Crop Rotation for Successful Winter Wheat Production

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Abstract

Successful production of winter wheat on most of the Canadian prairies requires direct seeding into standing stubble of the previous crop. Crop rotation is often seen as a limiting factor to the expansion of winter wheat acres in this system as the previous crop needs to be harvested early enough to allow winter wheat to be seeded by late August or early September, depending on location. This project was initiated with the objective of developing a practical tool to assist farmers in selecting seeding dates for several spring crop species so that winter wheat can be planted during the optimum period for fall establishment. Degree-days, or heat unit requirements, to produce a physiologically mature crop were determined for Polish canola, barley, oat, mustard, Argentine canola, hard red spring wheat, and flax. Daily climate data was then used to determine the probability of the crops reaching physiological maturity by specific dates in the fall when they were sown between May 1 and June 9 at selected locations in western Canada. Future plans are to expand the number of sites to include over 9,000 station years of weather data so that risk maps and fact sheets with tables can be produced to assist farmers in planning rotations for winter wheat. While the initial objective of this project has focused on winter wheat production, there are a large number of additional uses for this type of management tool.

Introduction

In western Canada, a high frequency of winterkill makes winter wheat sown into conventionally tilled seedbeds an unacceptably high-risk crop outside of the chinook belt in south-western Alberta. No-till or direct seeding of winter wheat into standing stubble from a previous crop (stubbling-in) has proven to be a successful method of reducing the risk of winterkill. During the winter the standing stubble traps snow that keeps soil temperatures warm enough to allow over wintering of winter wheat throughout the prairie region. When snow is maintained uniformly on winter wheat fields by snow trapping in standing stubble, a large area in western Canada has a winterkill risk level as good or better than the traditional production area in south-western Alberta (Savdie et al., 1991).

The production of stubbled-in winter wheat is straightforward and simple, but it does require adjustments to the production systems that are commonly use by most prairie farmers. The most difficult adjustment has been the need to have a standing stubble field available early enough to allow winter wheat to be seeded by August in the north and early September in the south of the agricultural area of Saskatchewan. While this may appear to be a small adjustment, the production system for stubbled-in winter wheat often requires a major change in management philosophy for farmers. Surveys have shown that western Canadian farmers have had great difficulty inserting winter wheat into their rotations and this step has become the factor most limiting the growth of winter wheat acreage. This project was initiated with the objective of developing a practical tool to assist farmers in selecting seeding dates for several spring crop species so that they can successfully integrate winter wheat into their production systems.

Materials and Methods

Crop growth and development is often described in terms of time, e.g., 60-day barley, frost-free days, heading date, etc. However, it is temperature and not time that plays the major role in determining rate of plant growth and development. The time/temperature relationship that governs plant growth and development is known as thermal time and it is measured in heat units or growing-degree days. Large variations in temperature exist from day to day and growing season to growing season. The use of thermal time rather than calendar time takes this variability into consideration and provides an explanation for differences in crop maturity when observations from different years are compared.

In the present study, daily degree-days (DD) or heat units were calculated using a base temperature of 5^oC and average daily temperature, i.e., daily DD = [(daily minimum + maximum temperature)/2 - 5]. The total growing degree-days (GDD) estimated to produce a physiologically mature (25 to 30 percent seed moisture = ready to swath) crop were as follows: Polish canola and barley = 850, oat = 961, mustard = 1004, Argentine canola = 1040, hard red spring wheat = 1175, and flax = 1200. Dr. Guy Lafond, Agriculture and Agri-Food Canada, Indian Head provided the GDD values for flax. Barley, oat, mustard and hard red spring wheat GDD were determined from Crop Development Centre research trials. Manitoba Agriculture provided the GDD for *Brassica rapa* (Polish) and *Brassica napus* (Argentine) canola. These are average values for each species and it should be noted that varietal differences can also be accommodated in the models.

Environment Canada daily climate temperature data base (Environment Canada, 1999) was used to determine the probability of physiological maturity (25 to 30 percent seed moisture) for Polish and Argentine canola, mustard, barley, hard red spring wheat, and flax sown between May 1 and June 9. Climate stations with greater than 30 years of records were selected for the Prairie region of Canada. This translated into 179 stations with an average of 52 years of record, some extending back as far as 107 years. The Eastern Cereal and Oilseed Research Centre of Agriculture and Agri-Food Canada supplemented missing records with data from the nearest active station (Eastern Cereal and Oilseed Research Centre, Land and Agronomy Section, Ottawa, Ontario. Daily Climate Archive). This infilling of missing data was required for the modeling needs of Agriculture and Agri-Food Canada and provided a continuous time series for GDD calculations. Accumulated DD were then determined for each year at each location for a range of spring seeding dates. The date that the accumulated GDD equalled the GDD requirement for each crop species to reach physiological maturity was then determined for a range of seeding dates for each year at each location for which weather data was available. Physiological maturity was assumed to have been reached when the accumulated DD equaled the predetermined GDD for the crop species being considered.

Data for each station were imported into Microsoft Access 2000 where GDD were calculated and accumulated for each season of the historical record. The resultant accumulations for each station were then queried given an assumed seeding or harvest date and the GDD requirement of a specific crop. The query outputs the probability of reaching a specified GDD target based on the historical trend. Multiple iterations of the query were used to assemble a probability matrix that represented the range of plausible seeding and harvest dates for a given station and crop type. Multiple stations can also be imported and summarized to compare the relative risk of a cropping scenario for a number of locations across the prairies.

Results and Discussion

Winter wheat survives the winter in the seedling stage. To attain maximum cold tolerance and to provide optimum energy reserves for the following spring, healthy vigorous plants must be established before freeze-up. In addition to influencing winter survival, stage of plant development prior to the onset of winter is of considerable importance in determining agronomic performance the following growing season. Seeding too early often results in a yield reduction and smaller seed size. Seeding too late usually results in a significant yield reduction, delayed heading, later maturity, reduced bushel weight and increased problems with weeds. For this reason, seeding date has a large influence on the degree of success that can be achieved in the production of stubbled-in winter wheat. Plants that enter the winter with well-developed crowns (area at the base of the shoot from which secondary roots develop) are most desirable. However, plants with 2 to 3 leaves by freeze-up are not usually disadvantaged.

Table 1. Optimum date for direct seeding winter wheat into standing stubble (Fowler 1983).

Location	Date
1. Lethbridge, AB	September 9
2. Maple Creek/Estevan, SK	September 6
3. Kindersley/Swift Current, SK	September 3
4. North Battleford/Saskatoon/Wynyard/Yorkton, SK	August 30
5. Meadow Lake/Prince Albert/Nipawin, SK	August 27

The main factor dictating seeding date is fall soil temperature. For this reason, optimum seeding dates differ among production areas in western Canada (Table 1). In general, optimum-seeding date is approximately a one-month window that is centered on September 9 in southern Alberta and August 27 along the northern fringe of the western Canadian agricultural region. Because of the requirement for standing stubble, winter wheat is better suited to rotations that include early maturing spring crops. Consequently, rather than leaving decisions until after harvest, winter wheat production requires forward planning to increase the probability of having standing stubble available during the optimum period for planting.

The management tool this paper outlines was developed to assist farmers in planning rotations and fine tuning their spring planting decisions. Just as the optimum seeding date for winter wheat varies with regions in western Canada, variation in the length of the growing season has a strong influence on the cropping options available to winter wheat growers (Table 2). Farmers in regions with lower GDD accumulations have fewer cropping options and they have greater pressure to seed their spring crops early if they want to include winter wheat in their rotation.

Table 2. Probability (%) of crop reaching physiological maturity by August 25 when seeded on May 15.

Site	Polish canola & Barley	Oat	Mustard	Argentine canola	Hard red spring wheat	Flax
Morden	100	100	100	100	90	90
Gravelbourg	100	100	96	96	80	74
Wynyard	100	97	88	88	35	29
Nipawin	100	95	95	88	33	17
Prince Albert	100	91	82	72	21	14

We have chosen Prince Albert and Gravelbourg in Saskatchewan as examples to illustrate how differences in growing season can influence the winter wheat growers choices of crops and management systems. A longer growing season at Gravelbourg means that early seeded flax (Table 3) is a good option for winter wheat growers and when spring seeding is delayed they can always fall back on barley or Polish canola (Table 4). In contrast, farmers in the Prince Albert area have fewer options. Even the earliest seeding dates give them less than a 50 percent chance of harvesting flax (Table 5) in time to seed winter wheat during the optimum period and Argentine canola (Table 6) would have to be seeded early to be an option most years. Early seeded Polish canola and barley (Table 7) are the most reliable choices but a lack of acceptable cultivars has meant that Polish canola it is no longer an attractive option to farmers.

The speed at which the mature spring crop is removed from the field is also an important factor in achieving winter wheat seeding date targets. We have suggested that seven to 14 days after physiological maturity will be required to allow time for the crop to dry down to safe moisture levels for storage (Tables 1 to 7). Experienced winter wheat growers often make extensive use of aeration grain drying to permit prompt removal of the previous crop from the field. A little preparation before the start of seeding, such as making sure that the drill is in good repair and that fertilizer and clean seed are available, can also eliminate many frustrations during this critical harvest and seeding period.

Table 3. Seeding and maturity dates for flax at Gravelbourg. Add 7 to 14 days for harvest date.

Seeding Date	Probability (%) of Maturity by									
	August						September			
	05	10	15	20	25	30	04	09	14	19
01-May	4	15	46	74	81	94	96	98	100	100
05-May	4	7	41	70	81	93	96	96	100	100
10-May	4	4	24	61	81	88	93	94	96	96
15-May	2	4	9	48	74	86	89	93	96	96
20-May	2	4	4	26	63	80	89	93	93	94
25-May	0	2	4	11	37	74	80	89	90	93
30-May	0	0	2	4	17	44	72	80	89	91
04-Jun	0	0	0	2	7	22	48	72	80	89
09-Jun	0	0	0	0	4	7	26	44	67	72

Table 4. Seeding and maturity dates for barley and Polish canola at Gravelbourg. Add 7 to 14 days for harvest date.

Seeding	Probability (%) of Maturity by									
	August						September			
Date	05	10	15	20	25	30	04	09	14	19
01-May	98	98	100	100	100	100	100	100	100	100
05-May	96	98	100	100	100	100	100	100	100	100
10-May	96	98	98	100	100	100	100	100	100	100
15-May	96	96	98	100	100	100	100	100	100	100
20-May	89	96	96	100	100	100	100	100	100	100
25-May	78	93	96	100	100	100	100	100	100	100
30-May	61	87	93	98	100	100	100	100	100	100
04-Jun	31	76	89	96	100	100	100	100	100	100
09-Jun	6	33	80	91	96	100	100	100	100	100

Table 5. Seeding and maturity dates for flax at Prince Albert. Add 7 to 14 days for harvest date.

Seeding	**Probability (%) of Maturity by**									
	August						**September**			
Date	05	10	15	20	25	30	04	09	14	19
01-May	0	2	6	14	33	49	65	77	87	88
05-May	0	2	6	12	25	44	64	71	80	87
10-May	0	1	4	7	21	38	59	68	74	81
15-May	0	0	2	6	14	30	48	62	68	77
20-May	0	0	1	2	8	22	34	47	62	66
25-May	0	0	0	1	5	12	28	37	45	54
30-May	0	0	0	0	0	5	17	27	33	43
04-Jun	0	0	0	0	0	0	5	15	22	30
09-Jun	0	0	0	0	0	0	1	4	11	18

Table 6. Seeding and maturity dates for Argentine canola at Prince Albert. Add 7 to 14 days for harvest date.

Seeding	**Probability of Maturity by**									
	August						**September**			
Date	05	10	15	20	25	30	04	09	14	19
01-May	9	25	55	74	87	93	98	100	100	100
05-May	6	20	49	70	84	91	98	100	100	100
10-May	5	14	39	64	76	88	95	98	99	100
15-May	3	10	33	57	72	83	90	95	96	99
20-May	2	5	16	45	63	77	88	92	96	98
25-May	0	2	8	26	51	69	78	90	91	95
30-May	0	0	4	12	31	53	68	83	88	90
04-Jun	0	0	1	4	16	34	53	70	81	87
09-Jun	0	0	0	1	5	17	32	49	63	70

Table 7. Seeding and maturity dates for Polish canola and barley at Prince Albert. Add 7 to 14 days for harvest date.

Seeding	Probability (%) of Maturity by									
	August						September			
Date	05	10	15	20	25	30	04	09	14	19
01-May	83	94	100	100	100	100	100	100	100	100
05-May	79	93	100	100	100	100	100	100	100	100
10-May	73	87	99	100	100	100	100	100	100	100
15-May	58	83	97	100	100	100	100	100	100	100
20-May	49	78	88	99	100	100	100	100	100	100
25-May	32	60	83	95	100	100	100	100	100	100
30-May	12	40	74	89	98	100	100	100	100	100
04-Jun	4	20	51	75	90	99	100	100	100	100
09-Jun	2	4	26	61	77	92	97	98	99	100

So far, the management tool has been developed for selected sites in western Canada but the plan is to expand the number of sites to include the entire database. Risk maps and fact sheets with tables will be produced for a cross section of sites once the database has been evaluated. If there is interest and funding can be found, an interactive Internet site or CD-ROM will also be developed so producers can evaluate various what if scenarios.

This project was initiated with the objective of developing a practical tool to assist farmers in selecting seeding dates for several spring crop species so that winter wheat can be planted during the optimum period for fall establishment. However, there are a large number of additional uses for this type of management tool.

1. Planning crop rotations to optimize or maximize the use equipment, manpower and growing season opportunities.

2. Estimating how late farmers can seed and still have a reasonable chance of harvesting a quality crop on years where very wet conditions delay spring seeding.

3. Identifying regional differences in the risk of killing frosts during the growing season.

4. Risk assessment for crop insurance and economic planning.

5. It could be expanded to include a wide array of weather related variables such as the probability of rainfall, snowfall, etc. These variables could then be used in to predict likelihood of adequate soil moisture for germination of fall-seeded crops, delays in harvest, risk of grade loss, etc., on a regional basis.

6. Real time models could be incorporated into the system to assist in the risk assessment of damage from diseases and insects, low temperature damage to winter crops, growing season injury to chill sensitive horticultural crops, etc.

7. Identifying growing season limitations for plant breeders interested in developing cultivars with regional adaptation.

8. Evaluation of long term weather trends and the effect of climate change as they relate to crop production.

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