SHORT COMMUNICATION

Availability of late-season heat and water resources for relay and double cropping with winter wheat in prairie Canada

Joanne R. Thiessen Martens and Martin H. Entz[1]

Department of Plant Science, University of Manitoba, 222 Agriculture, Winnipeg, Manitoba, Canada R3T 2N2.
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Thiessen Martens, J. R. and Entz, M. H. 2001. **Availability of late-season heat and water resources for relay and double cropping with winter wheat in prairie Canada**. Can. J. Plant Sci. **81**: 273–276. Long-term weather data for 21 sites across Manitoba, Saskatchewan and Alberta were analyzed to evaluate the availability of late-season heat and water resources between time of winter wheat maturity and freeze-up. Thermal time during this period ranged from 159 to 754 growing degree days; precipitation ranged from 42 to 152 mm. Southern Manitoba appears to be best suited to relay and double cropping. Southern Saskatchewan receives significant thermal energy; however, lack of precipitation may limit late season plant growth.

Key words: Legumes, no-till, cropping system intensity

Thiessen Martens, J. R. et Entz, M. H. 2001. **Disponibilité d'eau et de chaleur en fin de saison pour la double culture du blé d'hiver dans les Prairies canadiennes**. Can. J. Plant Sci. **81**: 273–276. Les auteurs ont analysé les données météorologiques à long terme de 21 endroits au Manitoba, en Saskatchewan et en Alberta afin d'établir s'il y avait assez de chaleur et d'eau en fin de saison pour amener le blé d'hiver à maturité avant la prise de la glace. Le temps thermique à cette période de l'année varie de 159 à 754 degrés-jours de croissance, tandis que les précipitations fluctuent de 42 à 152 mm. Le sud du Manitoba semble se prêter le mieux à la double culture. Le sud de la Saskatchewan reçoit assez d'énergie thermique, mais la rareté des précipitations pourrait nuire à la croissance des plantes en fin de saison.

Mots clés: Légumineuse, culture sans labour, intensité du système cultural

Relay and double cropping systems are used traditionally in places that have a growing season long enough to grow two grain crops in one season, commonly a winter cereal and a warm-season crop such as soybeans (*Glycine max* L. Merr). Although these systems have been adapted successfully to areas with somewhat shorter growing seasons (Moomaw and Powell 1990), there has been little research on the feasibility of relay and double cropping on the Canadian prairies.

The choice of crops is important in the development of a relay or double cropping system feasible for an area with a short growing season. Although crop production in western Canada has traditionally been dominated by spring-seeded cereals and oilseeds, winter wheat has recently gained popularity due to the development of improved cultivars and the use of zero-tillage seeding systems. In 2000, winter wheat was harvested on 51 000 ha in Manitoba, 59 000 ha in Saskatchewan, and 25 500 ha in Alberta (Winter Cereals Canada, Yorkton, SK; D. Struthers, personal communication). Production of this early-maturing crop leaves a relatively large span of time after harvest in which accumulating heat and light resources are not used for crop growth. This window of time is not long enough for a second grain crop to reach maturity, as in traditional multiple cropping systems; therefore, the second crop in multiple cropping systems in the Canadian prairies must be able to provide a product or service of value in a short time. The well-documented benefits of including legumes in grain rotations, even single-year hay (Kelner and Vessey 1995) or green manure (Biederbeck et al. 1996) crops, suggest that legume cover crops grown for only part of the season may be able to provide significant benefits to the cropping system, and thus may be a good choice as the second crop in a multiple cropping system.

The benefits of relay and double cropped legumes are closely linked to the amount of plant growth; therefore, heat and water resources available to a crop growing during the latter part of the season are critically important. Late-season resources are important even in relay cropping systems, since little growth and development occurs in the second crop until after first crop harvest. However, once established, legumes such as alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) are able to produce signifi-

[1]*To whom correspondence should be addressed (e-mail: m_entz@umanitoba.ca).*

Abbreviations: **GDD**, growing degree day cant amounts of dry matter in a relatively short period of time (Thiessen Martens et al. 2001). Kelner and Vessey (1995) observed that aboveground dry matter accumulated by alfalfa increased from approximately 200 kg ha^{-1} to approximately 900 kg ha^{-1} over a 2-wk period beginning 1 mo after planting. Several species of spring-seeded green manure legumes have been observed to reach full bloom in 6 to 7 wk, accumulating 500 to 3600 kg ha^{-1} dry matter during this time with 73 to 210 mm precipitation (Biederbeck et al. 1993). Thiessen Martens et al. (2001) observed dry matter accumulation of up to 1800 kg ha^{-1} by red clover relay cropped with winter wheat in southern Manitoba. Thus, the possibility exists that forage and green manure legumes grown after harvest of winter wheat could also produce significant amounts of dry matter, and thus contribute considerable amounts of nitrogen to the system. Implementation of a double cropping system, in which legumes are seeded after first crop harvest in mid-summer, is also dependent on the germination conditions (i.e., moisture availability) at the time of double crop seeding. Since production of the first crop may have depleted much of the soil water, moisture availability may depend mainly on rainfall during this time.

Given the importance of late-season heat and water resources to the feasibility of relay and double cropping, the objective of this study was to evaluate the potential of relay and double cropping systems for various locations in the Canadian prairies based on the availability of these resources, and thus identify the geographic areas in which potential for multiple cropping systems exists.

Long-term weather data for 21 sites across Manitoba, Saskatchewan, and Alberta (Environment Canada 1999) were used in the analysis. Sites were chosen based on their geographic location and on the availability of long-term weather data. Data from 1959 through 1998 was used in the analysis. Years in which more than two daily temperature values were missing from the data for 1 April through 31 October for any particular site were eliminated from the analysis. Sample sizes for each site are shown in Table 1.

In this study, only the thermal time requirements in the reproductive year of winter wheat were considered. Since this portion of the thermal time requirements of winter wheat is not generally discussed in the literature, the growing degree day (GDD) requirement used in this study was calculated from empirical observations in a related study. Based on data from two sites in southern Manitoba over 2 yr, a thermal time requirement for winter wheat of 1173 GDD with a base temperature of 5°C was calculated (Entz, unpublished). This figure is similar to GDD requirements for spring wheat (Wong and Baker 1986), which has been observed to have similar thermal time requirements to winter wheat in the time from tillering to maturity (Entz and Fowler 1991), and thus was assumed to have similar total GDD requirements for the whole reproductive year. No adjustment for the effects of daylength (photoperiod) on thermal time requirements for winter wheat maturity was made in the present study.

Using spreadsheet software, expected values were calculated for key parameters relating to relay and double cropping with winter wheat. The date of first crop harvest in each year was calculated by summing the GDDs accumulating from 1 April until reaching the 1173 GDD requirement for winter wheat. The thermal time available for post-winter wheat maturity plant growth was calculated by summing the GDDs accumulating after the date of winter wheat maturity until 31 October, without adjustment for the occurrence of frost. A preliminary study on the effects of late-season cover crops on the microclimate indicated that a red clover cover crop caused moderation of surface air temperatures and thus delayed the occurrence of a killing frost at 5 cm above the soil surface by 60 d (Thiessen Martens et al. 2001). Therefore, observation of below freezing temperatures at "Stevenson screen height" may not accurately reflect the end of the growing season for late-season cover crops. Other field studies in Manitoba have shown that double cropped chickling vetch (*Lathyrus sativus* L.) and Indian Head lentil (*Lens culinaris* Medikus) had levels of late-season frost tolerance similar to relay cropped red clover, and greater than relay cropped alfalfa (Entz and Bamford, unpublished). Nevertheless, additional research is required to determine the frost tolerance of potential relay and double crops for western Canada.

Precipitation was summed for the time period between winter wheat maturity and 31 October as a measure of the moisture available to a late-season cover crop. Germination conditions for double crops were evaluated by summing the precipitation received in the 15 d following winter wheat harvest. In cases where the date of winter wheat maturity occurred less than 15 d before 31 October, the precipitation occurring between winter wheat maturity and 31 October was used. Long-term averages and 75% probabilities were then calculated for all parameters.

Mean winter wheat maturity dates ranged from 3 August to 13 September for the sites included in the analysis (Table 1). Seventy-five percent probabilities for winter wheat maturity were 4 to 9 d later than the means. Morden, Portage la Prairie, and Glenlea, MB, had the earliest expected maturity dates, followed closely by several other sites across southern Manitoba as well as Regina, SK. Winter wheat matured latest at Calgary and Lacombe AB and matured relatively late at more northern sites in Saskatchewan and Manitoba. If the effect of daylength was considered, maturity dates for winter wheat at more northern sites could be earlier than those predicted by this analysis.

Of the total thermal time accumulated between 1 April and 31 October, 12 to 39% occurred after winter wheat maturity (Table 1). Nine of the 21 sites received approximately 550 GDDs or more after winter wheat harvest on average. This figure has been observed to be the GDD requirement for Indianhead black lentil to reach full bloom, the stage considered green manure maturity (Aase et al. 1996). Chickling vetch has been observed to reach this stage up to a week earlier than black lentil (Biederbeck et al. 1993). Sites with this level of late-season GDD accumulation were consistently located in the southern parts of the prairie provinces. South-central Manitoba appeared to be the only area that could expect this amount of late-season thermal time in 3 out of 4 yr. Sites receiving the lowest

Table 1. Means, standard deviations and 75% probabilities for parameters related to the availability of resources for relay and double cropping after winter wheat crop maturity at 21 sites across prairie Canada

		Date of winter wheat maturity (DOY[z])			Late-season thermal time[x]					Late season precipitation[w] (mm)			Precipitation 15 d after winter wheat maturity[v] (mm)		
					Mean			75% prob.							
Location	Sample size (yr)	Mean	SD	75% prob.	GDD[y]	% of total	SD	GDD	% of total	Mean	SD	75% prob.	Mean	SD	75% prob.
Manitoba															
Steinbach	39	223	9	229	558	32	151	461	28	150	63	104	38	32	13
Morden	39	215	8	219	754	39	156	662	36	152	77	87	30	36	14
Glenlea	26	219	10	223	617	34	156	536	31	144	59	103	27	24	9
Arborg	35	232	12	239	370	24	139	291	20	118	63	84	32	22	15
Portage la Prairie	39	218	9	224	606	34	139	532	31	115	171	99	32	31	8
Ninette	40	222	9	226	579	33	151	484	29	106	155	76	39	38	13
Brandon	39	223	8	228	546	32	148	446	28	117	56	77	28	27	9
Dauphin	36	228	10	233	447	28	141	376	24	120	67	70	29	33	3
Pierson	33	220	8	224	609	34	152	513	30	120	56	69	26	22	10
Russell	40	234	12	239	349	23	132	255	18	100	52	53	31	29	12
Saskatchewan															
Yorkton	40	231	11	235	392	25	130	320	21	97	49	66	28	30	9
Nipawin	32	235	12	239	310	21	128	251	18	94	40	59	29	22	11
Saskatoon	40	226	9	231	468	29	142	365	24	73	36	44	18	16	5
Broadview	40	233	10	238	366	24	136	276	19	63	165	50	24	26	6
Regina	40	223	8	227	539	31	138	437	27	82	37	60	18	15	5
Swift Current	40	227	8	232	503	30	141	403	26	66	31	43	17	12	7
Kindersley	40	227	8	232	458	28	133	371	24	59	30	37	17	12	7
Alberta															
Lethbridge	40	226	7	228	566	33	120	496	30	84	48	48	21	23	3
Calgary	40	250	14	254	232	17	111	140	11	52	36	24	21	15	9
Lacombe	38	256	17	265	159	12	100	76	6	42	30	19	19	17	7
Edmonton	40	229	7	234	423	27	116	333	22	93	42	66	29	23	14

[z]DOY (day of year) conversion 91 = April 1, 105 = April 15, 121 = May 1, 135 = May 15, 152 = June 1, 166 = June 15, 182 = July 1, 196 = July 15, 213 = August 1, 227 = August 15, 244 = September 1, 258 = September 15.
yGrowing degree days above a base temperature of 5°C.
xThermal time after harvest of winter wheat.
wPrecipitation after harvest of winter wheat.
vPrecipitation in 15 d after winter wheat maturity, or before 1 November, whichever occurs first.
SD = standard deviation.

amounts of late-season thermal time were those located farther north, or near a source of climate moderation (i.e. Manitoba's Interlake, and Alberta's foothills).

Late-season precipitation generally decreased from east to west, and was related to the date of winter wheat maturity to some degree. Western Saskatchewan and central Alberta received the lowest amounts of rainfall, and southeastern and south-central Manitoba received the most. Variability between years was considerable, with 75% probability values up to 65 mm lower than averages, and very high standard deviations in some cases (Table 1). Steinbach and Morden, MB, were the only sites that received at least 150 mm of rainfall on average, which is the level of evapotranspiration observed in a black lentil green manure crop producing 2000 kg ha^{-1} of dry matter from the time of seeding to full bloom (Aase et al. 1996). All of the Manitoba sites received at least 100 mm of late-season precipitation on average. Based on an evapotranspiration efficiency of 9.0 to 12.5 kg ha^{-1} mm^{-1} (Bonner 1997), an alfalfa relay crop at these sites should be able to produce 900 to 1250 kg ha^{-1} of dry matter, given sufficient thermal time. The distribution of late-season precipitation is also an important factor in determining the effectiveness of the precipitation. However, this parameter was not considered in this study.

Precipitation 15 d after winter wheat maturity (i.e., germination conditions for double crops) was extremely variable between years for all sites. No information was available on minimum water requirements for legume germination, and so a value of 15 mm precipitation was assumed. In general, sites in Manitoba received the most precipitation during this time, however 75% probabilities were 15 mm or lower for all locations. Because of the extreme variability in moisture conditions at this time of year, analysis of long-term weather data cannot provide much useful information as to the suitability of double cropping to a particular geographic location. Instead, decisions to plant a double crop after winter wheat harvest should be based on actual moisture conditions at that time, as well as the thermal time availability.

South-central Manitoba appears to be the best-suited to the implementation of relay and double cropping systems involving winter wheat. Average late-season heat and water resources appear sufficient for legumes to accumulate significant amounts of dry matter. Southwestern Manitoba and southern Saskatchewan receive sufficient amounts of late-season thermal time, but precipitation during this time period is low. Therefore, only certain parts of the landscape may be suitable to such a system, and soil water conservation techniques such as no-till would be very important. Such systems may also fit in years where considerable recharge of soil water occurs before winter wheat maturity. Selection of drought-tolerant legume genotypes may broaden the possibilities for relay and double cropping in these areas. Northern and western regions of prairie Canada lack the thermal time required for conventional relay and double cropping systems with winter wheat. Shorter-season crops such as cereal silage or fall rye (*Secale cereale* L.) grain crops may facilitate late-season cover cropping in these regions.

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