

ECO-PHYSIOLOGY OF MULGA (*ACACIA ANEURA*)

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ABSTRACT

Eco-physiological information about mulga is summarised under 5 headings—seed formation, germination and establishment, growth rates, mineral nutrition and water relations. Mulga is well adapted to its environment in utilising run-off and stem-flow water, by restricting water loss, and possessing strong resistance to desiccation.

INTRODUCTION

Mulga is an evergreen perennial shrub or tree, a true drought endurer, which dominates the vegetation over large areas of arid and semi-arid Australia. Literature on the ecological and physiological adaptation of mulga to its environment is reviewed under 5 main headings—seed formation, germination and establishment, growth rates, mineral nutrition, and water relations.

SEED FORMATION

Mulga plants flower after both summer and winter rain. Flowers induced by summer rain produce mature fruit, but not those from winter rain (Davies, 1968, Preece, 1971). Davies' data indicate that winter rain stimulates the quantity of fruit produced after summer flowering. Preece's data are inconclusive about a winter rain effect, reflecting either a regional difference or the limitations of data on numbers of fruiting trees without estimates of seed production. Regeneration of the species and communities which extend from the far western to eastern limits of arid Australia with the exclusion of the most northern and southern latitudes (i.e. limited to areas with bi-seasonal rainfall) will depend on adequate seed production in the small proportion of years with both summer and winter rainfall.

GERMINATION AND ESTABLISHMENT

Ripe pods are shed mostly in early summer months and nearly all mulga seeds mature with a hard testa, possessing a strophiole which may be the focal point for testa rupture. In the laboratory fresh seed will germinate when pretreated in any of several ways (Crocker and Barton, 1953) but it is not known how long the testa prevents germination in nature. Everist (1949) suggested that bushfire could break dormancy. Since fires are uncommon in mulga lands and establishment occurs without them, dormancy is not broken by fire alone. There is likely to be a general ageing process in which sequences of events, e.g. fluctuating temperatures and wetting and drying cycles, may play a part. Preece (1971a) subjected seeds to diurnal temperature fluctuation from 5°C to 45°C for periods from 1 to 12 months and tested germination on moist paper. Neither the fluctuating nor constant temperatures changed germination from 2% (soft seed) although viability of the seed, as judged by hot water pretreatment, was constant at 75%. Preece (1971a) reported enhanced germination rates in CO₂ enriched air of hot water pretreated seeds, suggesting that in nature a testa which restricts loss of respiratory CO₂ yet has a localised decay point for water entry, gives the seed good germination conditions. Further study of the germination process with particular reference to ageing of seed in natural environments may establish how mulga seed germinates and how soon after maturity.

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If a supply of viable seed is present in the soil then from time to time conditions of rainfall and temperature will occur in which some seeds germinate and seedlings establish. From limited data, Preece (1971a) suggested that optimum germination temperatures were between 20° and 30°C which is equivalent to wet soil temperatures in the warmer seasons. Suitable moisture regimes for germination and establishment have not been defined. Laboratory studies alone are inadequate for a large-rooted plant like mulga and environmental and plant measurements will be needed during regeneration after real or artificial rain. The conditions in the micro-environment of the seed and plant must be measured precisely to understand the growth processes and when related to simple climatic parameters such as daily rainfall and screen temperatures can be used for predictive modelling. At present lack of such data makes predictions of this type pure speculation.

GROWTH RATES

Estimates of biomass of mulga have been made but average growth rates cannot be deduced unless the various ages of plants or plant parts in a stand are known. Mulga plants apparently do not have morphological features which clearly indicate age, growth periods, and current growth. Net primary production cannot be determined easily over growth periods of a few weeks duration, either by harvest methods or by non-destructive estimations, since current growth is indistinguishable from past growth and changes in biomass are small in comparison to the total. New ways are needed to measure adequately the productivity of mulga.

Slatyer (1961) measured stem elongation as an index of growth activity. Winkworth compared the elongation of mulga shoots with the number of phyllodes they bore during 1959-1962 near Alice Springs and found only a broad agreement in the manner and rates of change of the two indices (Fig. 1). Phyllode counts at a given time gave the numbers present as the result of either or both the production and loss of phyllodes and did not accurately portray growth rates. Detailed analysis of growth responses needs more frequent measurement than weekly or fortnightly periods, but the small magnitude of changes in stem length limits the accuracy of measurement and many of the small changes in Fig. 1 are probably less than measurement errors.

Growth was stimulated and probably only occurred when soil water storage was recharged following rain. There were no cyclic periods of foliation independent of soil moisture recharge as described by Maconochie and Lange (1970) for some other arid browse species.

Phyllode fall, estimated by weighing the catch in traps under trees, showed peak rates after rainfall events (Fig. 1) as observed previously by Wilcox (1960) and Turner (pers. comm.). In the case of mature trees which have reached full canopy size, traps may provide an estimate of foliage dry matter production. As with phyllode number, phyllode fall rates indicate poorly the immediate growth responses after rain, perhaps because they are the end of a chain of events in the formation and abscission of phyllodes.

MINERAL NUTRITION

Mulga roots become nodulated with symbiotic *Rhizobium* which Beadle (1964) believed was specific to the arid *Acacia* species. Nodulation occurs in young plants with 3-7 phyllodes and in older plants after rain at any time of the year; the number of nodules produced varies widely, according to the sequence of rainfall events, up to 3-4 per 10 cm of root; from circumstantial evidence the nitrogen fixing capacity was thought to contribute significantly to the nitrogen economy of mulga (Beadle 1964). Significance of nitrogen fixation to associated plants in the communities is not known.

Other than nitrogen, mineral requirements are met by extensive root exploration of the infertile soils mulga mostly inhabits and the return of minerals from plant litter.

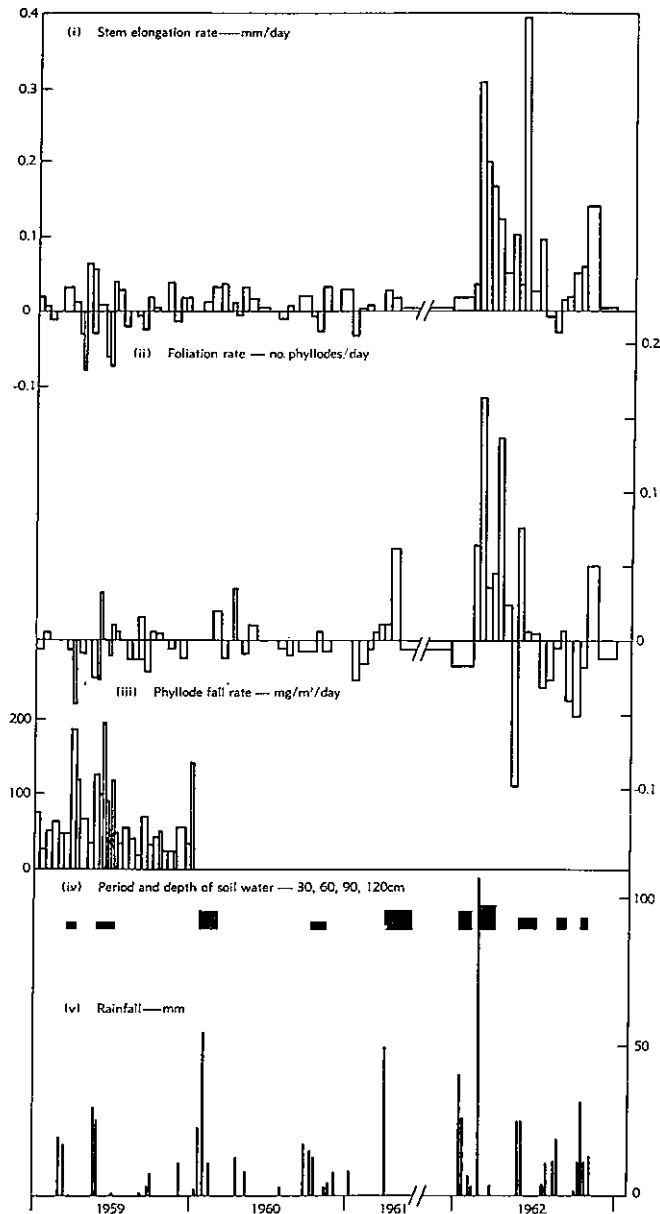


FIGURE 1

Measurements of mulga, rainfall and soil water, 1959 to 1962, 34 km north of Alice Springs, N.T. →

- (i) length of the distal phyllode-bearing portion of stem on 12 tagged branches of 3 mature trees of a grove.
- (ii) numbers of phyllodes on the 12 tagged shoots.
- (iii) oven dry weight of the phyllode catch in 16 traps, each a metre square, transecting the mulga grove.
- (iv) periods when soil water potential was greater than approximately -15 bars and depth of recharge (shown by height) in the soil profile of the grove determined by gypsum resistance blocks buried at 30, 60, 90, and 120 cm.
- (v) rainfall in a standard 8 inch (20.3 cm) gauge in the intergrove.

In a central Australian grove with negligible ground vegetation nearly all litter was mulga phyllodes, falling at an average annual rate of about 300 kg/ha. Chemical analyses on freshly shed and trapped phyllodes (Turner pers. comm.) were used to calculate approximately the *potential* return of minerals (Table 1). The quantities recycled are possibly a significant proportion of the total (unknown) needs of the plants. Minimal disturbance of the nutrient cycle should be a management goal because fertilizers are not likely to be applied generally to mulga lands.

TABLE 1
Estimated annual mineral returns from fallen mulga phyllodes in a mulga grove near Alice Springs

Element	Amount (kg/ha/per annum)
Nitrogen	4.2
Calcium	4.2
Potassium	1.8
Magnesium	0.3
Phosphorus	0.12
Sodium	0.06

Turner (pers. comm.) demonstrated an inverse proportionality between the rate of phyllode shedding and nutrient content. High shedding rates after rain coincided with low contents presumably after translocation to new phyllodes. Field studies with tracers would provide more information on translocation and nutrient cycling.

WATER RELATIONS

The work of Slatyer (1961), Turner (1965) and Winkworth (1970) characterized the atmospheric and soil water regime of the grove/intergrove mulga communities on relatively deep red earth soils near Alice Springs, N.T. The grove pattern is aligned to the contours of the terrain and forms a run-off/run-on system in which intergrove soils absorb less than half the rainfall and the excess water flows into the groves. The mulga plants, which are concentrated in the groves, occupy a favoured habitat. The system operates nearly every time rainfall exceeds 10 mm. Work on the water economy of groved mulga communities is continuing and that of the different mulga lands in western Queensland is now being studied (Pressland pers. comm.).

Mulga, as studied by Slatyer (1965) near Alice Springs efficiently partitioned the rainfall on the community. Up to about 2.5 mm was intercepted to wet the plant surfaces. Of rainfalls exceeding 2.5 mm up to 40% was channelled down the stems and flowed to the plant bases and the remainder fell through the canopy directly to the soil surface. The proportion of the rainfall directed into the stemflow rose sharply from 5% to 40% as rainfall or rainfall size increased from 2.5 mm to 12.5 mm above which there was little change. Increasing intensity of rainfall up to 18 mm/hr only slightly depressed stemflow. Evidence is needed that the depth of soil water recharge beneath the trees is significantly increased by stemflow resulting in relatively smaller proportions of the total rainfall over the trees being lost by surface evaporation. Root uptake of the water stored deep in the soil also requires confirmation.

After rain mulga phyllodes took 3-4 days to reach maximum hydration, but a longer time was needed when drought stress prior to rain had been more severe (Slatyer, 1961a). Hence a resumption of metabolism can be expected on the occasions when soil water storage is recharged. Maximum values of tissue water content of 95% relative turgidity and water potentials of about -10 bars decrease with decreasing soil water storage to minimum values of about 40% and -120 bars respectively. As

this occurred, increasing stomatal control was indicated by the progressively smaller diurnal fluctuations. The ability to withstand low tissue water potentials results in the extraction of soil water down to -120 bars. In these soils the water extracted to -120 bars is double that extracted to -15 bars. Hence the plants obtain significantly more water but it is likely that photosynthesis and growth is negligible when tissue water potentials fall below -15 bars. A lack of carbon assimilation can be assumed during the long periods of desiccation.

Tissue water losses resulted in larger decreases in water potential in mulga than in more mesophytic species like privet and tomato (Slatyer, 1960). In the latter species changes in water potential corresponded to expected increases in the osmotic concentrations of the desiccating tissues. In mulga water potentials decrease from -30 bars less than calculated from changes in osmotic pressure, the mechanism of this resistance to desiccation remaining unexplained.

CONCLUSIONS

The adaptation of mulga to arid conditions has been demonstrated by several ecological and physiological aspects of its water relations. In the Alice Springs area mulga occupies areas receiving extra water supplied by run-off. The plants may increase soil water storage around their bases by channeling a substantial proportion of rainfall down their stems. Stomatal control restricts water loss as tissue stresses increase and low water contents and potentials are tolerated by mulga over long periods without death. Water potentials do not decrease to the extent expected on the basis of osmotic pressure changes alone as in mesophytes.

Methods of conservation of carbon in the face of respiratory drains during dry periods and efficiency of replacement by photosynthesis during short periods of hydration have not been studied. The resulting net productivity, which is of prime interest for practical purposes, in relation to water usage has not been measured, though work is in progress. Since there are no measurements of productivity, the significance of mulga as a forage producer and the consequences of grazing on mulga growth cannot be assessed.

A consecutive summer-winter rainfall requirement for adequate fruit production suggests a precarious seed supply for regeneration. The areas of germination, establishment, nitrogen fixation, and nutrient cycling have been insufficiently studied though the information before us suggests entire dependence on soil water recharge following rainfall—adaptive mechanisms doubtless have evolved. Growth and reproduction of mulga is dependent on these 5 processes and understanding them is vital to management of mulga lands.

REFERENCES

- BEADLE, N. C. W. (1964)—Nitrogen economy in arid and semi-arid plant communities. Part 111. The symbiotic nitrogen-fixing organisms. *Proceedings of the Linnean Society of New South Wales* 89: 273-286.
- CROCKER, W., and BARTON, L. V. (1953)—Physiology of seeds. Waltham: Massachusetts.
- DAVIES, S. J. J. F. (1968)—Aspects of a study of emus in semi-arid Western Australia. *Proceedings of the Ecological Society of Australia* 3: 160-166.
- EVERIST, S. L. (1949)—Mulga (*Acacia aneura*) in Queensland. *Queensland Journal of Agricultural Science* 6: 87-139.
- MACONOCHIE, J. R., and LANGE, R. T. (1970)—Canopy dynamics of trees and shrubs with particular reference to the arid zone topseed species. *Transactions of the Royal Society of South Australia* 94: 243-248.
- PREECE, P. B. (1971)—Contributions to the biology of mulga I. Flowering. *Australian Journal of Botany* 19: 21-38.

- PREECE, P. B. (1971a)—Contributions to the biology of mulga II. Germination. *Australian Journal of Botany* **19**: 39-49.
- SLATYER, R. O. (1960)—Aspects of tissue water relationships of an important arid zone species (*Acacia aneura* F. Muell.) in comparison with two mesophytes. *Bulletin of the Research Council of Israel D. Botany* **8**: 159-168.
- SLATYER, R. O. (1961)—Methodology of a water balance study conducted on a desert woodland (*Acacia aneura*) community in central Australia. *UNESCO Arid Zone Research* **16**: 15-24.
- SLATYER, R. O. (1961a)—Internal water balance of *Acacia aneura* F. Muell. in relation to environmental conditions. *UNESCO Arid Zone Research* **16**: 137-146.
- SLATYER, R. O. (1965)—Measurements of precipitation interception by an arid plant community (*Acacia aneura* F. Muell.). *UNESCO Arid Zone Research* **25**: 181-192.
- TURNER, J. C. (1965)—Some energy and microclimate measurements in a natural arid zone plant community *UNESCO Arid Zone Research* **25**: 63-70.
- WILCOX, D. G. (1960)—Studies in the mulga pastoral zone. 2. Some aspects of the value of the mulga scrub. *Journal of Agriculture of Western Australia Series* **4**: 581-586.
- WINKWORTH, R. E. (1970)—The soil water regime of an arid grassland (*Eragrostis eriopoda* Benth.) community in central Australia. *Agricultural Meteorology* **7**: 387-399.