Response of grain crops to drought

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Introduction

Recurrent and variable drought is one of the chief causes of year to year variation in grain yield in New Zealand. Canterbury, which is a major producer of wheat and barley with an expanding area of maize, has summer potential evapotranspiration approximately twice its mean rainfall. This seasonal shortfall in rainfall is aggravated by its large variability, both between and within years.

Several experiments in New Zealand have investigated the response of grain crops to drought, but the results are often inconclusive due to the occurrence of untimely rainfall. Consequently, a series of experiments were conducted in the Crop and Food Research rainshelter at Lincoln to define the sensitivity of grain crops to variable droughts at different times in the growing season. This paper compares the responses of spring barley, maize and winter wheat to imposed drought of varying times and intensities.

Materials and Methods

The rainshelter at Lincoln is a mobile 55 m x 12 m greenhouse which automatically covers the experimental crop during rainfall, but otherwise has little effect on the field environment. The rainshelter is on a deep (>1.6 m) Templeton sandy loam soil (*Udic Ustochrept*, USDA Soil Taxonomy) with an available water holding capacity of about 190 mm per metre of depth. The working section of the rainshelter is divided into 24 3.6 m x 5 m plots, each with its own metered trickle irrigation supply.

Treatments were designed to impose droughts of varying severity at different times during the growth of each crop. In the barley and maize experiments droughts were imposed early, middle and late in the growing season, while in the wheat experiment droughts were imposed in the spring and the summer. Plots scheduled for irrigation were watered weekly, with all treatments receiving the same amount of water. This was equal to the calculated water use of the fully irrigated treatment during the previous week, using the measured soil moisture content to 1.6 m depth. Leaf area index (LAI) measurements were made throughout the growing season in all experiments. Grain yield and its components were determined at harvest.

Potential soil moisture deficits for each treatment were calculated weekly based on the potential evapotranspiration of the control and the amounts of water applied to each treatment.

Results and Discussion

A range of maximum potential soil moisture deficits (D_{pmax}) was achieved in each experiment, and although the corresponding yield range in the barley and wheat experiments was quite wide, in the maize experiment it was narrow (Table 1). For each experiment, simple linear models were fitted to the yield and D_{pmax} data. These models defined the critical deficit (D_c) below which yield was unaffected by drought and the slope of the yield/D_{pmax} curve above this deficit.

Spring barley yield appeared quite sensitive to drought as the D_c was less than the D_{pmax} experienced by the control treatment (i.e., <75 mm). In contrast, winter wheat was unaffected by drought until D_{pmax} exceeded 262 mm. This difference was probably a reflection of the greater rooting depth and thus the amount of plant-available water to the winter-sown compared with the spring-sown crop when drought was imposed. However, once D_c was exceeded, the barley and wheat crops showed a similar decline in yield as D_{pmax} increased. There was no evidence that the timing of drought had any effect on yield response, as all barley or wheat treatments were described by the same linear model.

In contrast, the response of maize yield to drought varied throughout the season, as the D_c increased from 97 mm for early drought to 157 mm for middle drought and was not reached (i.e., >338 mm) for the late drought treatments. This was probably a reflection of the relatively slow development of a very deep root system through the growing season. Once D_c was exceeded, the

Table 1. Range of potential soil moisture deficits and grain yields, critical deficits and yield response to drought for all crops.

Crop	D_{pmax}[a] (mm)		Grain yield (t/ha)		D_c[b] (mm)	Yield response to drought (kg/ha/mm)[c]
	Min	Max	Min	Max		
Barley	75	332	3.5	9.2	≤75	25
Maize	97	338	9.6	12.0	97 (early) 157 (mid) ≥338 (late)	11
Wheat	98	510	3.6	9.8	262	21

[a] Maximum potential soil moisture deficit
[b] Critical potential soil moisture deficit
[c] Above D_c

maize yield showed a substantially smaller response to drought than wheat or barley.

There was a considerable difference in the expression of yield variation between crops. In the barley and wheat, variation in yield was largely a reflection of grain number, whereas in the maize most of the yield variation was associated with grain size.