

Effect of water stress on three native mulga grasses and one exotic grass

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Summary

A series of glasshouse experiments was designed to study the effect of water stress on three grasses native to the mulga lands of south-west Queensland, and one exotic grass. Both the above and below ground mass of plant matter decreased, but root:shoot ratio increased as the degree of water stress increased.

The ability of a seedling to grow rapidly even under adverse conditions is an important attribute in an arid environment. *Antheophora pubescens*, the exotic species, outyielded but grew more slowly than the three native species. *Aristida* spp. has the capacity to flower under adverse conditions and consequently has a greater reproductive capacity than either of the other two natives (*Thyridolepis mitchelliana* and *Digitaria ammophila*) and *Antheophora pubescens*.

1. INTRODUCTION

The environmental hazard which has the greatest effect on pasture plants in semi-arid and arid regions is moisture stress. This is particularly so for seedlings. Survival of buffel grass (*Cenchrus ciliaris*) seedlings growing in an arid red earth in south-western Queensland and subjected to soil moistures below -1500 J kg^{-1} decreased as the length of stress increased (Christie 1975a), while the growth of buffel seedlings and seedlings of a native mulga mitchell grass was significantly affected by soil moisture stress (Christie 1975b). The addition of phosphorus to the soil significantly improved survival and growth of the seedlings. Other studies have examined the effects of water stress on plants native to the soils supporting mulga (*Acacia aneura* F. Muell.) scrub, although mulga itself can withstand extreme water stress (Burrows 1973).

This work examines the reaction to water stress of seedlings of three native and one exotic grass species growing with and without additional phosphate in a soil typical of the mulga communities of south-west Queensland.

2. MATERIALS AND METHODS

Three pot trials were established to assess the effects of water stress. For all experiments, pots 20 cm in diameter were filled with sieved, air dried mulga soil similar to that described by Burrows (1972). The pots were watered with deionized water and maintained at about field capacity by daily weighing and surface watering for 5 days to allow the emergence and removal of naturally occurring seedlings. Field capacity was determined from a laboratory derived moisture characteristic curve for this soil, as were the stress levels imposed. The physical nature of the soil ensured that the soil was similarly compacted in each pot.

The soil of Experiment 1 was supplied with the equivalent of 55 kg ha⁻¹ P in solution (as NaH₂PO₄·2H₂O), as were half the pots used in Experiment 3. Pregerminated grass seeds were sown one species per pot. Pots were maintained at field capacity by daily weighing and surface watering until the two leaf stage of growth, when plants were thinned to one per pot and the stress treatments begun. The species used and treatments imposed were as follows.

Experiment 1. A randomized block design of 4 grass species, 3 watering treatments, 2 harvests and 5 replications was used.

Grasses: One exotic (*Antheophora pubescens*) and three natives (*Aristida jerichoensis*, *Digitaria ammophila* and *Thyridolepis mitchelliana*).

Watering treatments: Pots were allowed to dry to three levels of total soil moisture equivalent to soil water potentials of -60 J kg⁻¹ (W1), -100 (W2) and -950 J kg⁻¹ (W3). The pots were maintained at the first two stress levels by daily weighing and surface watering, but when the third stress level (W3) was reached the pots concerned were watered to field capacity and the cycle restarted. The stresses imposed were representative of the field situation, where water potential gradients occur in the soil profile.

Harvests: Harvest 1 at 6 fully expanded leaves, harvest 2 at 12 leaves.

Experiment 2. A randomized block design of 3 grass species (*Antheophora pubescens*, *Aristida jerichoensis* and *T. mitchelliana*), 4 watering treatments, 3 harvests and 5 replications was used.

Watering treatments: In addition to the stress treatments imposed in Experiment 1 (W1, W2 and W3), one group of pots (W4) was allowed to dry to a soil tension of -1500 J kg⁻¹ before being watered to field capacity and the cycle restarted.

Harvests: As for Experiment 1 with an additional harvest when 3 fully expanded leaves were present.

Experiment 3. A randomized block design of 4 grasses (as for Experiment 1), 3 watering treatments (W1, W2 and W3), 2 levels of soil phosphorus, 2 harvests (as for Experiment 1) and 4 replications was used. The phosphorus levels were equivalent to an additional 0 and 55 kg ha⁻¹ P. The stress treatments were similar to those described for Experiment 1, but when the desired level (W1 and W2) was reached, the pot was rewatered to field capacity as for W3.

Before harvest the stomatal resistance to vapour flow of the uppermost leaf of the plants grown in Experiment 3 was determined by the method of Kanemasu, Thurtell and Tanner (1969), except that the boundary layer resistance was ignored. Thus, the resistance actually measured was $1/R = 1/r_1 + 1/r_2$, where R is the total stomatal resistance, and r_1 and r_2 are the resistances measured with a diffusion resistance porometer on the adaxial and abaxial leaf surfaces. Following this the leaf was excised and its relative turgidity determined in the laboratory under room light intensity and temperature.

At harvest, the number of tillers and fully expanded, partly expanded and dead leaves was recorded. Shoots were removed, dried at 80°C for 36 h and weighed. The weight of the leaf excised for relative turgidity study was added to the shoot mass. Roots and soil were immersed in a 2% detergent solution for 24 h before being separated over a 1.2 mm sieve and the roots dried and weighed.

Data from each experiment were subjected to analysis of variance, and Duncan's Multiple Range test or Student's 't' test was used to determine significant differences between means where appropriate.

3. RESULTS

The top and root weights of *Antheophora*, *Aristida* and *Digitaria* were greater overall than those of *Thyridolepis* (Table 1). However, *Antheophora* was so severely affected by the low level of soil phosphate and the type of water stress imposed in Experiment 2 compared with Ex-

periments 1 and 3 that its top and root weights were less than those of *Aristida*. In both Experiments 1 and 3 the biomass of *Antheophora* exceeded that of any other species.

In all experiments the weight of the plant tops tended to decrease as water stress increased (Figures 1, 2 and 3a). *Antheophora* and *Aristida* were affected most, though the addition of phosphorus to *Antheophora* resulted in an increase in weight at the highest level of stress in Experiments 1 and 3.

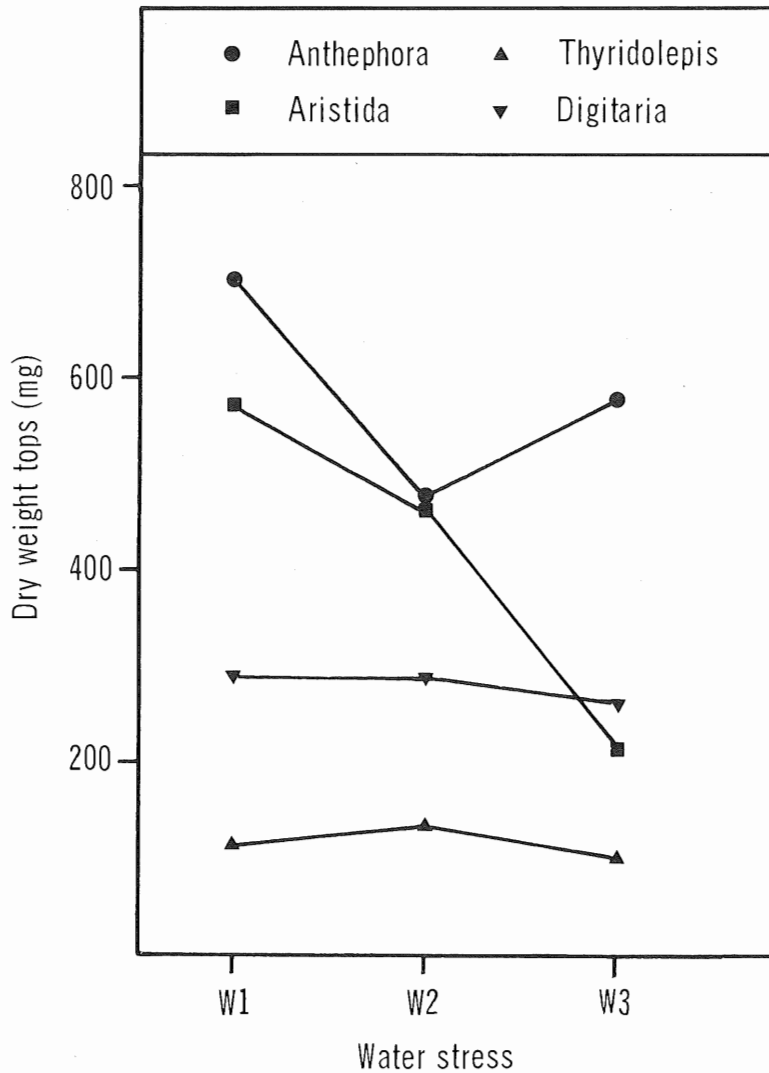


Figure 1. Effect of water stress on the dry weight of tops at the 12 leaf stage of growth of grass seedlings (Experiment 1) growing in mulga soil supplied with 55 kg ha⁻¹ phosphorus.

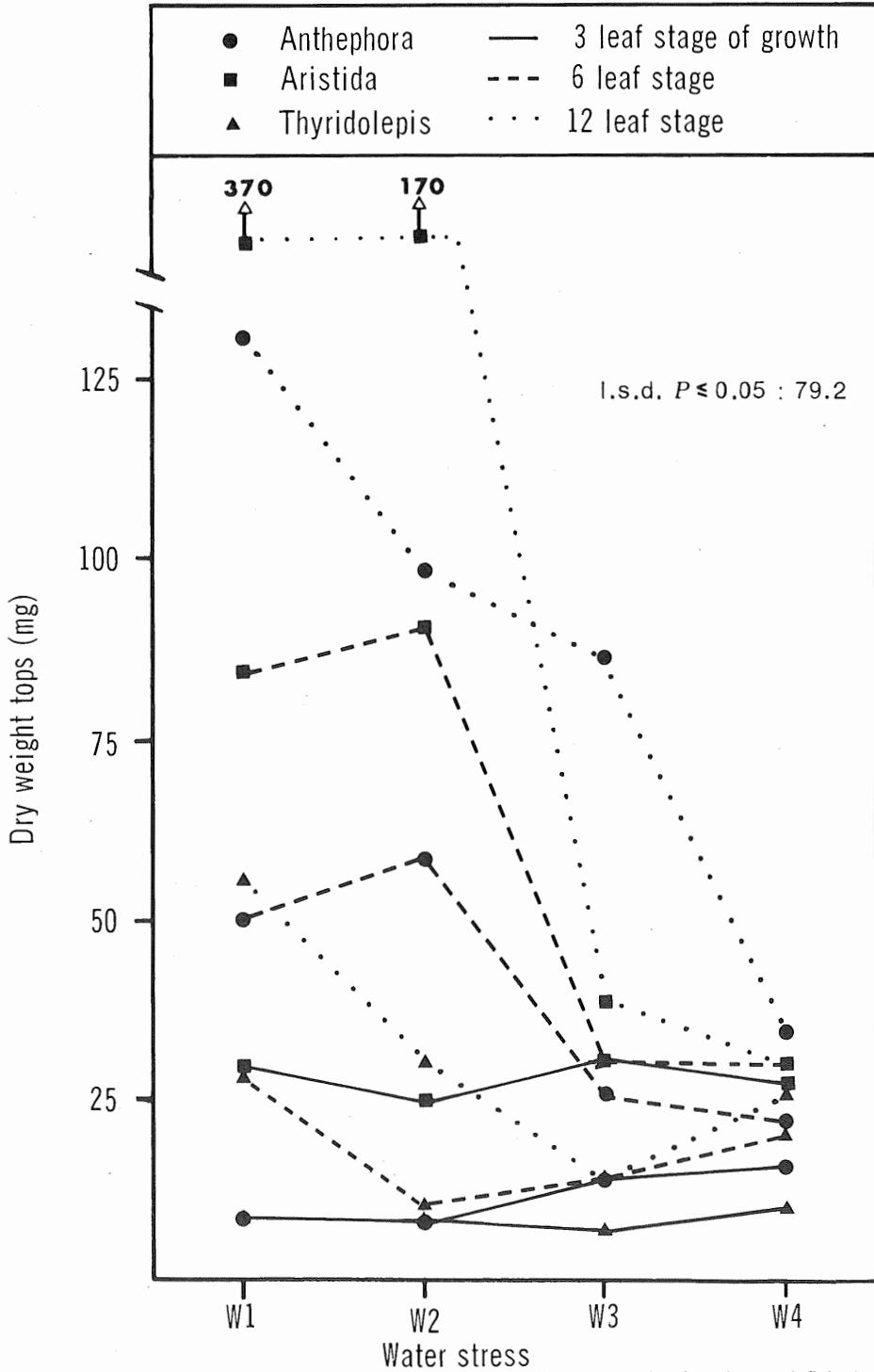


Figure 2. Effect of water stress on the dry weight of tops of seedlings grown in phosphorus deficient mulga soil (Experiment 2).

Table 1. Dry weights (mg) of the tops and roots of the grasses in all experiments at water stress level W1

	<i>Antheophora</i>	<i>Aristida</i>	<i>Digitaria</i>	<i>Thyridolepis</i>
Experiment 1 (+P)* Tops.....	708	572	296	120
Roots	374a	549a	212b	54c
Experiment 2 (-P) Tops.....	131b	369a	. .	56b
Roots	38b	280a	. .	13b
Experiment 3 (+P) Tops.....	582a	130b	183b	99b
Roots	304a	50b	83b	29b
(-P) Tops.....	546a	128b	196b	70b
Roots	298a	59c	153b	16c

* +P — with 55 kg ha⁻¹ phosphorus.
 -P — without phosphorus.

Values in the same row followed by the same letter are not significantly different ($P \leq 0.05$). For Experiment 3, weights of the same plant part may be compared irrespective of the phosphorus status of the soil.

The effect of water stress on the roots was not clear, though *Aristida* and *Antheophora* were again most affected. The root mass of plants supplied with additional phosphorus (Experiments 1 and 3) tended to increase with increasing stress (Figures 3b and 4), although the weight of *Aristida* roots (Experiment 1) by the 12 leaf stage exhibited the reverse trend. In general, plants growing in phosphorus deficient soil (Experiments 2 and 3) had lower root weights under greater water stress (Figures 3b and 5). *Aristida* in Experiment 2 and *Antheophora* in Experiment 3 exhibited this most markedly.

Root:shoot ratios increased as water stress increased in Experiments 1 and 3, but there was no difference in the ratios found in Experiment 2. The addition of phosphorus led to a decrease in root:shoot ratios (Experiment 3) but this was not obvious in a comparison of the results of Experiments 1 and 2. Root:shoot ratios also varied between species (Figure 3c).

The number of tillers produced by all species in the three experiments decreased with increasing water stress but was increased in the presence of additional phosphorus. However, only in Experiment 3 were differences between species statistically ($P \leq 0.05$) significant: at the highest level of stress more tillers occurred on *Digitaria* than any other species, and at the other two stress levels *Thyridolepis* had the fewest tillers.

Harvest (Experiment 3) was delayed increasingly by greater water stress at both levels of soil phosphorus (Figure 3d); the delay was greatest for *Antheophora* at both phosphorus levels and for *Aristida* at the higher level of phosphorus. The addition of phosphorus significantly decreased the mean time to harvest for all species from 27 and 40 days at the low phosphorus level for harvest 1 and 2, respectively, to 11 and 18 days, respectively ($P \leq 0.01$).

Floral initiation occurred only in the *Aristida* plants grown in Experiment 3.

Antheophora possessed significantly ($P \leq 0.05$) more dead leaves than *Aristida* at the highest level of water stress (Experiment 3) with the other two species intermediate. A similar trend was evident at the medium stress level. Adding soil phosphorus significantly ($P \leq 0.01$) reduced the number of dead leaves at harvest.

Water stress and additional soil phosphorus had no effect on either leaf turgidity or stomatal resistance at either harvest (Experiment 3). There were statistical differences in turgidity between species (for example 93% for *Thyridolepis* as against 99% for *Aristida*).

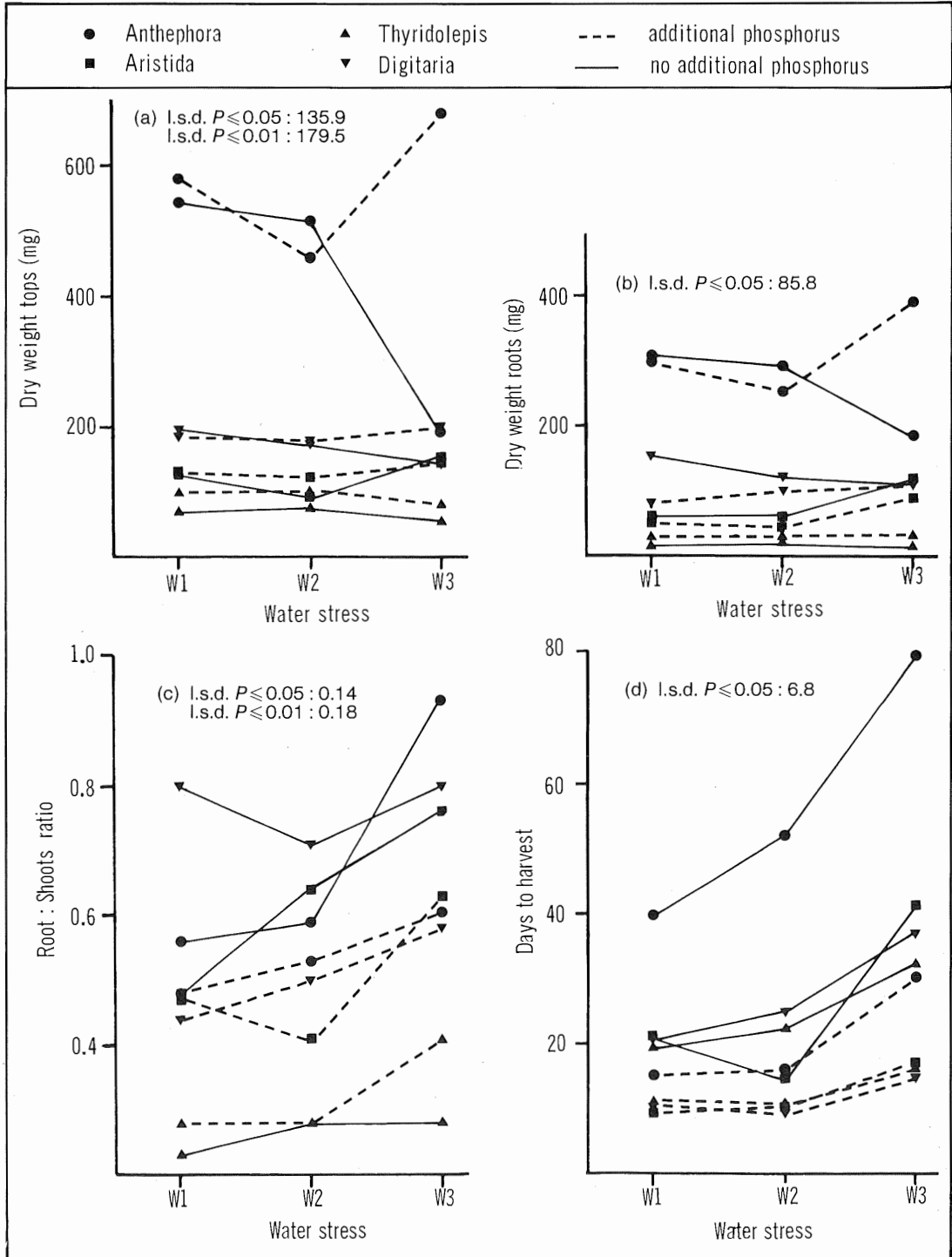


Figure 3. Effect of water stress on (a) dry weight of tops and (b) roots; (c) root:shoot ratios and (d) mean number of days from imposition of stress on seedlings grown in mulga soil (Experiment 3).

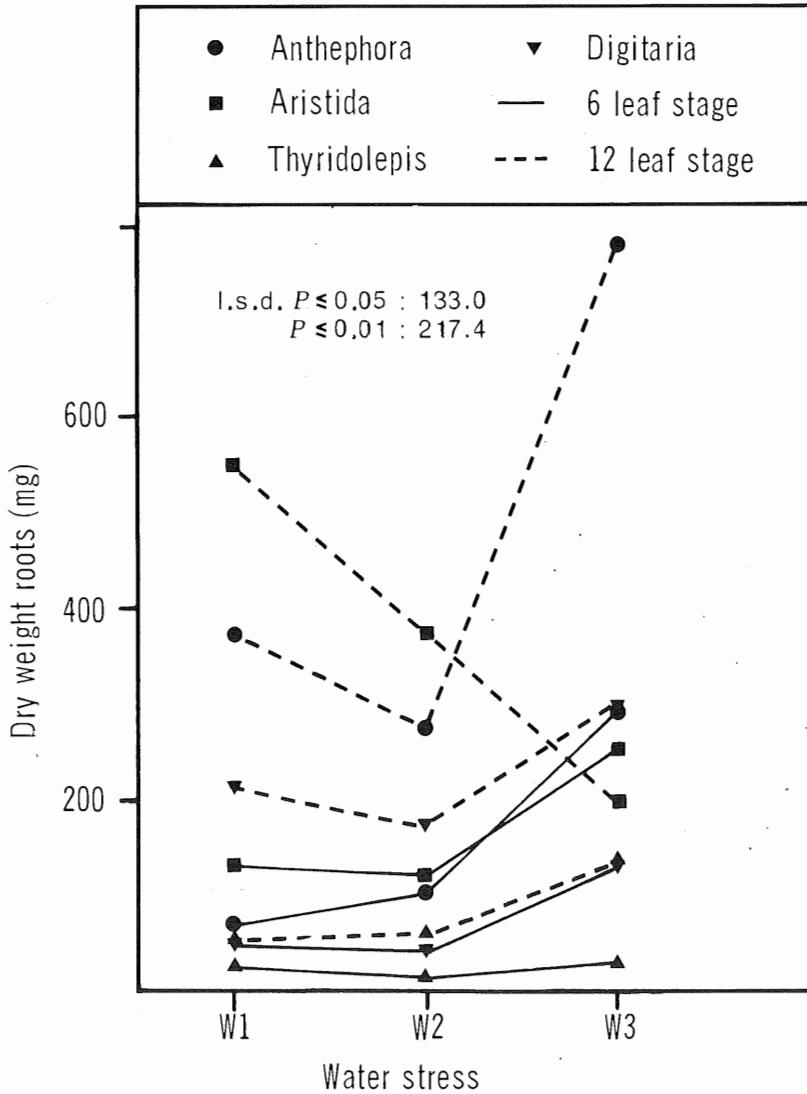


Figure 4. Effect of water stress on the dry weight of roots at two stages of growth of grass seedlings (Experiment 1) growing in mulga soil supplied with 55 kg ha⁻¹ phosphorus.

Further, stomatal resistance to transpiration in *Aristida* leaves (9.9 s cm⁻²) was higher ($P \leq 0.01$) than in any of the other species, while the resistance of *Thyridolepis* (2.6 s cm⁻²) was lower ($P \leq 0.01$) than that of either *Digitaria* (6.9 s cm⁻²) or *Anthephora* (7.0 s cm⁻²).

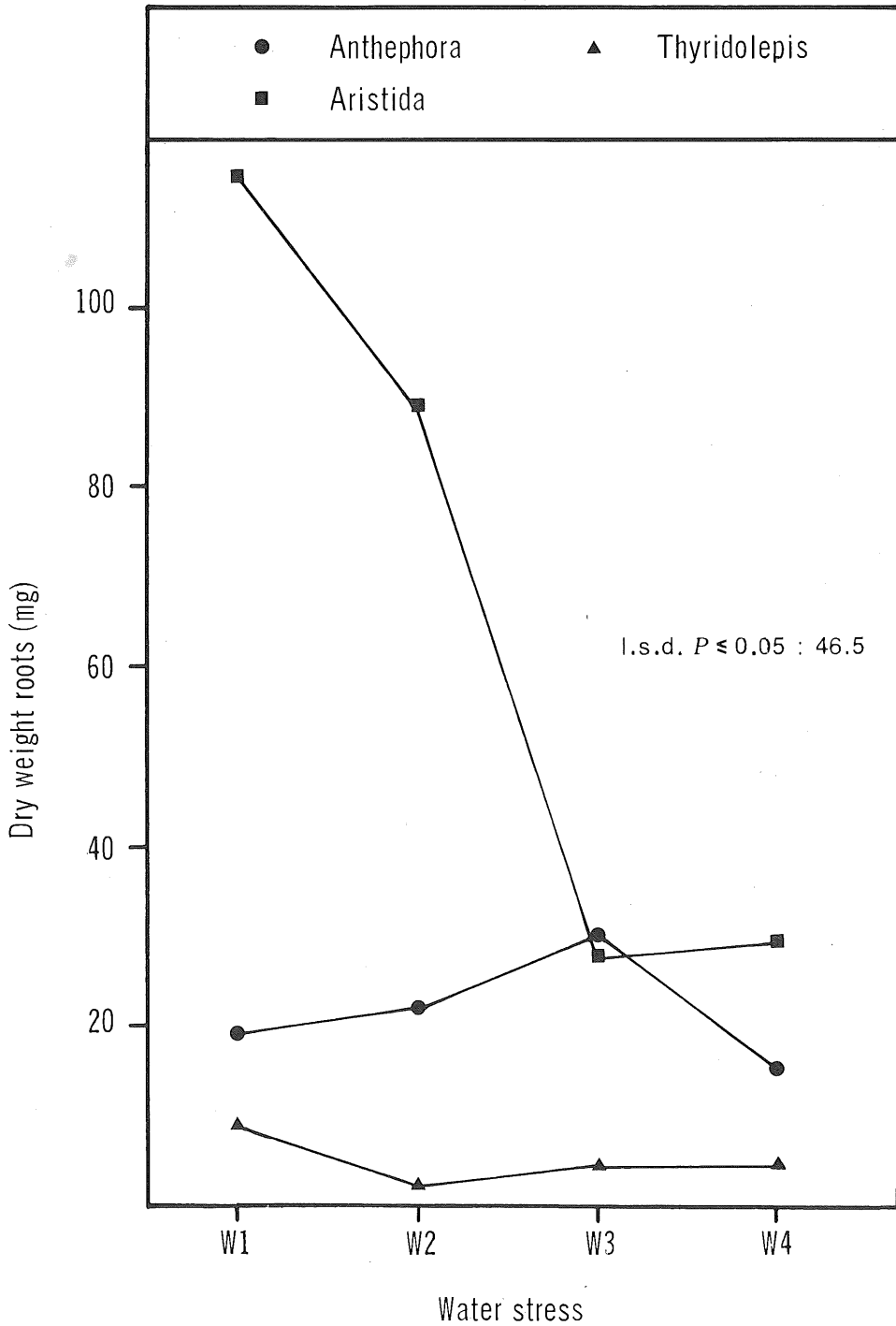


Figure 5. Effect of water stress on the dry weight of roots of seedlings grown in phosphorus deficient mulga soils (Experiment 2).

4. DISCUSSION

Some of the water stresses imposed on the plants in Experiments 1 and 2 were more severe than in the third experiment because of the way they were imposed: when pots reached the predetermined stress levels in the first two experiments, the levels were maintained; in the third experiment, pots were watered to field capacity as soon as the stress level was reached. Thus, plants did have regular growth periods in the absence of water stress.

Antheophora outyielded the other species irrespective of soil phosphorus level under the stress conditions applied in Experiment 3. However, only at the 12 leaf stage did it outyield *Aristida* when grown in a soil with additional phosphorus under the stresses imposed in Experiment 1. Under low soil phosphorus conditions (Experiment 2) *Aristida* outyielded *Antheophora*. The decline in the top weight of all species with increasing water stress is in agreement with previously published work (Gates 1968; Christie 1975a), though the marked drop in yield of *Aristida* in Experiment 2 caused by water stresses in excess of W2 was exceptional. The increase in top weight of *Antheophora* grown under additional phosphorus at the highest stress level (Figure 3a) may have been due to its greater root system (Figure 3b).

The effects of water stress on the grass roots generally followed the normal pattern of a relative increase in root weight compared with top weight as the degree of water stress increased.

The increase in root:shoot ratios due to increasing water stress recorded from all species and all stress treatments was also in accord with previously published work (Christie 1975b), as was the notable effect of additional soil phosphorus on decreasing the ratio (Experiment 3).

Neither the leaf turgidity nor resistance to vapour pressure data allowed the effects of water stress to be defined because of the way the grasses were treated before harvest. For example, some pots may have been watered 2 days before harvest, while others may not have been watered for several days or more. However, *Thyridolepis* consistently showed the lowest resistance to leaf vapour flow and leaf turgidity even though the latter was sufficiently high (93%) to suggest that the plants were still unstressed and the difference was not physiologically significant. *Aristida* had a high level of resistance to vapour flow and was able to maintain its leaf turgidity at almost 100%.

The ability of a species to grow rapidly even under adverse conditions is an important attribute in an arid environment. *Antheophora* had a yield advantage over the other species in Experiments 1 and 3 but it did not compare favourably with the native species in terms of speed of seedling growth. It took significantly longer than the natives to reach the 6 and 12 leaf stages in both unfertilized and fertilized mulga soil (Experiment 3), and it suffered higher leaf mortality than the other species at the highest level of stress imposed in that experiment.

Previous studies have shown that although *Antheophora* has a higher percentage germination than many native species, this is not correlated with establishment success (Silcock and Whalley 1974). These authors offered as reasons for this the slowness to tiller and lateness of flowering of *Antheophora* compared with the native species. They also found that seedlings of the natives were smaller in stature, a point which was borne out in this series of experiments. Silcock and Whalley (1974) concluded that, during the establishment phase, exotic grasses may be easily removed from a pasture by drought or other natural causes because they lack sufficient growing points and/or have no seed reserves available for subsequent germination. None of the experiments reported here showed large differences in tillering between species, although *Digitaria* was found to tiller more freely than the other three species in Experiment 3. *Aristida* has a very large reproductive capacity (Experiment 3, and Pressland and Lehane 1980). This, together with its low acceptability to stock (Beale 1975), is probably the reason that *Aristida* spp. occur more frequently than any other naturally occurring grass species in the mulga lands of south-west Queensland (Roberts 1972). On the other hand, the slow growth of the exotic, *Antheophora*, suggests that it may not compete well with the native species,

especially *Aristida*, except under higher soil phosphorus conditions than those normally found in the mulga country of south-west Queensland.

5. ACKNOWLEDGEMENTS

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