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ROOT GROWTH RESPONSES TO VARYING WATERING REGIMES OF GMELINA ARBOREA SEEDLINGS

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ABSTRACT

Gmelina arborea Roxb (Verbenaceae) is a very fast growing species widely planted in the tropics for fuel and pulp wood purposes. However, poor quality seedlings have often led to poor field survival rates and costly replanting. This failure seems mainly due to inadequate nursery practices, particularly related to watering. Therefore, an experiment was designed to assess relative root and shoot growth responses of *Gmelina* seedlings grown under greenhouse conditions to three water stress treatments. Control, medium, and severely stressed seedlings were watered back to field capacity whenever their predawn leaf water potential reached -0.2, -0.6, and -1.0 MPa, respectively. Two seedlings per treatment were destructively sampled every two weeks for data collection. Treatments had no significant effects on root and height growth, leaf area, collar diameter, or shoot:root ratio of _Gmelina_ seedlings. At any given time, seedling total root length was approximately 30 times shoot height. Although not significantly different, mean total root length per liter of growing medium after 16-weeks of water stress was 2384%, 1323%, and 1535% of its initial value (960 mm) in the control, mild, and severe water stress treatments, respectively. This corresponds, in the same order, to a 2-week root growth average of 13826, 8530, and 10598 mm. Since root growth was similar regardless of treatments, optimal watering regimes can be established which could not only assist in producing _Gmelina_ seedlings more closely adapted to specific soil and climatic conditions, but also help to minimize seedling production costs.

INTRODUCTION

Water stress affects seedling shoot structure, root physiology and morphology. Leaf area, shoot height, collar diameter, and shoot:root ratio are shoot parameters markedly affected by water stress (Kramer, 1983). Physiological effects of water stress on roots include (1) decreased root uptake due to precocious root suberization (Leshem, 1965), (2) increased root starch content (McNabb, 1985), and (3) either overall increase (Sharp and Davies, 1979) or cessation (Seiler, 1984) in root growth, depending upon species, ecotype, and severity of drought stress. Total root length, as an expression of root growth, and mean root surface area are common root morphology descriptors reportedly affected by water stress (Seiler, 1984). However, most reports of root effects have been either qualitative or based only on total root dry weight. The assessment of total root length, to which the capacity of a plant to take up water and nutrients is more closely related, has been judged too tedious and time consuming to be practical (Thompson, 1984). Findings such as those of Seiler (1984) have implications for adapting pot size to seedling root growth rates based on definable watering regimes. For example, seedlings of *Gmelina arborea* Roxb, a widely planted, rapidly growing tropical species, are often culled because of root curling. The cause of root curling in *Gmelina* has been determined to be over watering that causes the root systems to outgrow pots.

The objective of this study was to determine the relationships between water availability and relative root and shoot development in nursery grown seedlings of *Gmelina,* in the context of establishing optimal nursery watering regimes. The null hypothesis of the study was that the root and shoot growth of pot-grown *Gmelina* seedlings is the same regardless of the magnitude of the xerophycity of the soil growing conditions.

MATERIALS AND METHODS

Scarified *Gmelina* nutlets presoaked for 48 hours in cold distilled water, were germinated in a wooden flat filled with vermiculite. Upon germination, 527 seedlings were selected and transferred, three by three, into 51 black plastic pots arrayed on a bench in a greenhouse, and containing 4.71 of white coarse sand each. For eight weeks the seedlings were watered every other day and fertilized every two weeks with a 20-20-20 NPK fertilizer supplemented monthly with micronutrients. Following this pregrowth period, seedlings were rogued to one per pot based on height and vigor. The selected seedlings then underwent 16-week water stress treatments in a three block x three treatment x three replicate, completely randomized block design. Sixty-three seedlings, arrayed on a bench, made up a block, buffered on two sides with a row of seven extra seedlings.

Each treatment was comprised of 21 seedlings, 16 of which were destined for destructive sampling, and five of which were to be used for determining predawn leaf water potential of mature leaves using a pressure chamber (Scholonder et al., 1965). Whenever a water potential limit value was reached, water was added to corresponding pots to just reestablish field capacity, determined by letting 10 flooded pots drain completely under no tension. Water potential at the wilting point, -1.5 MPa, was determined by keeping a set of 10 potted seedlings unwatered over time. Watering regimes for medium water stress and severe water stress treatments were established based on these results to yield minimal seedling water potentials between -0.2 and -1.5 MPa. The treatments were, therefore, defined as follows:

1. Control treatment - seedlings were watered whenever their water potential reached -0.2 MPa.
2. Medium water stress treatment - seedlings were watered wherever their water potential reached -0.6 MPa.
3. Severe water stress treatment - seedlings were watered whenever their water potential reached - 1.0 MPa.

Water potential measurements and pot weighing were jointly carried on so that a known amount of water could be added to pots whenever the water potential limit value was reached.

Two seedlings were destructively sampled per treatment every two weeks, resulting in 18 seedlings which made up a run. The seedlings of the first run were harvested at the onset of the treatments to establish initial conditions. Sand was washed out of the pots over a sieve with a low pressure spray of water to extract the root systems. Leaf area was measured to the nearest 1 cm ^{2} using a LI-3000 portable leaf area meter, and the collar diameter to the nearest 0.05 mm with a mini-caliper. The plant was then clipped at the ground level and the shoot height measured to the nearest mm. The complete root system was spread out and photographed against a 13x13 mm squared mesh grid, and total root length estimated by the modified line intercept method of Tennant (1975). The main root was then separated from lateral roots. Finally, each seedling part was dried to a constant weight at 70°C in an oven.

Analysis of variance followed by Duncan's multiple range test was used to determine treatment means and statistical differences due to water stress.

RESULTS

The effects of water stress on the root systems of Gmelina seedlings were both qualitative and quantitative. Lateral roots of control seedlings were the finest but the least numerous, while those of severe treatment seedlings were the thickest and most numerous. Furthermore, moderate and severe treatment seedlings had white, coarse adventitious roots which had no counterparts in control seedlings. These adventitious roots appeared first at the root collar early in the experiment and progressed toward the apex of the main root as the experiment proceeded.

In terms of root growth as expressed by total root length, root system development did not show any well-defined patterns (Table 1, Fig. 1). The overall average differences (2% and -0.8%) were not statistically significant. Therefore, the effect of time overrode treatment effects ($P < 0.001$). By the end of the experiment (16 weeks), two-week mean root length increments averaged 13828, 8530, 10598 mm in control, moderate and severe treatment seedlings, respectively, as derived from data in Table 1. At the same time, total root length per liter of soil growing medium was 2157%, 1337%, and 1668% of its initial value (951 mm/1) in control, moderate and severe treatment seedlings, respectively (from Table 1).

Variations of total root length per liter (Fig. 2), leaf area (Table 2, Fig. 2), shoot height (Table 3, Fig. 4), collar diameter (Table 4, Fig. 5), shoot-to-ratio (Table 5, Fig. 6), and root length to shoot height ratio (Fig. 7)

TWO-WEEK GROWTH INTERVAL VARIATIONS AMONG TREATMENT MEANS

(as Percentages of control seedling values)

Table 1

TOTAL ROOT LENGTH (mm)

WEEK	control	moderate	severe
2	4469	0	0
4	14171	12	10
6	19456	-26	-23
8	29545	-5	-33
10	31589	43	18
12	40741	11	3
14	60186	24	-2
16	100856	-36	-22
	MEAN	2	-0.8

Table 2

LEAF AREA (cm^2)

control	moderate	severe
242	0	0
515	-9	3
599	-14	8
599	-15	2
768	-20	-12
847	-14	16
994	3	-1
1036	10	6
MEAN	-9	.4

Table 3

SHOOT HEIGHT(mm)

WEEK	control	moderate	severe
2	158	0	0
4	218	-7	0
6	246	-5	3
8	272	-12	1
10	298	0	-11
12	358	-15	-3
14	393	-1	5
16	406	10	6
	MEAN	-4	3

Table 4

COLLAR DIAMETER(mm)

WEEK	control	moderate	severe
2	3.5	0	0
4	4.5	0	-2
6	5.6	18	-7
8	6.7	-6	-11
10	8.4	-8	0
12	9.3	1	8
14	10.8	-1	-8
16	12.0	-7	-5
	MEAN	-0.5	-3

Table 5

SHOOT:ROOT RATIO

WEEK	control	moderate	severe
2	3.5	0	0
4	3.6	-17	0
6	2.7	-8	-4
8	2.0	-10	-20
10	2.1	-14	0
12	1.9	-11	-5
14	1.9	-5	11
16	1.9	-5	-5
	MEAN	-9	-3

Fig. 1 MEAN TOTAL ROOT LENGTH (mm)

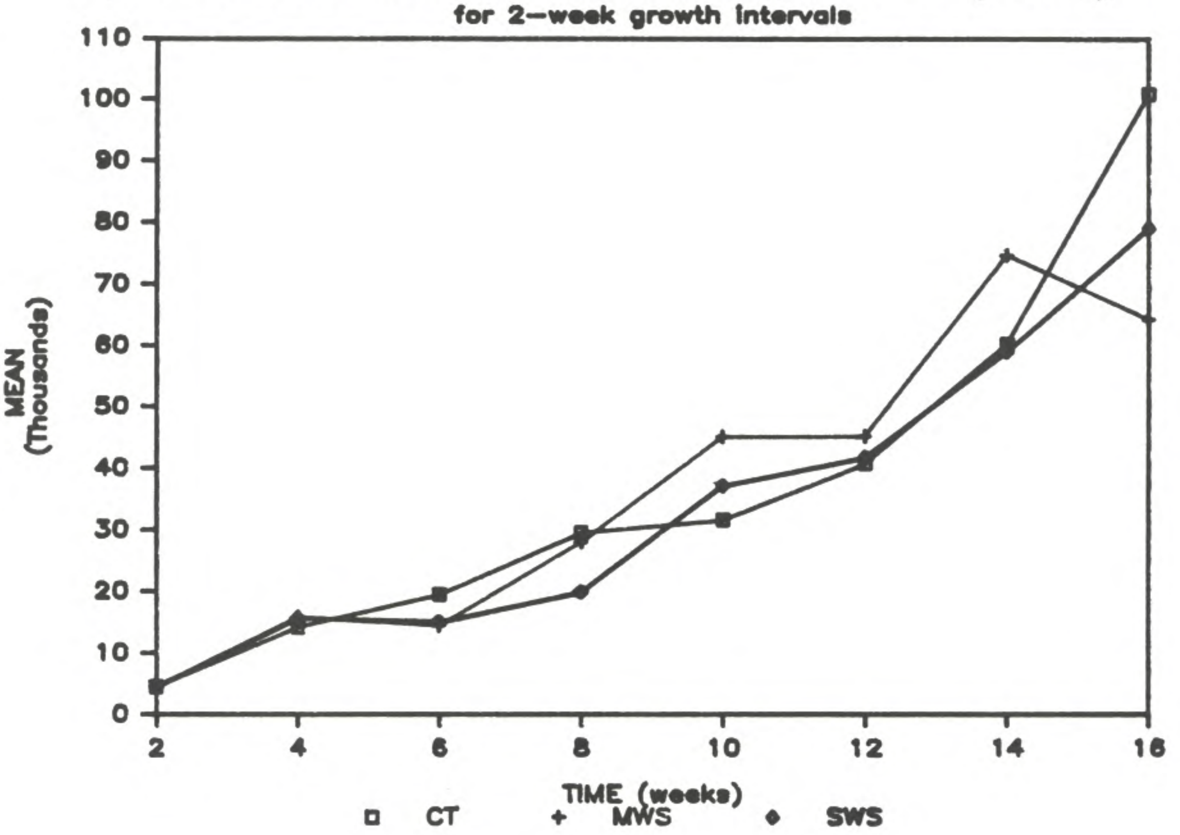


Fig. 2 MEAN TRL/LITER OF GROWTH MEDIUM

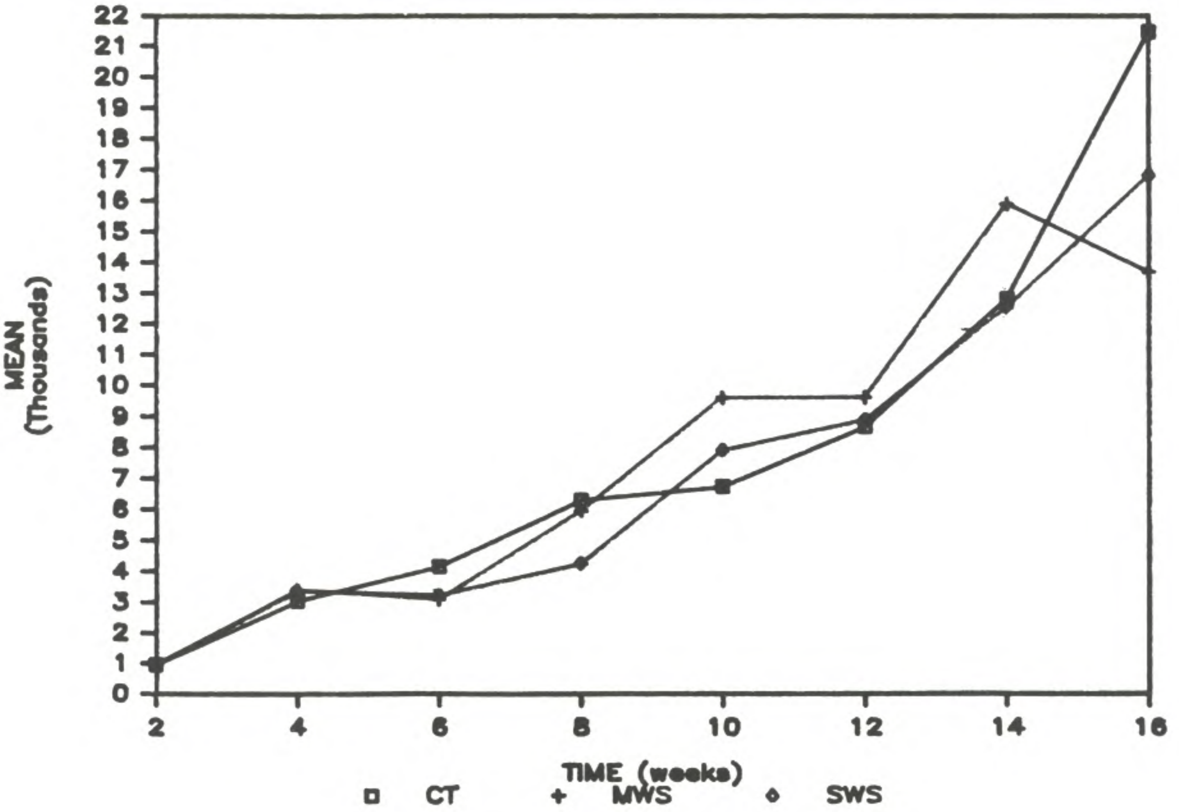
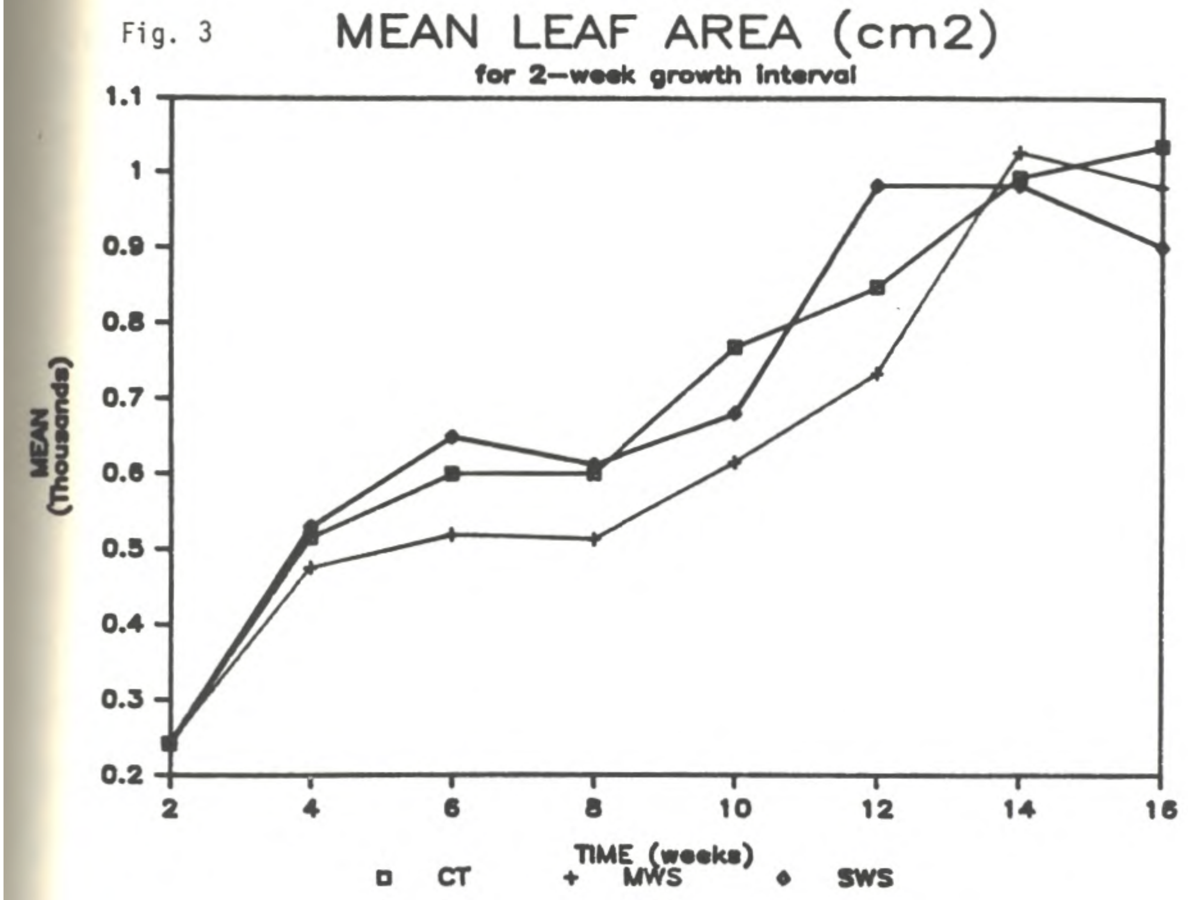
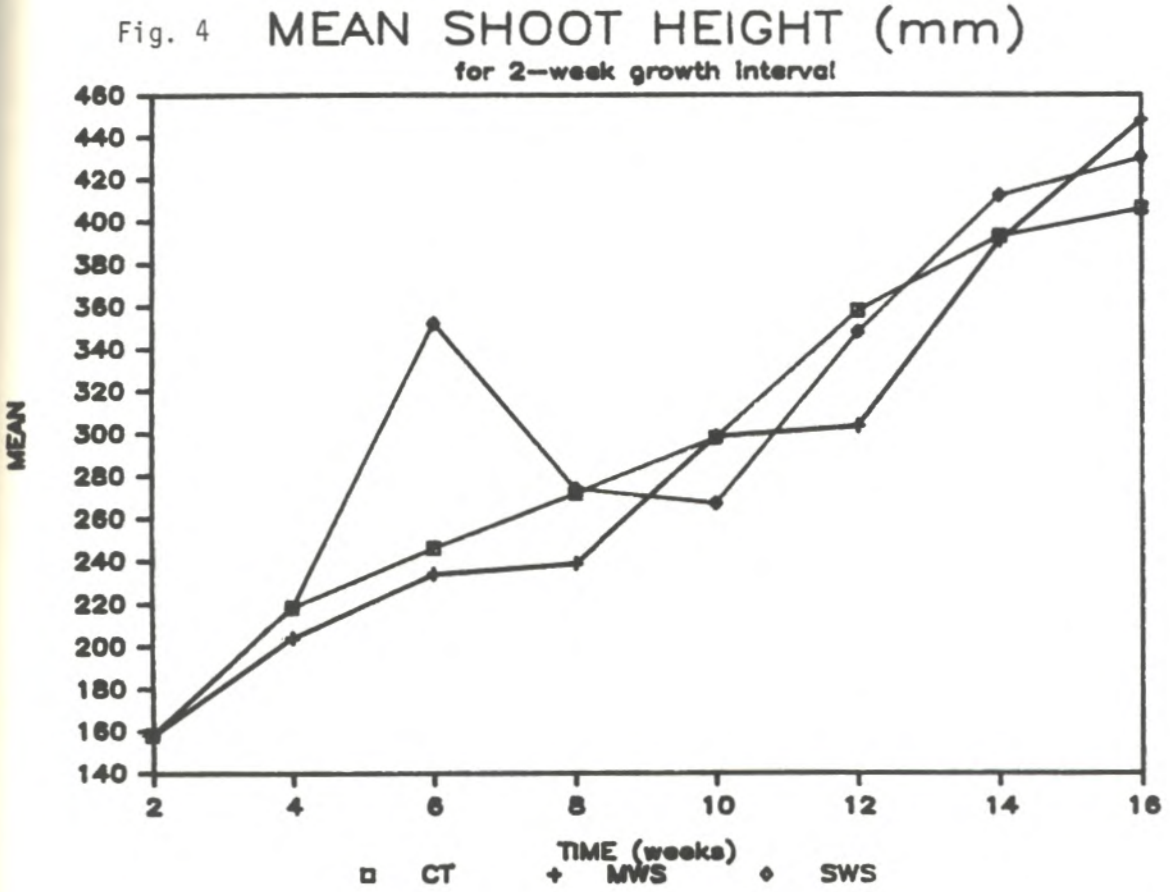


Fig. 3


MEAN LEAF AREA (cm2)

for 2-week growth interval

Fig. 4


MEAN SHOOT HEIGHT (mm)

for 2-week growth interval

Fig. 5 MEAN COLLAR DIAMETER (mm)

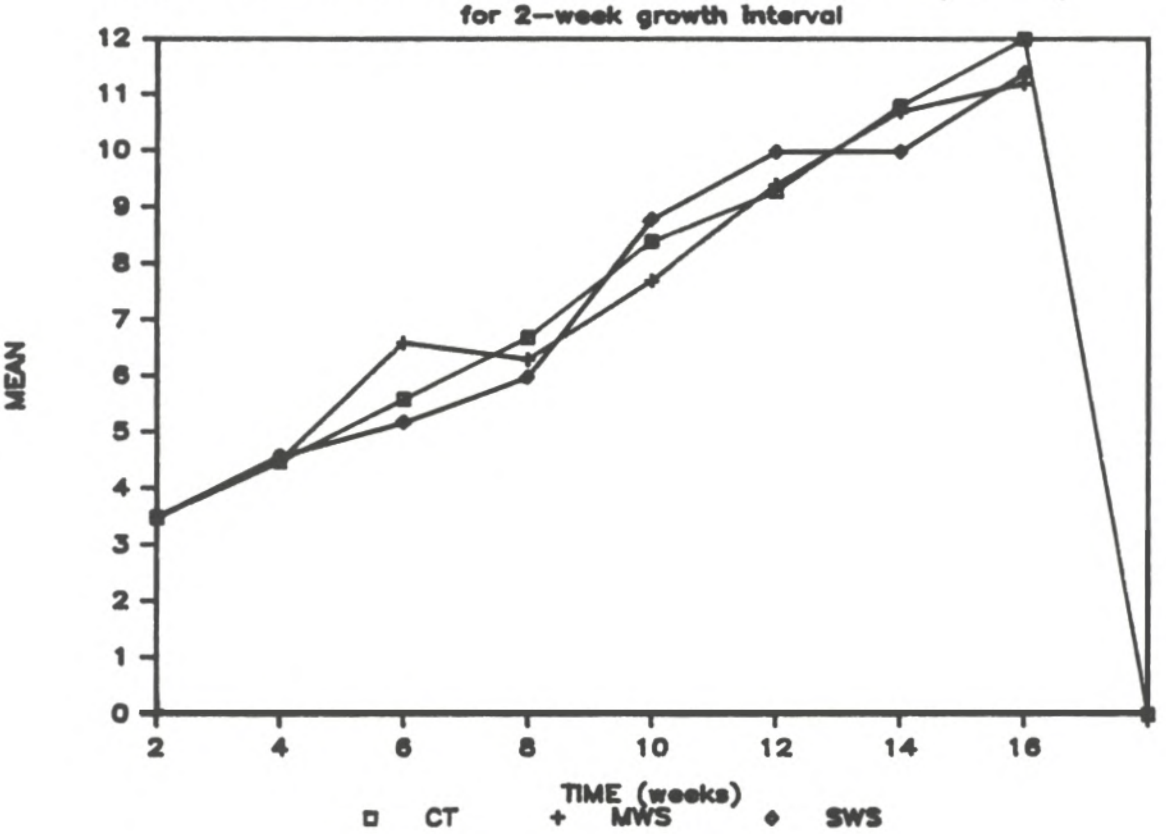
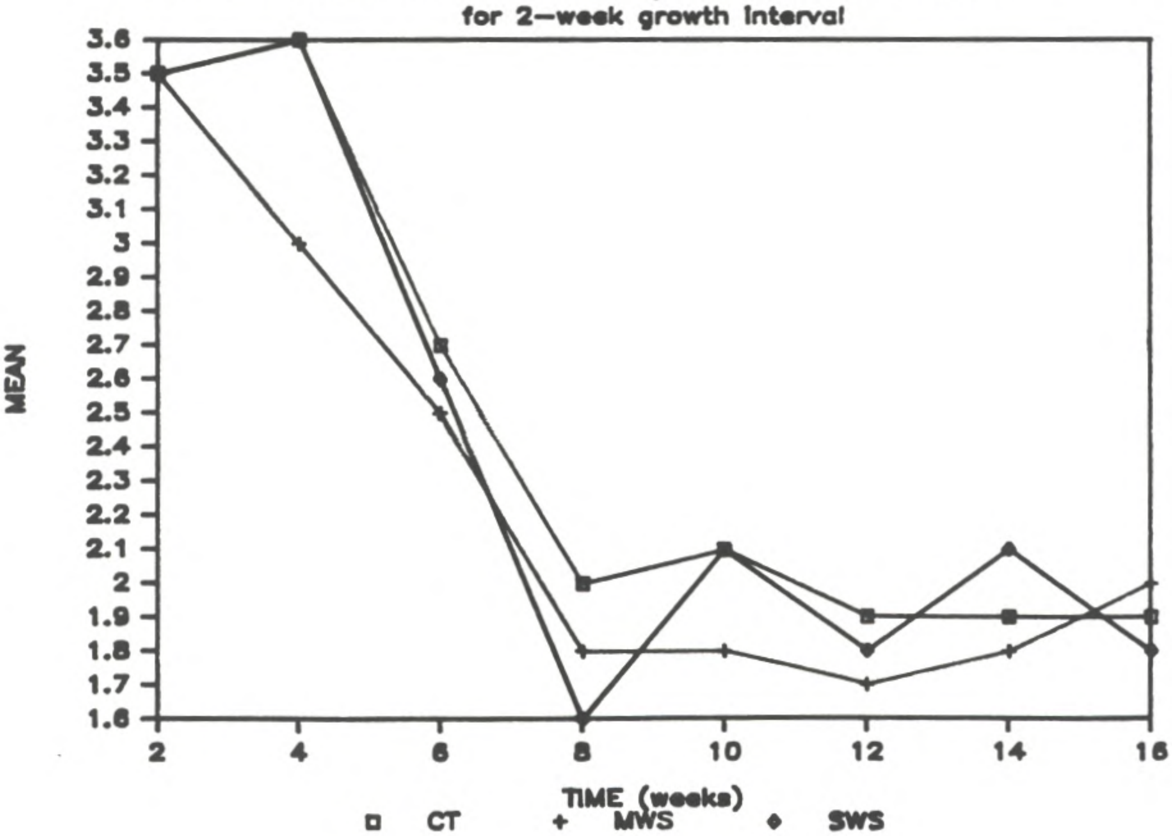


Fig. 6 MEAN SHOOT/ROOT RATIO



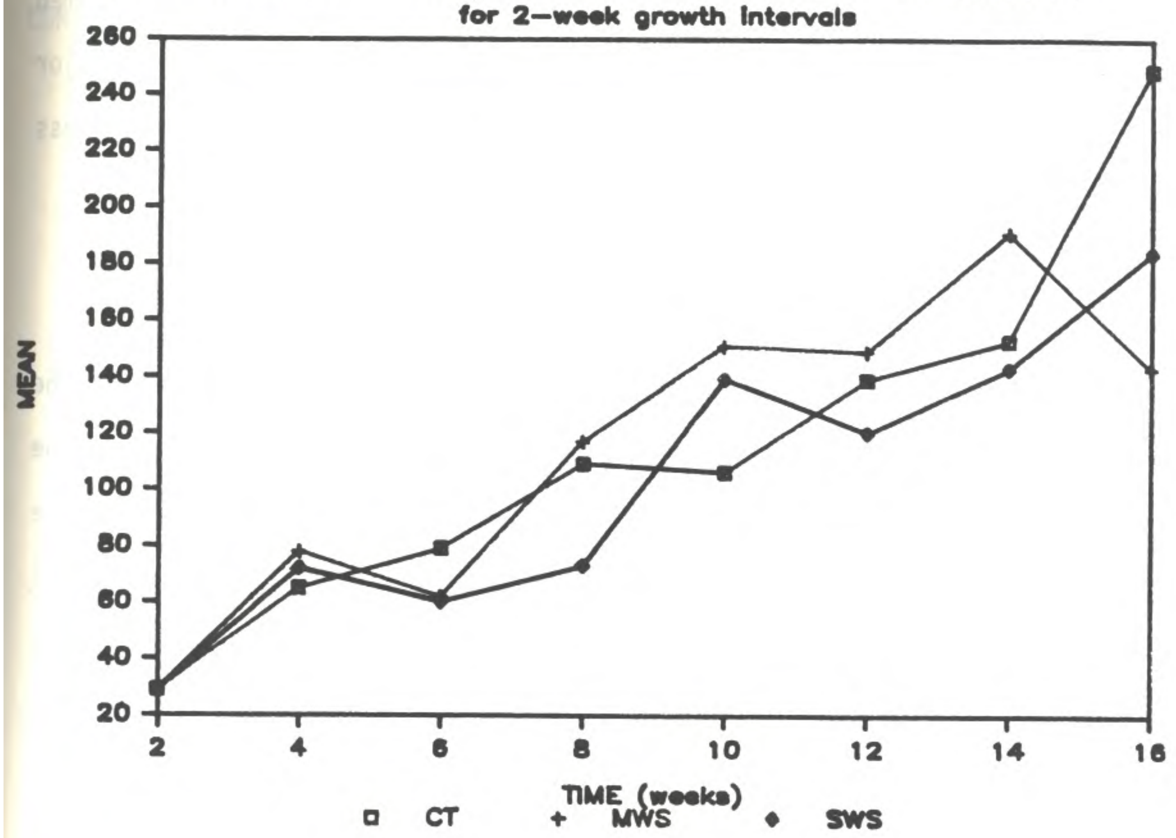


Fig. 7 MEAN TRL/MEAN SHOOT HEIGHT

were similarly inconsistent. Leaf area, shoot height and collar diameter seemed less affected by water stress than total root length, although the major influencing factor was, once again, time, with variations due to water stress not significant.

DISCUSSIONS

These results indicate that water stress has no significant bearing on the growth of above- and below-ground components of Gmelina seedlings of the ecotype examined in this study. This contrasts with Seiler's (1984) loblolly pine (Pinus taeda L.) and McNabb's (1985) slash pine (Pinus elliottii var elliottii Engelm) results. However, these results corroborate those of Osonubi and Davies (1978) for English oak (Quercus rober L.). In fact, water stress did not have any significant effect on height, dry weight, or leaf area of the English oak seedlings. Osonubi et al. (1985) also found no significant differences between total root length of control and flooded seedlings of Gmelina arborea Roxb of a Nigerian ecotype. This might be due, as in our experiment, to the occurrence of adventitious roots and a larger profusion of normal lateral roots in stressed seedlings. The overall impact is that root systems of control and stressed seedlings are similar in terms of total root length.

The mean root densities (21, 13, and 16 m/l) found in this study are similar to those found by Nutman (1934) for Coffea arabica (21 m/1), but very small compared to Dittmer's (1938) values for various grasses (66-548 m/l). Nonetheless, root densities were quickly increasing in our oldest control seedlings. This rapid root profusion may explain how Gmelina seedlings are often able to out-perform their competitors in tropical grasslands where Gmelina is very successfully cultivated.

CONCLUSIONS

1. - Soil water availability had no significant bearing on Gmelina root and shoot development.
2. - Occurrence of adventitious roots may partly account for Gmelina water stress tolerance.
3. - Gmelina root system development may be manageable through water management.
4. - It is of no apparent use any longer to water Gmelina seedlings as frequently as is the practice.
5. - Less expensive and drought-hardened Gmelina seedlings may be produced.

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