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Arable Update

Herbage: Issue 80

Irrigation management for perennial ryegrass seed crops

Background

This Herbage Update summarises three seasons of irrigation experiments investigating yield penalties from early versus late-season drought and identifying mechanisms to guide irrigation strategies for improved water-use efficiency.

Water stress is a major constraint for seed production on New Zealand's east coast, where evapotranspiration (ET) often exceeds rainfall from September to February. Under these conditions, soil moisture reserves decline rapidly, and when root-zone water cannot meet crop demand, wilting, leaf senescence, and tiller death occur. The timing of water deficit influences yield loss. Early-season drought during tillering and stem elongation reduces seed head numbers, while late-season drought, during flowering and seed fill, mainly affects seed development (Hebblethwaite, 1977). Water stress post flowering reduces photosynthesis, forcing reliance on stored carbohydrates (Rowarth, 1997). When reserves are insufficient, seeds fail to reach full size, lowering thousand-seed weight and marketable quality (Chastain *et al*., 2015).

Key points

- Around 220–320 mm of irrigation water increased seed yield of 'Grasslands Samson' by 520–1300 kg/ha across three seasons.
- In a single season trial, the later-flowering cultivar 'One50' needed about 97 mm more irrigation than 'Grasslands Samson' to achieve the same seed yield.
- Yield losses only occurred when the soil moisture deficit exceeded about 75 mm, no matter when the dry period (drought) happened.
- Applying 50–66% of evapotranspiration (ET) each week used less irrigation water but still kept soil moisture above the critical deficit level in all seasons by making better use of rainfall.
- In fully irrigated treatments, rainfall was commonly lost as drainage.
- Greater yields came from more seeds per square metre and heavier seed, compared with droughted (non-irrigated) plots.

Methods

Three field experiments were conducted over consecutive seasons (2009-10, 2010-11 and 2011-12) at the FAR Arable Site, Chertsey, Canterbury, New Zealand. Each trial was established on a new perennial ryegrass (*Lolium perenne* L.) stand sown during April in 15 cm rows at 8–10 kg/ha, with suSCon® Green (15 kg/ha; a.i. 100 g/kg chlorpyrifos) applied for grass grub (*Costelytra giveni*) control. 'Grasslands Samson' was grown in the first two seasons using a randomised complete block design, while season three included both 'Grasslands Samson' and 'One50' in a factorial design. Both cultivars are diploid ryegrasses with 'Grasslands Samson' having a mid-season heading date and 'One50' a heading date 18 days later. All seedlines sown contained the AR1 endophyte.

The soil was a Templeton silt loam with ~60 cm topsoil over free-draining gravel and a water-holding capacity of ~120 mm (Lilburne *et al*., 2012). Irrigation was applied via trickle tape between rows at 11 mm/hr, scheduled using potential soil moisture deficit (PSMD) calculated from evapotranspiration and rainfall, and verified by weekly neutron probe readings (0–60 cm). The profile was generally restored to field capacity during winter rainfall (Table 1). Management followed standard best practices with ~180 kg N/ha applied during spring, up to 2.4 L/ha Moddus (a.i. 250 g/L trinexapac ethyl) plant growth regulator applied for lodging control and a two-three spray fungicide programme implemented.

Harvest procedures were consistent across years where plots were windrowed at ~40% seed moisture and harvested 6–9 days later using a plot combine, except for the untreated plot in season two where direct combining occurred. Subsamples were machine-dressed to first-generation seed certification standards and expressed as kg/ha. Thousand seed weight was determined from 200 seeds weighed to three decimal places.

Potential ET (PET) was estimated using the Priestley–Taylor method (Jamieson, 1982), and the potential soil moisture deficit (PSMD) calculated by adding PET throughout the growing season while subtracting rainfall and irrigation with the maximum seasonal deficits recorded as MPSMD. Seed yield and component data were analysed by ANOVA, with significant differences (P<0.05) separated using LSD (Seabold and Perktold, 2010).

Table 1. Monthly rainfall and calculated potential evapotranspiration (PET) from sowing to harvest for three seasons, recorded at the FAR Arable Site, Chertsey, New Zealand.

	2009-2010			2010-2011			2011-2012		
Month	**Rain**	**PET[1]**	**Deficit[2]**	**Rainfall**	**PET**	**Deficit**	**Rainfall**	**PET**	**Deficit**
April	54	57	-3	32	59	-27	90	56	34
May	129	33	96	224	26	198	76	33	43
June	14	22	-8	92	19	73	35	23	12
July	33	30	3	40	25	15	12	34	-22
August	41	49	-8	112	31	81	46	45	1
September	21	76	-55	33	65	-32	47	77	-30
October	76	101	-25	28	112	-84	107	95	12
November	18	118	-100	52	144	-92	59	132	-73
December	38	135	-97	38	144	-106	50	144	-94
January 1-11	19	55	-36	14	68	-54	38	154	-116
Seasonal total	**443**	**676**	**-233**	**665**	**693**	**-28**	**560**	**793**	**-233**
Sept - harvest	**172**	**485**	**-313**	**165**	**533**	**-368**	**301**	**602**	**-301**

Note: [1] Monthly PET values calculated using the Priestly Taylor method. [2] Positive monthly deficit equals soil moisture recharge while negative monthly deficit results in soil moisture draw down.

Results and discussion

In season one, seed yield increased (P<0.05) from 1,997 to about 2,500 kg/ha when irrigation exceeded 205 mm (Table 2). Timing of drought, before or after anthesis, did not influence seed yield response with similar reductions (~500 kg/ha) occurring when water stress intensity was equal regardless of timing. The seed yield response was driven by increases in TSW.

In season two, irrigation lifted seed yield from 410 kg/ha in the control to 1,776 kg/ha under full irrigation, a fourfold increase. A minimum of 220 mm of irrigation was required to maximise seed yield, when efficient use of rainfall occurred.

Treatments replacing 66% of evapotranspiration (PET) achieved yields comparable to the full PET replacement treatments in both seasons (Table 2), largely due to extra soil capacity to capture and hold rainfall. The mechanisms responsible for seed yield increases were changes in the number of seeds reaching maturity (Figure 1) and TSW.

In season three, cultivar and irrigation treatment interacted such that overall, 'Grasslands Samson' outperformed 'One50' which matured later in hotter conditions and experienced increased drought intensity (Table 3, Figure 3). For example, both cultivars produced the same fully irrigated seed yield, but no irrigation reduced seed yield by 1,044 kg/ha in 'One50' versus 498 kg/ha in 'Grasslands Samson'. Maintaining the seed yield of 'One50' required ~97 mm of additional irrigation, equivalent to 20 extra days of PET replacement.

On average over three seasons, seed yield increased with irrigation up to 264 mm. However, the appropriate application rates varied by season and cultivar e.g. for 'Grasslands Samson' appropriate irrigation quantities ranged from between 219 to 323 mm depending on seasonal rainfall and ET (Figure 2).

The critical deficit (D_c) for this Templeton silt loam soil was identified as 75 mm, above which seed yield declined at 0.223%/mm or 4.7 kg/mm. Therefore on a warm summer day with a PET of 4.5 mm, each day above D_c costs $52/ha, at a seed price of $2.50. The seed yield decline was consistent among years and cultivars with increasing MPSMD, regardless of when drought occurred. The consistancy demonstrates that the timing of water stress was less critical than its severity (Figure 2B). Thus, the greater yield losses observed during post-anthesis drought (e.g. 'One50' Figure 3) were likely a consequence of higher daily PET during this phase of development, which caused D_c to be reached more rapidly, rather than greater sensitivity of perennial ryegrass to water stress during later developmental stages.

Similar results have been shown for wheat, barley and tall fescue (Huetting *et al*., 2013; Jamieson *et al*., 1995). Commonly D_c can be estimated as 50% of the available water content (Brown *et al*., 2010), for this Templeton silt loam with gravels below approximately 65 cm the available water content is approximately 120 mm (Lilburne *et al*., 2012) making D_c 63% of the available water content.

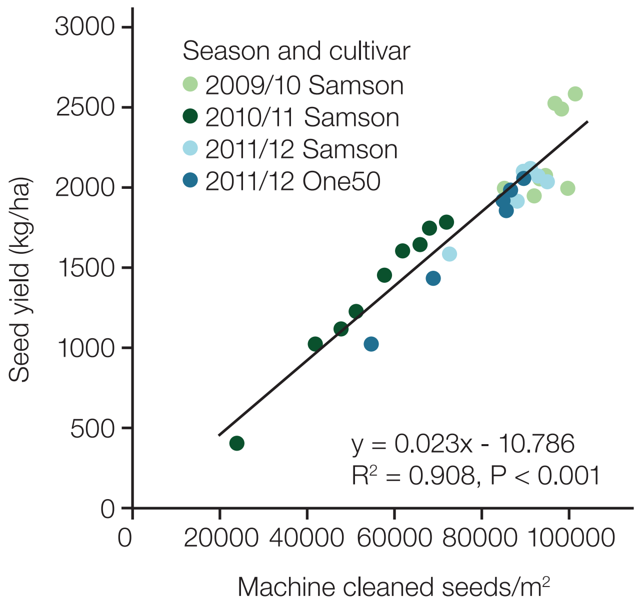

Figure 1. Seed yield response to the number of seeds per square metre for two perennial ryegrass cultivars grown over three seasons and treated with different irrigation quantities and timings near Chertsey, Canterbury, New Zealand between 2009 and 2012.

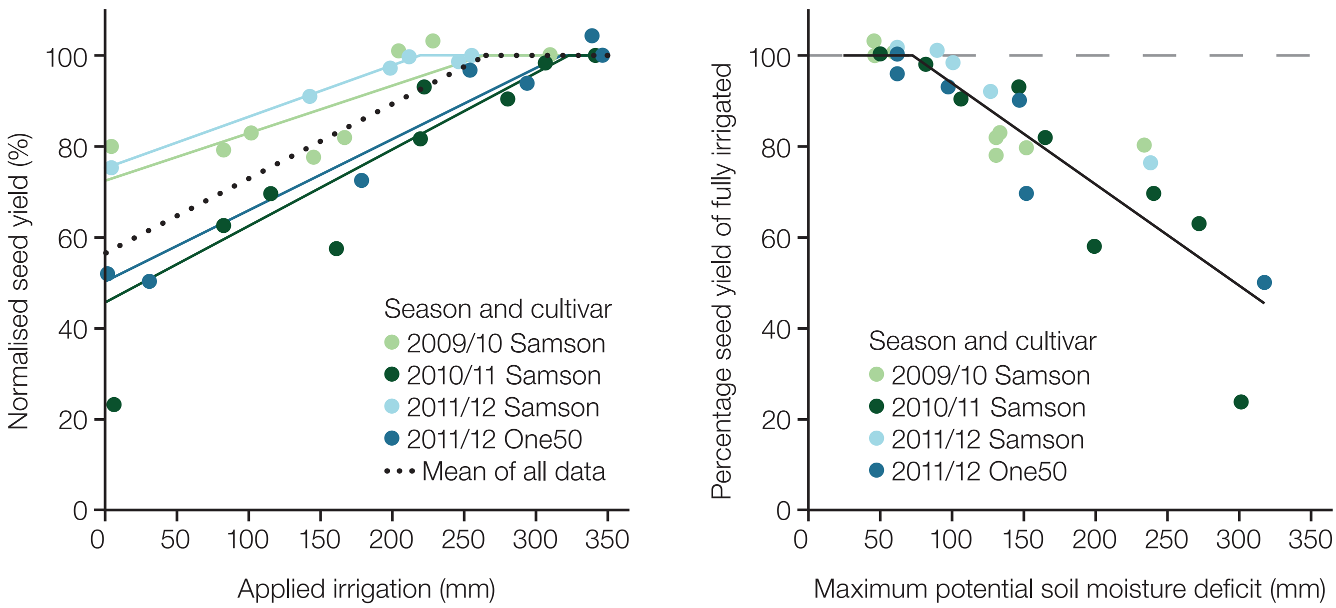

Figure 2.A. Normalised seed yield response of two perennial ryegrass cultivars following different irrigation treatments over three seasons and **B.** normalised seed yield response of two perennial ryegrass cultivars following different drought intensities expressed as maximum potential soil moisture deficit when grown near Chertsey, Canterbury, New Zealand between 2009-10 and 2011-12. Breakpoint = 75 mm (± 14), Slope = -0.223 (±0.026) %/mm additional deficit, seed yield at 100% is 2105 kg/ha, R^2 = 0.80.

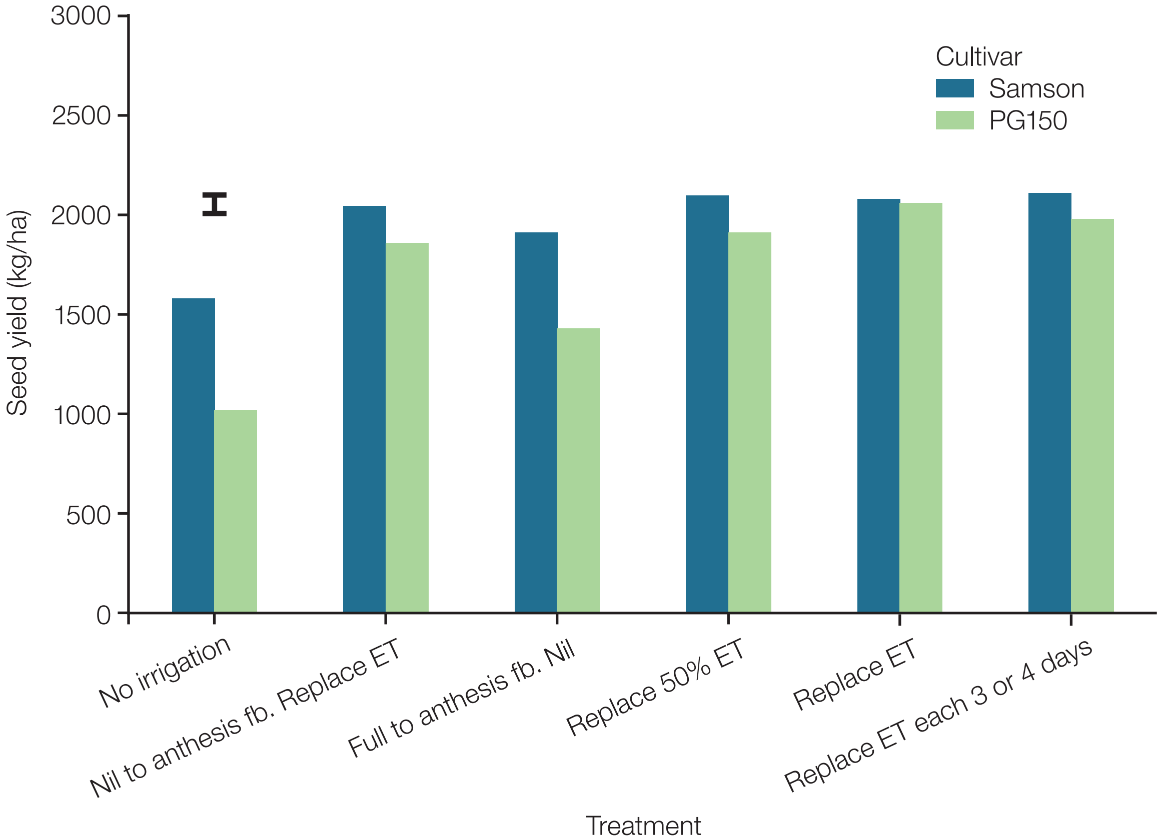

Figure 3. Seed yield of two perennial ryegrass cultivars in response to six irrigation treatments when grown at FAR Arable Site, Chertsey Canterbury, New Zealand in the 2011-12 growing season. Bar = the interaction LSD0.05 = 96.9.

Summary

On average over all three seasons, seed yield increased with irrigation up to 264 mm. However, the appropriate application rates varied by season and cultivar e.g. for 'Grasslands Samson' appropriate irrigation quantities ranged from between 219 to 323 mm depending on seasonal rainfall and PET. Deficit irrigation, replacing 50–66% of PET, gave the same seed yield response as full replacement of PET due to the ability of the soil to capture and hold rainfall, thereby keeping the soil moisture status above D_c. In fully irrigated treatments, rainfall was commonly lost as drainage when the soil profile was near field full.

References

Brown *et al*., 2010; Chynoweth *et al*., 2012; Chynoweth & Moot, 2017; Fereres & Soriano, 2007; Jamieson *et al*., 1995; Hebblethwaite, 1977; Rowarth *et al*., 1997.

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