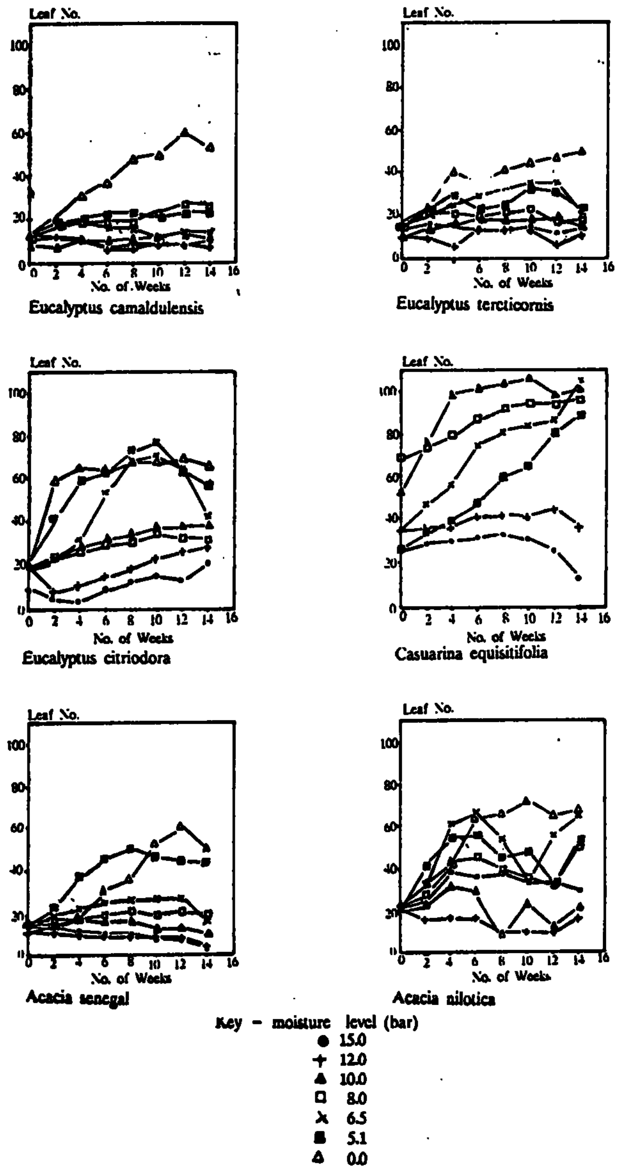

Figure 4. Variation of mean number of leaves under seven moisture stress levels.

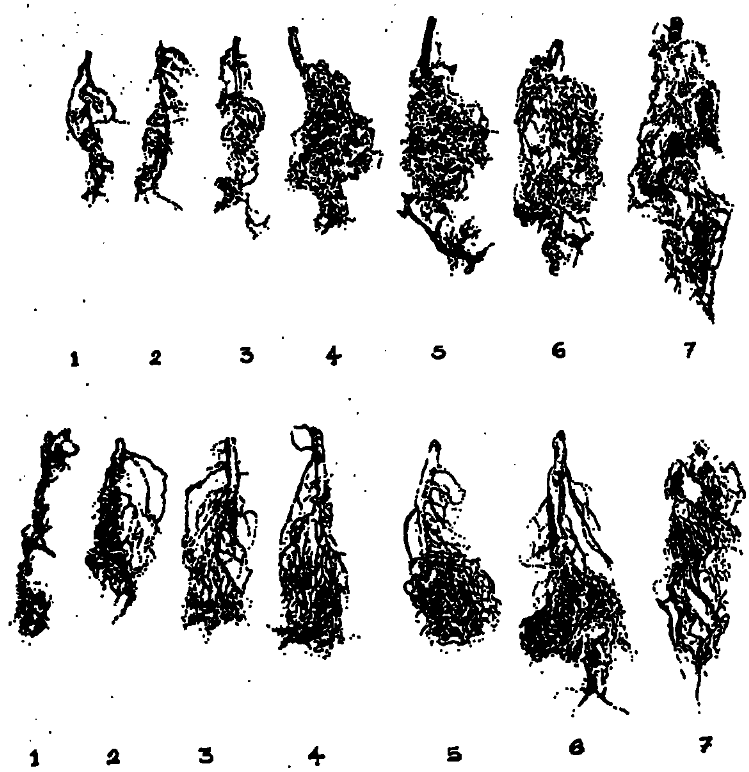

Figure 5. Variation of root growth under seven moisture deficit levels. A. senegal (below) and A. nilotica (above) – Common to other tested species.

Table 2. **Percentage moisture content in leaf, stem and root.**

	Water deficit level (bars)	% moisture leaf	% moisture stem	% moisture root
		(Fresh weight basis)		
Eucalyptus camaldulensis	- 15.0	59.82	51.20	49.29
	- 12.0	49.37	47.93	49.45
	- 10.0	55.19	47.31	46.05
	- 8.0	55.45	50.44	51.31
	- 6.5	49.51	47.95	48.47
	- 5.1	46.25	50.23	48.46
	0.0	46.22	60.48	63.05
Eucalyptus tereticornis	- 15.0	61.36	54.61	51.06
	- 12.0	61.61	56.09	52.41
	- 10.0	60.15	52.87	41.58
	- 8.0	52.71	51.68	52.06
	- 6.5	56.42	54.29	55.16
	- 5.1	56.82	50.48	55.11
	0.0	58.68	58.12	48.41
Eucalyptus citriodora	- 15.0	61.97	58.10	62.04
	- 12.0	57.17	53.45	61.46
	- 10.0	59.87	54.57	61.96
	- 8.0	56.11	52.44	61.99
	- 6.5	57.03	52.51	68.20
	- 5.1	59.17	50.16	62.20
	0.0	58.57	51.72	69.59
Casuarina equisitifolia	- 15.0	0.0	0.0	0.0
	- 12.0	70.08	37.07	54.35
	- 10.0	66.19	51.89	57.17
	- 8.0	61.62	32.94	58.99
	- 6.5	65.93	51.75	59.67
	- 5.1	68.33	49.22	56.72
	0.0	70.82	56.48	69.68
Acacia senegal	- 15.0	59.68	49.66	37.08
	- 12.0	61.82	44.66	38.04
	- 10.0	53.06	42.27	35.89
	- 8.0	57.75	48.31	41.18
	- 6.5	62.46	48.95	48.72
	- 5.1	60.74	48.35	41.67
	0.0	60.63	52.14	64.82
Acacia nilotica	- 15.0	62.00	52.57	33.33
	- 12.0	61.90	55.33	25.00
	- 10.0	60.26	44.92	28.48
	- 8.0	64.82	48.18	28.80
	- 6.5	61.89	43.52	39.48
	- 5.1	65.50	47.51	44.91
	0.0	63.01	51.12	65.90

Percentage moisture content of stem and fresh weight of leaves significantly different between species and moisture levels at $p < 0.05$

relationships are observed by Kozlowski (1968) too. It is to be noted that the tap root of *A. senegal* elongated prominently, and this deep vertical penetration of the root regardless of soil moisture availability indicates the strong intrinsic development of a tap root in this species, strengthening the findings of Zahner (1968) observed for some plantation species. This development is helpful in reaching the ground water table to survive during the prolonged drought periods in the dry zone. There had been coralloid root formation in *Acacia* which was rapid at lower stress levels. Similar increasing trend with lower moisture tension had been observed for *Frankia* root association of *Casuarina equisitifolia*. This finding gains support from observed reduction by Gates (1968) in the uptake of nitrogen due to the lowered internal demand during water shortage. In *Eucalyptus* species, development of collar was prominent at higher moisture levels, but minute at lower levels.

The six species behaved differently in the characters studied. Some showed adaptability to stress, whereas others did not.

Under the tested moisture deficit levels of this study, *A. senegal* and *A. nilotica* proved best in the ranking of species. Maximum germination percentage, seedling survival, root penetration and comparatively higher percentage of dry matter in the stem under severe water deficiency, confirm their successful growth during the drought periods. The higher rate of germination and the greater percentage of plant material available in leaf, stem and root under poor moisture availability prove *E. camaldulensis* the most promising among the tested *Eucalyptus* species. *E. tereticornis* occupies a central position in the ranking of species performance, supported by a better seed germination, leaving *E. citriodora* in the fifth position. Kaul (1989) too found similar type of ranking on species performance for the tested *Eucalyptus* species.

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