Soil and air temperature and leaf development of spring wheat

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Introduction

- In wheat, development of the apical meristem and leaf appearance are coordinated.
- Hence, the development of the apical meristem in response to the environment can be monitored in terms of leaf appearance rate (or its inverse, the phyllochron).
- Leaf appearance rate depends on the temperature of the growing point (apical meristem) (Jamieson et al. 1995).
- When the rate is expressed in thermal time based on air temperature, a marked contrast is apparent between rates determined before and those determined after stem elongation begins.
- Until stem extension begins, the apical meristem is below the soil surface so that leaf appearance rates are controlled by soil temperature.
- Once stem extension begins, the apical meristem extends above the soil surface and leaf appearance rates are dependent upon canopy (plant) temperature.

Objective

- To demonstrate that a model of leaf appearance based on near-surface soil temperature before stem elongation and air temperature thereafter gives superior predictions than a model based on air temperature alone.

Methods

- Katepwa spring wheat was grown under dryland and irrigated conditions. Under irrigation, the soil profile was filled to field capacity before seeding and kept above 60% available water until the start of grain filling when further irrigation caused the crop to lodge.
- Leaf stages were determined using the Haun scale (Haun 1973).
- Duration of study: 1993, 1994, 1995. Location of study: SPARC< Swift Current, SK.
- Hourly soil temperatures at 1 and 10 cm depths were recorded under dryland and irrigation. Soil temperatures at 2.5 cm were interpolated from the 1 and 10 cm soil temperatures. Daily maximum and minimum air temperatures within a Stevenson screen were recorded at a nearby (within 200 m) meteorological site. Daily average soil and air temperatures were used to determine the relationships reported in this study.

Results

- For Katepwa, when the final leaf number of the main stem is 8, stem elongation begins at approximately the 4.5 to 5 leaf stage.
- During the seedling growth period, soil temperatures 2.5 cm deep were higher than air temperatures (accumulated differences between soil and air temperatures are increasing) (Figure 1). Soil temperatures were higher under dryland than under irrigation.
- For both dryland and irrigation, leaf appearance rates (slope of the relationship between Haun growth stage and accumulated thermal time) calculated using air temperature were significantly different from those calculated using soil and air temperatures (Table 1 and Figure 2).
- For dryland within a given year and for irrigation in 1993, when leaf appearance rate was expressed in thermal time based on air temperature, rates determined before and those determined after stem elongation began were significantly different (Table 1 and Figure 3). However, when the rate was expressed in thermal time based on soil and air temperatures, rates determined before and those determined after stem elongation began were not significantly different.
- For irrigation in 1994, whether using air temperature alone, or soil and air temperature together to calculate thermal time, rates determined before and after stem elongation began were

significantly different (Table 1). However, the differences between rates before and after stem elongation began were reduced by using soil and air temperatures compared to using air temperature alone.

Conclusions

- To minimize the contrast between leaf appearance rates determined before and those determined after the beginning of stem elongation, calculate thermal time using near-surface soil temperature before stem elongation and air temperature thereafter.
- We suggest leaf appearance models use temperatures near the apical meristem (near-surface soil temperature before the onset of stem extension, air temperatures thereafter) when simulating leaf growth and development.
- Further improvement in leaf growth simulation would likely occur if canopy temperature rather than air temperature was used after the beginning of stem extension.

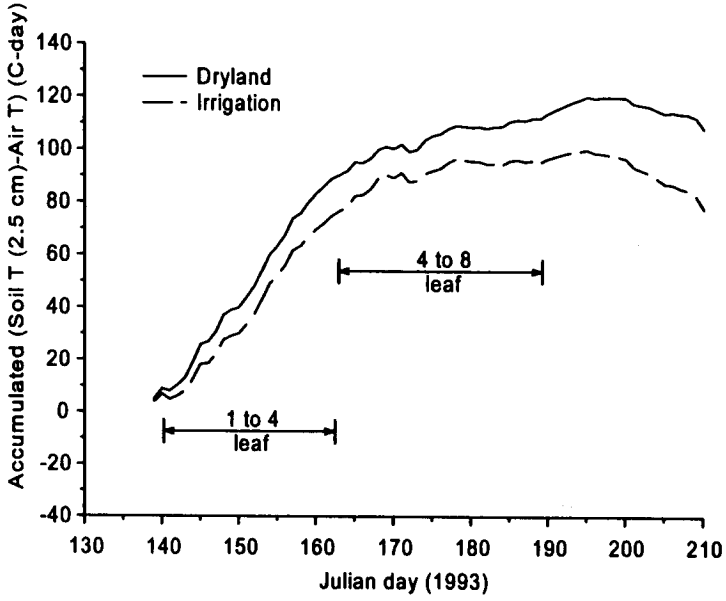
References

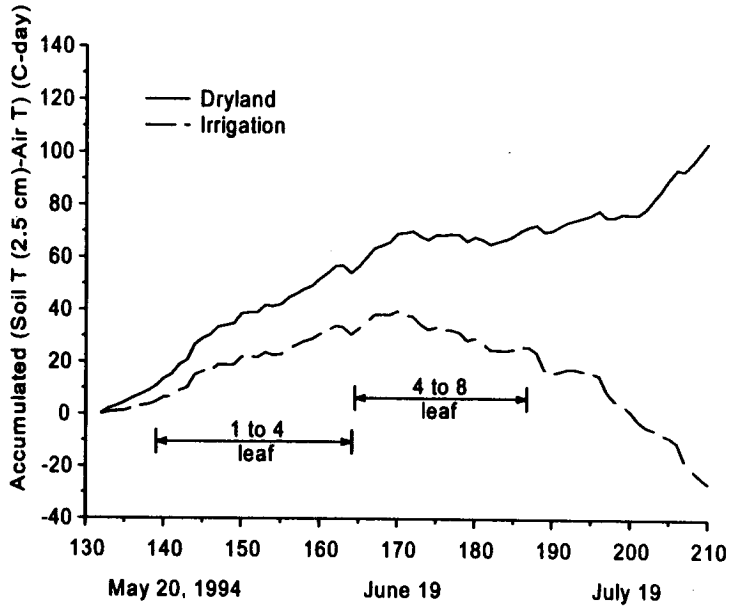
- Haun, J.R. 1973. Visual quantification of wheat development. Agron. J. 65116-l 19.
- Jamieson, P.D., Brooking, I.R., Porter, J.R. and Wilson, D.R. 1995. Prediction of leaf appearance in wheat: a question of temperature. Field Crops Res. 41:35-44.

Table 1: For dryland and irrigation, leaf appearance rates (LAR) (leaves C-day^{-1}) determined from the relationship of Haun leaf growth stage versus accumulated thermal time from seeding (C-day) based on air temperature (°C) alone and on soil temperature before stem elongation and air temperature thereafter. Se is standard error. Phyllochron (phyll) (C-day leaf^{-1}) is the inverse of LAR.

Year	Dryland				Irrigation ‡			
	Air Temperature		Soil & Air Temperature		Air Temperature		Soil & Air Temperature	
	LAR (se)	phyll	LAR (se)	phyll	LAR (se)	phyll	LAR (se)	phyll
	From first to last leaf							
1993	.0139 (.000338)	72	.0120 (.000211)	83	.0135 (.000281)	74	.0120 (.00017)	83
1994	.0122 (.000247)	82	.0116 (.000218)	87	.0117 (.000244)	85	.0113 (.0002)	88
1995	.0115 (.000255)	87	.0108 (.000181)	93				
	Before stem elongation began							
1993	.0150 (.000441)	67	.0119 (.00041)	84	.0147 (.000396)	68	.0115 (.000375)	87
1994	.0127 (.00062)	79	.0115 (.00054)	87	.0125 (.00037)	80	.0119 (.000337)	84
1995	.0119 (.00034)	84	.0107 (.00026)	93				
	After stem elongation began							
1993	.0119 (.000163)	84	.0119 (.000171)	84	.0118 (.000247)	85	.0117 (.000279)	85
1994	.0115 (.00062)	87	.0115 (.000624)	87	.0106 (.000408)	95	.0105 (.000408)	95
1995	.0106 (.00058)	94	.0107 (.000581)	94				

‡ - In 1995, the irrigated plots were damaged with herbicide.





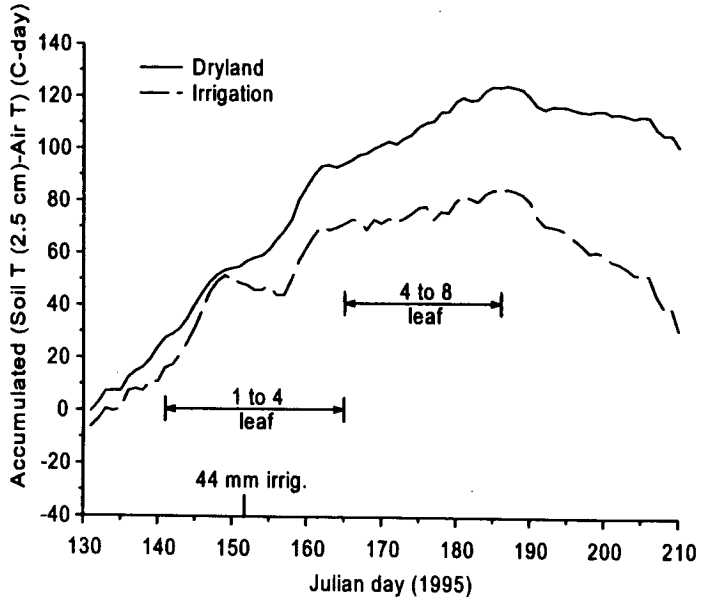


Figure 1: Accumulated differences of the average daily soil temperature (°C) at the 2.5 cm depth minus the average daily air temperature for dryland and irrigation in 1993, 1994 and 1995. When accumulated temperatures increase with Julian day, soil temperatures are greater than air temperatures; when thermal time decreases with Julian day, air temperatures are greater than soil temperatures.

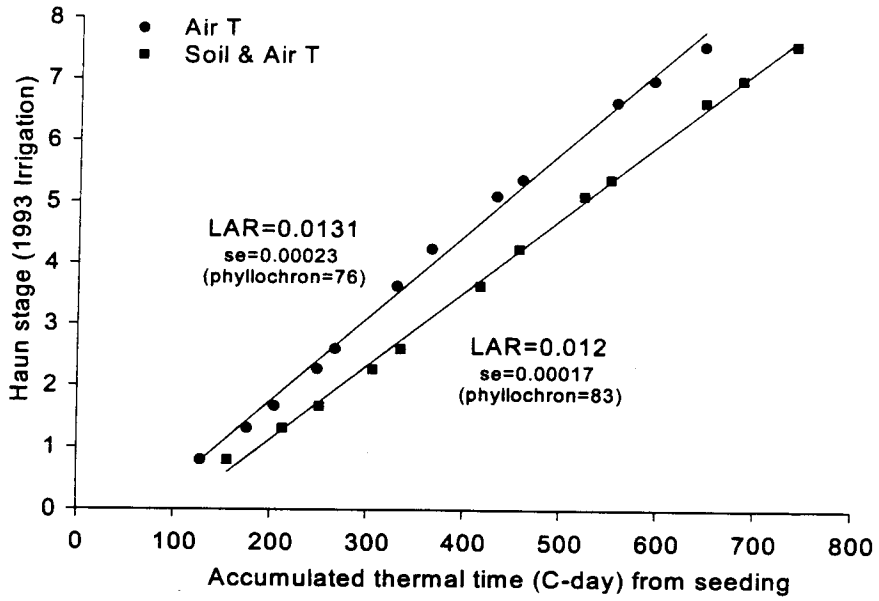


Figure 2: For irrigation in 1993, the relationship of the Haun leaf growth stage to accumulated thermal time from seeding based on air temperatures alone, and based on soil temperature before stem elongation and air temperatures thereafter. The slopes of the relationships are leaf appearance rates (LAR) (leaves C-day^{-1}). se is the standard error. Phyllochron is the inverse of LAR.

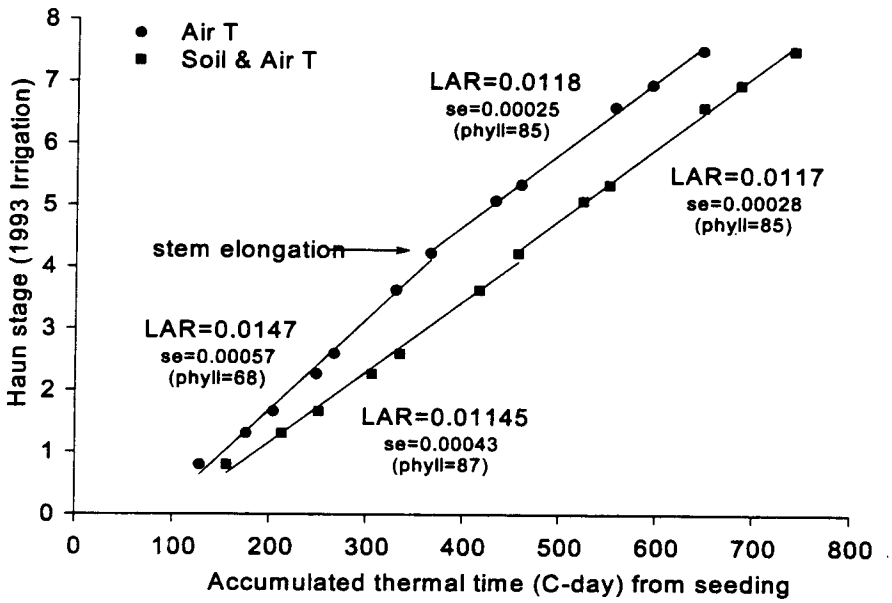


Figure 3: For irrigation in 1993, Haun leaf growth stage before and after stem elongation began as a function of accumulated thermal time from seeding based on air temperature (T) alone, and based on soil T before stem elongation and air T thereafter. The slopes of the relationships are leaf appearance rates (LAR) (leaves C-day^{-1}). se is standard error. Phyllochron (phyll) is the inverse of LAR.