ADAPTATION OF COOL-SEASON PULSES TO WATER-LIMITED ENVIRONMENTS

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Summary. Drought is one of the major constraints in the production of cool-season pulses in southern Australia. The leaf water potential, rate of net photosynthesis, osmotic adjustment and yield of six pulses were measured in irrigated and rainfed plots in the field in Merredin, Western Australia. Growing season rainfall in 1994 was 154 mm. Leaf water potential in the rainfed plots decreased from -0.5 to -0.7 MPa to about -3 MPa in chickpea and lentil and -2 MPa in faba bean, field pea, grass pea and lupin. Photosynthesis decreased markedly as the leaf water potential decreased to -1 MPa and did not vary among the six species. Net photosynthesis was zero or near zero at -2 MPa in faba bean, field pea, grass pea and lupin, but did not reach zero until -3 MPa or lower in lentil and chickpea, both of which showed the greatest degree of osmotic adjustment. However, biomass and grain yields under rainfed conditions did not correlate well with osmotic adjustment or the rates of net photosynthesis. We suggest that yields of pulses under water limited conditions may be determined by the rates of leaf area development and time of pod development rather than the photosynthetic activity of the leaves.

INTRODUCTION

Crop and pasture legumes are important components of the agricultural system in southern Australia. Lupins have proved to be a successful commercial option for farmers with coarse textured soils, but have been less successful on the fine-textured red-brown earths and shallow duplex soils. Alternative pulses are being sought that are adapted to the fine-textured soils (2). The major constraint to crop legumes on these soils is drought, particularly drought during grain filling. This paper reports on studies on the response to water deficits in six pulses that are potential candidates for adoption on fine-textured soils of southern Australia.

MATERIALS AND METHODS

Six pulses, field pea (*Pisum sativum* L. cv. Dundale), chickpea (*Cicer arietinum* L. cv. T1587), faba bean (*Vicia faba* L. cv. Fiord), lupin (*Lupinus albus* L. cv. Kiev mutant), lentil (*Lens culinaris* L. cv. Digger) and grass pea (*Lathyrus sativus* L. selection 453), were grown in plots 40m long by 1.4m wide (8 rows with 18 cm between rows) in the field at Merredin, Western Australia (31^{o} 29' S., 118^{o} 12' E.). The plots were sown on 24 May 1994; growing season rainfall was 154 mm. Five metres at one end of each plot was irrigated by drip irrigation twice weekly from 2 August to 20?September 1994. Each species was replicated four times in a randomised block design.

From 16 August to 27 September 1994, the leaf water potential of three upper fully-expanded leaves in each plot was measured. Measurements were taken approximately weekly around midday (11:00h to 15:00h Western Standard Time) on clear sunny days using the pressure chamber technique (4). On each occasion, the rate of net photosynthesis was measured with a portable open gas exchange system (Model LCA3, ADC, Hoddesdon, U.K.) on similar leaves to those measured for leaf water potential.

On 24 August, 6 September, 20 September and 27 September upper fully-exposed leaves were also sampled for relative water content (3) and measurement of osmotic potential by vapour pressure osmometry (3). The osmotic potential at full turgor (Π_{100}) was calculated from:

$$\Pi_{100} = \Pi/R$$

were R is relative water content and Π is the measured osmotic potential at that R.

At maturity, $2 m^2$ in each of the irrigated and rainfed plots was hand harvested, the samples oven dried at 70^oC for 48h and weighed. The grain was then threshed, oven dried and grain weights determined.

RESULTS

The 154 mm of growing-season rainfall in 1994 was extremely low compared with an average growing-season rainfall of 210 mm. Leaf water potentials in the rainfed plants began to decrease below those in the irrigated plants on 24 August (Fig. 1). After 27 September there were no measurable leaves on the rainfed plants and measurements were terminated. The leaf water potential decreased below -3 MPa in lentil and chickpea, but decreased to only about -2 MPa in the other four species.

Figure 1. Change of leaf water potential with time in six irrigated and rainfed pulse species.

The rate of photosynthesis of the irrigated plants varied with species. In chickpea and lupin the photosynthetic rate was about 30 $\mu mol/m^2/s^1$, compared to 20 $\mu mol/m^2/s$ in lentil and about 10-20 $\mu mol/m^2/s$ in grass pea, field pea and faba bean. The rate of net photosynthesis decreased

Figure 2. Relationship between net photosynthesis rates and leaf water potential in six pulse species.

markedly in the six species as the leaf water potential decreased to -1 MPa. The relationship between net photosynthesis and leaf water potential was similar in all species except at values of photosynthesis below 5 $\mu mol/m^2/s$ (Fig 2). Chickpea and lentil reached zero or near zero photosynthesis at a leaf water potential of about -3 MPa compared to -1.5 to -2.0 MPa in the other four species. Osmotic adjustment was 0.6 to 0.7 MPa in chickpea and lentil, 0.4 MPa in field pea and near to 0.2 MPa in the other three species (Table 1).

Biomass production varied from 4300 to 7300 kg/ha and grain yields varied from 960 to 4000 kg/ha in the irrigated plots (Table 1). The rainfed plots produced 1600 kg/ha of biomass in the

Table 1. Biomass, grain yield, harvest index and osmotic adjustment of six pulses grown with and without irrigation at Merredin, Western Australia, in 1994.

	Faba bean	Field pea	Lentil	Grass peas	Chickpea	Lupin	l.s.d.
Irrigated							
Biomass (kg/ha)	7270	4610	5450	5160	4720	4270	930
Grain yield (kg/ha)	4000	2320	2760	960	1640	1820	490
Harvest index	0.55	0.50	0.50	0.18	0.35	0.42	0.04
Rainfed							
Biomass (kg/ha)	3270	3080	2380	2020	2060	1570	420
Grain yield (kg/ha)	1350	1040	720	520	480	330	190
Harvest index	0.41	0.35	0.30	0.25	0.23	0.21	0.05
Osmotic adjustment (MPa)	0.18	0.40	0.63	0.19	0.66	0.16	0.17

lupin to 3300 kg in faba bean. Compared to the grain yields in the irrigated plots grain yields were reduced in the rainfed plots, varying from 330 kg/ha in lupin to 1350 kg/ha in faba bean (Table 1). The harvest index was very low in the irrigated grass pea, possibly due to shattering before harvest (Table 1). In all species except grass pea, the harvest index was lower in the rainfed compared to the irrigated plots.

DISCUSSION

The results from this study clearly demonstrate that the cool-season pulse species currently being grown in Australia are vulnerable to end-of-season water deficits. In all cases except grass pea in which the irrigated plants likely shattered before harvest, the yields of the unirrigated plots were about 25 to 45% of those in the irrigated plots. While this ratio will vary depending on when irrigation is terminated, the results do demonstrate significant reductions in yield and harvest index from water deficits. The highest yielding species in this very dry season was faba bean, which also responded well to irrigation, indicating that it will yield well in favourable seasons as well as unfavourable seasons (2).

When soil water was plentiful, the rate of net photosynthesis was at least 50% higher in chickpea and lupin than in the other species. Lupin has been observed previously to have higher rates of net photosynthesis when adequately watered (1,5). Despite differences in the rate of photosynthesis at high water potentials, the species responded similarly when leaf water potentials decreased until values about 5 μmol/m^2/s. Low rates of photosynthesis were maintained to lower leaf water potentials in chickpea and lentil than the other four species. Chickpea and lentil were the two species that osmotically adjusted to the greatest degree as the leaf water potentials decreased. Osmotic adjustment aids in the maintenance of turgor (6), but in the case of the two pulses it did not maintain high rates of photosynthesis. The degree of osmotic adjustment has been shown to vary with cultivar in chickpea, but we suggest that it is unlikely to maintain active growth because it is effective only at low rates of photosynthesis. However, it may aid in the maintenance of physiological activity near zero turgor, and this may be important in translocation of assimates to the grain.

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