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Effect of Soil Matric Potential on Leaf Water Potential, Diffusive Resistance, Growth and Development of *Gmelina arborea* L. Seedlings*

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Abstract. *Gmelina arborea* L. seedling growth and diurnal stomatal opening (as measured by stomatal resistance) were studied at soil matric potential 0, -0.1 and -0.72×10^5 Pa. Leaf area, leaf number, plant height and dry weights of the vegetative parts were significantly reduced as soil matric potential decreased from 0 to -0.72×10^5 Pa. The growth responses followed the same trend as net assimilation rate and relative growth rate. The highest moisture stress induced leaf senescence and leaf fall. Leaf water potential decreased from -2×10^5 Pa to -20×10^5 Pa with increasing soil moisture stress. Results indicate that the diurnal stomatal opening is controlled by photon flux density when this species is grown at soil matric potential 0 Pa. However, with decreasing soil matric potential (-0.10 and -0.72×10^5 Pa) the internal plant water deficit appears to control the stomatal opening.

The effect of soil moisture on growth and yield has been often studied. Water stress affects the rate of photosynthesis, transpiration, photorespiration and dark respiration, enzyme activities, chlorophyll content, polyribosomal content, hormonal balance and so on. (For recent review see *e.g.* HSIAO 1973, SLAVÍK 1975, LANGE 1975, LANGE *et al.* 1976, BOYER 1976.) In this study *Gmelina arborea* L. seedlings were grown under various soil matric potentials and the effects of these treatments on dry weight accumulation in vegetative parts, net assimilation rate, relative growth rate, plant height, leaf area, number of leaves, leaf water potential, and diurnal stomatal resistance were determined. The species used for this study is very important in the tropics. It is a fast growing species which is being used for pulp wood. Identification of environmental factors controlling its growth and physiology is very important for its efficient management. The experiments reported were carried out mostly with greenhouse-grown material and in this sense essentially represent the first steps towards a study of the more complex field conditions.

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Material and Methods

Gmelina arborea L. seedlings were grown in greenhouse in polyethylene bags. The soil used for the experiment was sandy loam (FASEHUN 1975) obtained from top 10-cm layer from the University of Ibadan Teak Plantation. Seedlings were irrigated adequately for 4 weeks, then the soil was allowed to dry to soil matric potentials -0.1 and -0.72×10^5 Pa and 1 day after, the soil was rewatered to field capacity. Soil matric potential was measured by soil tensiometers with the ceramic tips located 10 cm below the soil surface. The control plants were watered every day.

The treatments were in a randomized complete block design with three replication of 12 plants each. The plants were grown for 10 weeks in the greenhouse before they were sampled for measurement of leaf water potential and stomatal resistance. The sampling time coincided with the end of a soil drying cycle of each treatment. The range of temperature in the greenhouse was 19 °C (night) to 35 °C (day) and range of humidity was 85% (night) to 50% (day).

At the start of the experiment a sample was taken and used for the determination of initial dry weights and leaf area. Height, area and number of leaves were recorded weekly throughout the growth period. At the final harvest the seedlings were separated into root, stem and leaf fractions and dry weights were recorded after the various vegetative parts were dried at 70 °C for 24 h. The total dry weights and leaf areas were then used to calculate relative growth rate (RGR) and net assimilation rate according to the equations used by OKALI (1971) and LEDIG (1974).

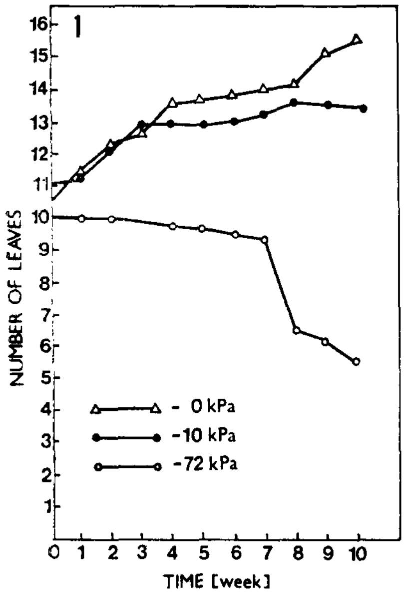
For the measurement of the stomatal resistance, 4 plants per replicate were moved from the greenhouse to the open. The top fourth leaf of each plant optimally oriented to the sun was used to determine stomatal resistance with a stomatal diffusion porometer as described by KANEMASU and TANNER (1969). The measurement was done every 2 h from 07.00 to 17.00 o'clock on 4 and 5 October 1977. The photon flux density (PAR) at each time of measurement was recorded by use of a LI-185 photometer. Leaf water potential was measured with a pressure chamber by the method of BOYER and GHORASHY (1971). The leaf water potential was determined for the same leaves used for stomatal resistance measurements at 09.00 on October 6, 1977.

Results

Dry weights of stem and root, area and number of leaves, plant height, of seedling decreased significantly, while shoot/root ratio increased, as soil moisture stress increased (Table 1). Change in soil matric potential from 0 to -0.10×10^5 Pa produced a greater change in growth than from -0.10 to -0.72×10^5 Pa. Both relative growth rate and net assimilation rate decreased with increasing soil moisture tension (Table 1).

The highest moisture stress caused leaf senescence of *Gmelina arborea* seedlings. This is characterized by yellowing of leaves followed by the development of necrotic spots beginning from leaf tips. This is followed by leaf fall five weeks after application of treatment (Fig. 1).

Leaf water potential decreased as soil matric potential decreased (Table 2). There was an increase in stomatal resistance with a decrease in soil matric potential. The diurnal behaviour of stomatal opening is shown in Fig. 2.



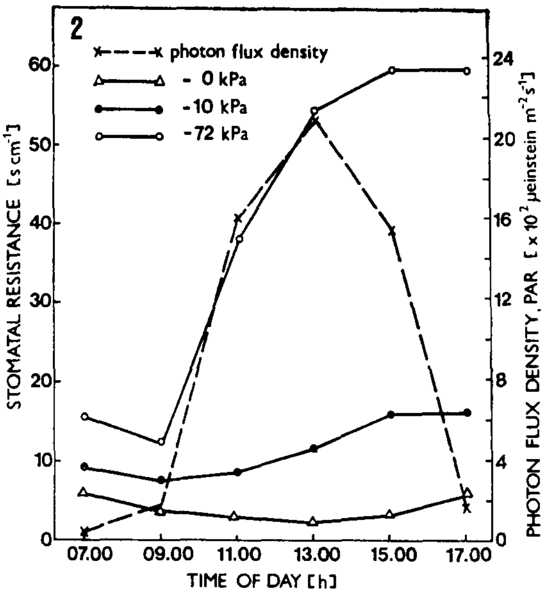


Fig. 1. Effect of soil matric potential on leaf growth of *Gmelina arborea* L. seedlings.
Fig. 2. The relationship between *Gmelina* stomatal resistance, soil matric potential and photon flux density.

When water is not limiting, the stomatal resistance appears to be inversely related to photon flux density. But in water stressed plants, there was an initial decrease in stomatal resistance indicating stomatal opening at 09.00. Further increase in photon flux density does not produce decrease in stomatal resistance. In these stressed plants there was an increase in stomatal resistance up to the maximum at 15.00 (Fig. 2).

TABLE 1

Height, dry weight of stem, root and leaf, shoot/root ratio, area and number of leaves, net assimilation rate and relative growth rate of *Gmelina arborea* L. seedlings grown at soil matric potential 0, -0.10 and -0.72×10^5 Pa. Harvest time 12 weeks. Each value is a mean of 12 observations

	Soil matric potential [$\times 10^5$ Pa]		
	0	0 to -0.1	0 to -0.72_a
Height [cm]	26.10	21.84	15.96
Stem dry weight [g]	16.59	8.16	2.61
Leaf dry weight [g]	21.38	14.58	3.02
Root dry weight [g]	21.96	12.55	1.98
Shoot/root ratio	1.72	1.81	2.83
Leaf area [cm^2]	503.40	322.02	89.58
Net assimilation rate [g cm^{-2} week^{-1}]	0.002	0.001	0.0009
Relative growth rate [g g^{-1} week^{-1}]	0.23	0.06	0.02

$_a$: All treatment-effects were significant at 5% level of probability.

TABLE 2
Effect of soil matric potential on leaf water potential of *Gmelina arborea* L.

Soil matric potential [$\times 10^5$ Pa]	Leaf water potential [$\times 10^5$ Pa]
0	-2_a
0 to —0.10	-5_b
0 to —0.72	-20_c

$_{a, b, c}$: Means in the same column followed by the same letter are not significant at the 5% level of probability.

Discussion

Growth decreased as moisture stress increased. There was also a decrease in leaf water potential and increase in stomatal resistance with increasing soil moisture stress. Decrease in soil matric potential also resulted in smaller and fewer leaves. With smaller and fewer leaves, there will be less photosynthesis and thus reduction in growth. The reduction in net assimilation rate with increased moisture stress as ascertained in this study substantiates this statement.

There will also be reduced CO_2 assimilation as a result of stomatal closure.

The diurnal behaviour of the stomata is affected by soil matric potential. When the seedlings are grown at soil matric potential 0 Pa, the stomatal opening of this species is inversely related to photon flux density. With the increase in photon flux density we have an increase in the opening of stomata and thus a decrease in the stomatal resistance. At 13.00 when the photon flux density was 2100 μeinstein s^{-1} m^{-2} the least stomatal resistance was recorded. This is probably due to the fact that with the increasing photon flux density there would be an increase in photosynthesis, leading to a greater opening of stomata, and thus to less stomatal resistance. However, at the highest moisture stress the increasing photon flux density does not lead to reduction of stomatal resistance after 09.00. As the day progresses, the environment becomes more desiccating and because water is limiting in the rooting medium this species apparently closes its stomata in order to conserve the water present in the plant.

The increasing water stress leads to reduction of growth of *Gmelina arborea* L. seedlings. Also the net assimilation rates and relative growth rate were reduced in stressed plants. The soil matric potential also affected the stomatal resistance and leaf water potential.

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BOOK REVIEW

Campbell, G. S.: **An Introduction to Environmental Biophysics.** Heidelberg Science Library. — Springer-Verlag, New York—Heidelberg—Berlin 1977. 159 pp. US $ 8.90.

This is one of the best textbooks dealing with interactions between living organisms and their physical surroundings, that has appeared during the last years. Using the up-to-date knowledge of environmental biophysics, the author gives a characterization of all main components of a microclimate (*i.e.* temperature, air humidity and turbulence, radiation), which is necessary for understanding the exchange processes (heat, mass and momentum transfer) between plants or animals and environment. As far as the plant-environment exchange processes are concerned, they are described and discussed on the level of both the individual organism (or its organs) and plant communities and include variables such as photosynthesis, transpiration, leaf energy budget, radiation and evapotranspiration in plant canopies, *etc.*

The presentation of problems is not intended to be exhaustive but it is clear enough to make the text comprehensible to readers of different specializations. Emphasis is laid on teaching the reader how to quantify the effects of physical environment on the behaviour of organisms. That is why the author chose mainly numerical examples to demonstrate a practical application of basic physical laws and principles to single exchange processes. He uses simple simulation models and appurtenant mathematical equations in order to calculate rates of heat and mass transfer and to perform energy budget analysis. The understanding of relations between variables analyzed is made easier by an abundant number of figures and tables which illustrate the limits of applicability of single mathematical solutions. At the end of each chapter, some problems are given to help the reader to develop skill in using the particular equations and to stimulate active approaches to the subject discussed.

The book is arranged in keeping with strictly logical structure of explanations. It is complemented with the subject index, tables of physical constants and list of symbols and units consistent with the Système International d'Unités (SI). It is highly reccommended not only as a really modern textbook but also as the useful manual for specialists working in various fields of plant physiology, ecology, crop productivity, agronomy, *etc.*

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