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Assessing the Winter Hardiness of Perennial Cereal Rye Relative To Winter Cereals Traditionally Grown in Western Canada.

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Abstract

Perennial cereal (PC) rye (*Secale cereale* x *S. montanum*) is reported to be a three to four year perennial forage crop. At AAFC-Swift Current, SK, PC rye was compared to three winter triticale varieties (Pika, Prego, and Bobcat), CDC Clair winter wheat and Prima fall rye for winter hardiness. Small plots were seeded at six dates (July 18, Aug. 3, Aug. 16, Aug. 30, Sept. 7, and Sept. 17) in 2001, with a defoliation treatment occurring during the first week of October. When compared to the winter cereals for winter survival under field conditions, PC rye was tied for second for a mid-July seeding date, and tied for first for early and mid-Aug. seeding dates. PC rye survival was not different (P>0.05) between varieties for late Aug. and Sept. seeding dates. Results found the optimum time to plant PC rye to ensure maximum winter hardiness was mid-to-late Aug. PC rye was sensitive to late-fall defoliation with the greatest survival reduction occurring for the mid-July seeding date.

Introduction

Perennial cereal (PC) rye is a new forage crop in western Canada. It is an interspecific hybrid derived from crossing cultivated rye (*Secale cereale* L.) and a wild perennial ryegrass (*S. montanum* Guss.) that grows well in southern Europe and central Asia, and then back-crossing with *S. cereale* (Acharya 2001).

To date, PC rye has not yet been widely available for commercial production due to the recent release of the variety, AC E-1. Kenneth C. Long Seeds of Spring Coulee, AB will market AC E-1 under a licensing agreement as soon as sufficient seed is available.

Preliminary research at the Semiarid Prairie Agriculture Research Station found PC rye's winter-hardiness a concern because it was not able to survive the consecutive winters between 2000 and 2002, although it had survived the previous two winters. The objective of this project was to compare the winter hardiness of PC rye to that of other winter cereals. In addition to assessing the winter hardiness of PC rye, this study evaluated management practices that could affect the hardiness of PC rye. In particular, the effect of seeding date and a fall defoliation upon winter hardiness were examined.

Materials and Methods

The entire study site was initially sprayed with Glyphosate on July 6, 2001 for weed control. On July 18, 2001 the site was worked with a cultivator and harrow-packed to create a firm seedbed. Plots were seeded on the following 6 seeding dates in 2001: July 18, August 3, August 16, August 30, September 7 and September 17. The seed was placed at a depth of 1.25 cm using a plot-seeder with 25 cm spacings. Although no soil test was done to determine soil nutrient status, 56 kg/ha of 11-51-0-0 fertilizer was applied with the seed.

Five winter cereal varieties, from three species, were seeded in this project for comparison to PC rye. Prima fall rye, CDC Clair winter wheat, Pika winter triticale and Bobcat winter triticale were chosen because they are traditionally grown on the western prairies. Prego winter triticale, a high-yielding variety from Europe, was selected to see how this European variety differs in winter hardiness from the Canadian varieties.

Irrigation was applied twice during the establishment year of the study in order to ensure sufficient moisture for germination at each of the seeding dates. The research site was irrigated on August 13 and September 11, 2001, with approximately 5 cm of moisture applied each time.

A defoliation (mowing) treatment occurred during the first week of October 2001, defoliating the plants to a height of 5 cm. This defoliation date was selected because fall grazing of winter cereals often occurs as this time due to depletion of perennial pastures.

Between October 30 and November 1, 2001, randomly selected plants were removed with roots intact from each plot and transported to the University of Saskatchewan to determine the lethal temperature at which 50% of the plants were killed (LT 50). No plants were collected from the last seeding date (Sept. 17) due to limited plant size and development for the LT 50 test.

On May 10 and 11, 2002, field survival and mortality counts were done for each plot. Within each plot, 50 randomly selected plants were evaluated to determine percent survival and mortality under field conditions at Swift Current. Any plant with green growth as of the date of sampling was considered alive.

Data Analysis

Data analysis was analysed using Proc Mixed (SAS Institute 1990). A split-split model was used with seeding date, species, defoliation and their interactions as fixed effects and replicates as random effects. Significant seeding date X species X defoliation interactions for plant survival and plant height were further examined by removing seeding date from the model, and analyzing the experimental data within each seeding date separately by the least significant difference (LSD) test of the general linear model procedure (SAS Inst. 1990). Mean comparisons generally emphasized comparisons among forage varieties and defoliation treatments within seeding dates, rather than direct comparisons among seeding dates. Significance was considered at $P<0.05$, unless otherwise stated. The LT 50 tests were not included in a formal statistical analysis due to a lack of replication. However, several trends can still be detected in the LT 50 data.

Results and Discussion

Plant survival and morphology

For plant survival and height in 2002, the main effects of seeding date, forage species and defoliation treatment were significant ($P < 0.0001$), as were the interactions of species X defoliation and seeding date X species ($P<0.001$). Significant seeding date X species X defoliation interactions were also observed for plant survival ($P<0.001$) and height ($P<0.01$). As a result, each seeding date was analysed separately with the results presented in Table 1.

Plant survival

When averaged across all seeding dates, Prego triticale had the lowest plant survival of all forage varieties; ranging from a low of 0.3 ± 4.7 % with July 18 seeding to a high of 96.9 ± 1.9% for Sept. 7 seeding (Table 1). The low survival of Prego is likely due to its European origin, where low-temperature tolerance is not as critical to winter survival as on the Canadian prairies. In contrast, Prima fall rye had the greatest plant survival when averaged across all seeding dates; ranging from a low of 93 ± 4.4 % for Aug. 30 to a high of 100% for seeding on Aug. 3 and 16, as well as Sept. 7.

Of the three winter triticale varieties, Pika had the greatest survival when averaged across all seeding dates, Bobcat was intermediate, and Prego had the lowest plant survival (Table 1). Plant survival was observed to be greatest for the winter triticale varieties and CDC Clair winter wheat when planted on Sept. 7, and generally lowest for July 18 seeding (Table 1).

When compared to the winter cereals for plant survival under field conditions, PC rye was tied for second greatest for a mid-July seeding date, and tied for the best survival for early-and-mid August seeding dates ($P<0.05$) (Table 1). Plant survival of PC rye was not significantly different from the other varieties within the Aug. 30, Sept. 7, and Sept. 17 seeding dates ($P<0.05$).

Averaged across all varieties within seeding dates, defoliation significantly reduced plant survival ($P<0.05$) for all seeding dates except Aug. 3, which showed only a weak ($P>0.05$) trend for reduced survival under defoliation (Table 1). The lower winter survival for the defoliated plants may be a result of the overall lower soil temperatures experienced by these plants (Table 1). Defoliation reduced the amount of standing plant material, causing increased exposure of the soil to the environmental elements, particularly soil surface cooling. For PC rye, defoliation significantly changed plant survival ($P<0.05$) only on the July 18 seeding date, reducing survival from 78.2 ± 5.6 % to 30.0 ± 5.6 % for non-defoliated and defoliated plants, respectively.

When looking at differences in plant survival for the 6 varieties by seeding date (Table 1), there were no differences among forage varieties for the Aug. 30 to Sept. 17 dates. In contrast, there were differences evident for the Aug. 16 seeding date ($P<0.05$), and in moving from Aug. 16 to earlier seeding dates, even greater reductions in survival became evident (table 1). Plant survival of PC rye was equal to Prima fall rye (100% ± 4.8 %) for Aug. 16 seeding date ($P>0.05$), but was lower than fall rye ($P<0.05$) when seeded on July 18 (54.1 ± 4.7 % and 95.7 ± 4.7 % for PC and fall rye, respectively). Based on this information, planting PC rye in mid-August or later should ensure maximum winter hardiness, while planting in mid-July may significantly lower hardiness. Baron et al. (1999) indicated the cold tolerance of winter wheat was reduced if plants were too large prior to winter dormancy, as the incidence of disease was greater in larger plants. The reduced survival of early-seeded PC rye may be partially related to disease as well, and is an area that requires further research.

The LT 50 tests (Fig. 1) indicate many useful trends related to cold tolerance and help assess the relative differences among varieties examined in this study. The few missing columns for the first 2 seeding dates occurred because the LT 50 occurred at a temperature (i.e. -12°) outside the temperature range in which plants were removed from the freezer. The LT 50 results shown in Figure 1 identify two basic groups with similar responses; the triticales and winter wheat, as well as fall rye and PC rye. The latter 2 were similar regardless of defoliation treatment. The results indicate the winter hardiness of PC rye is comparable to that of Prima fall rye. Despite this, it is important to differentiate between the results of the LT 50 test and the field survival counts, as the LT 50 test was done on plants collected at just one point in time (i.e. late fall) whereas field survival counts show the overall winter effect from several months of exposure to environmental conditions in the field. Therefore, the field survival counts are perhaps a more accurate reflection of relative survival differences resulting from the various treatments imposed the previous fall. The field survival counts (Table 1) show PC rye had moderately lower ($P<0.05$) winter hardiness than Prima fall rye when seeded on Aug. 3, but similar survival ($P>0.05$) for all seeding dates after that date. The July 18 seeding date is the only date that shows a prominent difference between PC rye and Prima fall rye in field survival counts (Table 1).

The temperature ranges selected for the LT 50 tests were determined by L. Gusta at the University of Saskatchewan based upon previous research with winter cereals. However, results of the LT 50 tests indicated the plants did not have the same level of cold tolerance that were originally expected (i.e. LT 50 values were outside the temperature range selected for the first two seeding dates). It is possible that acclimation was not finished in these plants and that they were dug up too early in the fall.

Another useful way to look at winter hardiness is in terms of plant survival for varying growing degree-days (GDD's) accumulated from the time of seeding to freeze-up during the year of planting (Fig. 2). The GDD's indicated in Figure 2 correspond with the 6 seeding dates at which the cereals were planted. For all cultivars except Prima fall rye, plant survival significantly declined ($P< 0.05$) when GDD's increased from 1023 to 1603, which corresponds with a change in seeding date from Aug. 16 to July 18, respectively. The GDD's accumulated for each day were calculated by adding the maximum and minimum temperatures for each day and dividing by 2. A base of 0°C was used for calculating GDD's.

The temporal seeding 'window' for successful over-wintering of Prima fall rye is much broader than the other less winter hardy cultivars. The window for successful PC rye production appears to be narrower than for fall rye, but is broader than for winter wheat and triticale (Fig. 2). Winter survival of PC rye approached 100% for both defoliated and non-defoliated plants when GDD's were between 468 (mid-Sept. seeding date) and 1023 (mid-Aug. seeding date). In contrast, when 1603 GDD's (mid-July seeding date) were reached, fall defoliation reduced subsequent winter survival of PC rye from 78% to 30% (Table 1). Triticale appears to be the most sensitive GDD's accumulated prior to freeze-up, having an ideal range of 468 to 733 GDD's (corresponding with

Aug. 30 to Sept. 17 seeding dates), whereas the other forage varieties did not change much until GDD's exceeded 1023 (mid-Aug. seeding date).

Winter survival is not only a concern in the southern prairies, but is also a major issue in the Black soil zone as well. In a study conducted at Lacombe, AB, Jedel and Salmon (1994) investigated three dates of fall seeding (late-Aug., early Sept., and late Sept.) at two seeding rates using fall rye, winter wheat and winter triticale. Survival was found to be greatest in all years when planting occurred in late-August and early September, regardless of species. Notably, results of that study are in agreement with our research at Swift Current, SK.

Summary and management implications

Winter hardiness is a major limitation to growing PC rye and winter cereals in Southwest Saskatchewan. When PC rye was compared to winter cereals for hardiness in this study, PC rye was similar to fall rye, and hardier than winter wheat and triticale. Results also indicate management is critical to maintaining the winter hardiness of PC rye. PC rye obtained maximum winter hardiness with mid-to-late August seeding. Seeding prior to August significantly reduced hardiness, while seeding in September only minimally reduced winter hardiness. A defoliation treatment during the first week of October also lowered the number of plants surviving the winter, particularly when occurring on plants seeded in mid-July. In contrast, defoliation of plants seeded in mid-August suffered little effect from defoliation.

This study has shown the potential benefits of PC rye as an alternative forage for extending the grazing season. It also indicates that further research is warranted on PC rye, particularly given that the results presented in this report are for only 1 year of data. More effort also needs to be directed into studying the mechanisms that control winter hardiness in PC rye. Once a clearer understanding is obtained of the mechanisms involved in controlling winter hardiness, plant breeding can focus on improvements, such as the development of new cultivars of PC rye with improved tolerance to grazing, without sacrificing hardiness.

References

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Table 1. Least square means (±s.e.) for plant survival in 2002 of winter triticale (Bobcat, Pika and Prego), Clair winter wheat, Prima fall rye and PC rye, seeded at Swift Current, SK at six different dates in 2001; plants were either defoliated (D) or non-defoliated (ND).

		Varieties						
Seeding date	**Defoliation**	Bobcat trit.	Pika trit.	Prego trit.	Clair wheat	Prima rye	PC rye	Mean
		Plant Survival (%)						
July 18								
	D	34.7a^{x} (5.6)^{y}	48.0a	0.3a	36.7a	95.3a	30.0a	40.8A (2.3)^{y}
	ND	25.3a	58.7a	0.3a	37.9a	96.0a	78.2b	49.4B
	Mean	30.0B^{z}(4.7)^{y}	53.4C	0.3A	37.3B	95.7D	54.1C	
Aug. 3								
	D	52.0 (7.7)^{y}	74.0	18.7	64.7	100.0	82.7	65.4 (3.1)^{y}
	ND	46.0	68.0	24.0	75.3	100.0	94.0	68.9
	Mean	49.0B^{z} (6.4)^{y}	71.0C	21.4A	70.0C	100.0D	88.4D	
Aug. 16								
	D	73.3 (5.8)^{y}	98.7	53.3	92.0	100.0	100.0	86.2A (2.4)^{y}
	ND	90.7	99.3	74.7	88.0	100.0	100.0	92.1B
	Mean	82.0B^{z} (4.8)^{y}	99.0C	64.0A	90.0BC	100.0C	100.0C	
Aug. 30								
	D	76.0 (6.0)^{y}	94.0	64.7	80.7	92.7	80.7	81.5A (2.4)^{y}
	ND	94.7	94.0	86.0	90.7	93.3	98.7	92.9B
	Mean	85.3 (4.4)^{y}	94.0	75.3	85.7	93.0	89.7	
Sept. 7								
	D	90.7 (2.4)^{y}	99.3	95.3	94.0	100.0	92.7	95.3A (1.0)^{y}
	ND	100.0	100.0	98.6	97.3	100.0	98.7	99.1B
	Mean	95.3 (1.9)^{y}	99.7	96.9	95.7	100.0	95.7	
Sept. 17								
	D	80.7 (3.8)^{y}	88.0	78.0	84.7	93.3	89.3	85.7A (1.5)^{y}
	ND	94.7	96.0	92.7	94.7	96.7	96.7	95.2B
	Mean	87.7 (3.1)^{y}	92.0	85.3	89.7	95.0	93.0	

z = Means in the same column within a seeding date with different lower case letters are significantly different according to a LSD test (P<0.05)

y = pooled S.E. in parentheses

x = Means in the same row or column with different upper case letters are significantly different according to a LSD test (P<0.05)

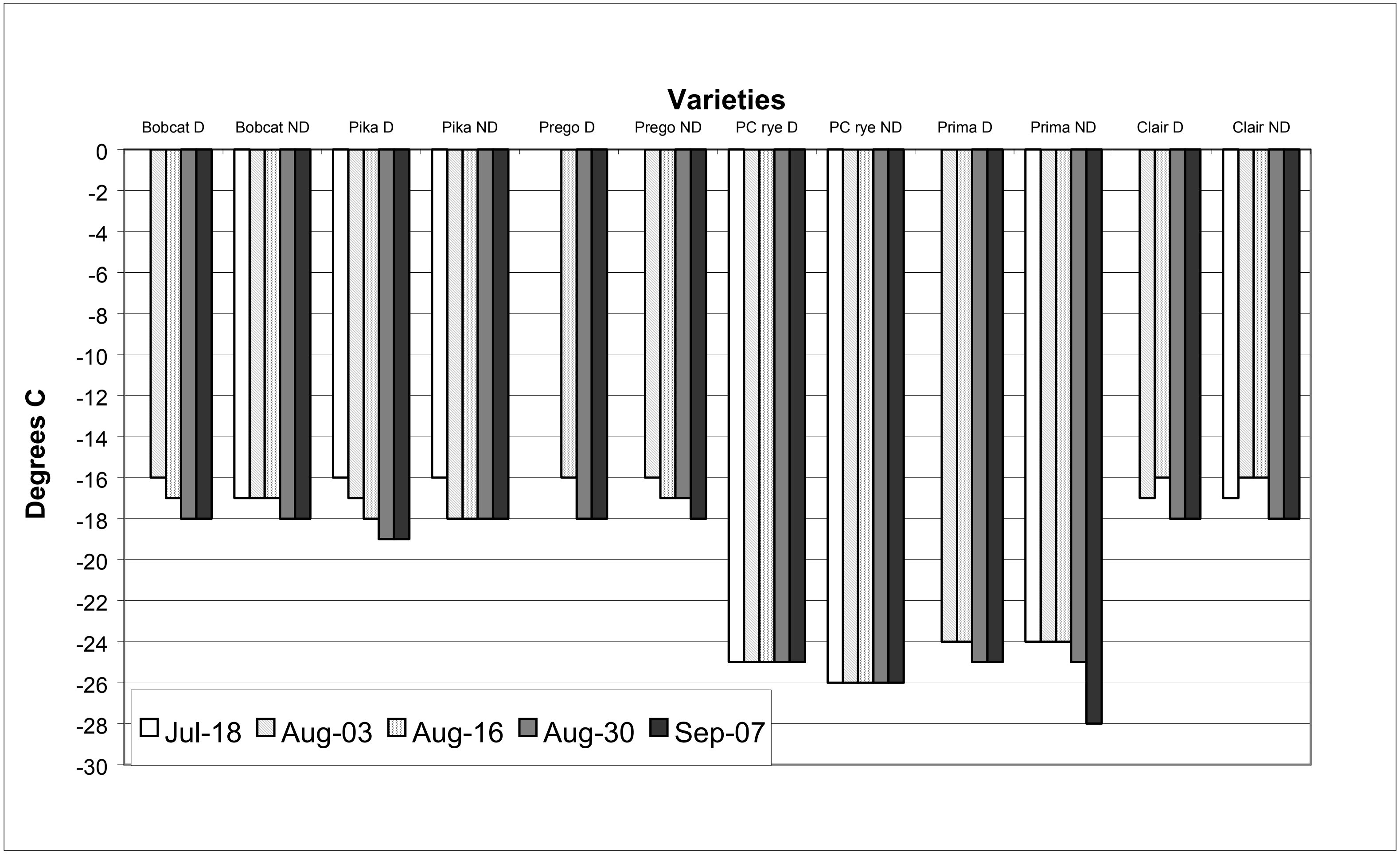

Figure 1. Lethal temperature at which 50% of the plants are killed (LT 50) for defoliated (D) and non-defoliated (ND) winter triticale (Bobcat, Pika and Prego), Clair winter wheat, Prima fall rye and PC rye, seeded on 5 different dates (July 18, Aug. 3, Aug. 16, Aug. 30 and Sept. 7) in 2001 at Swift Current, SK.

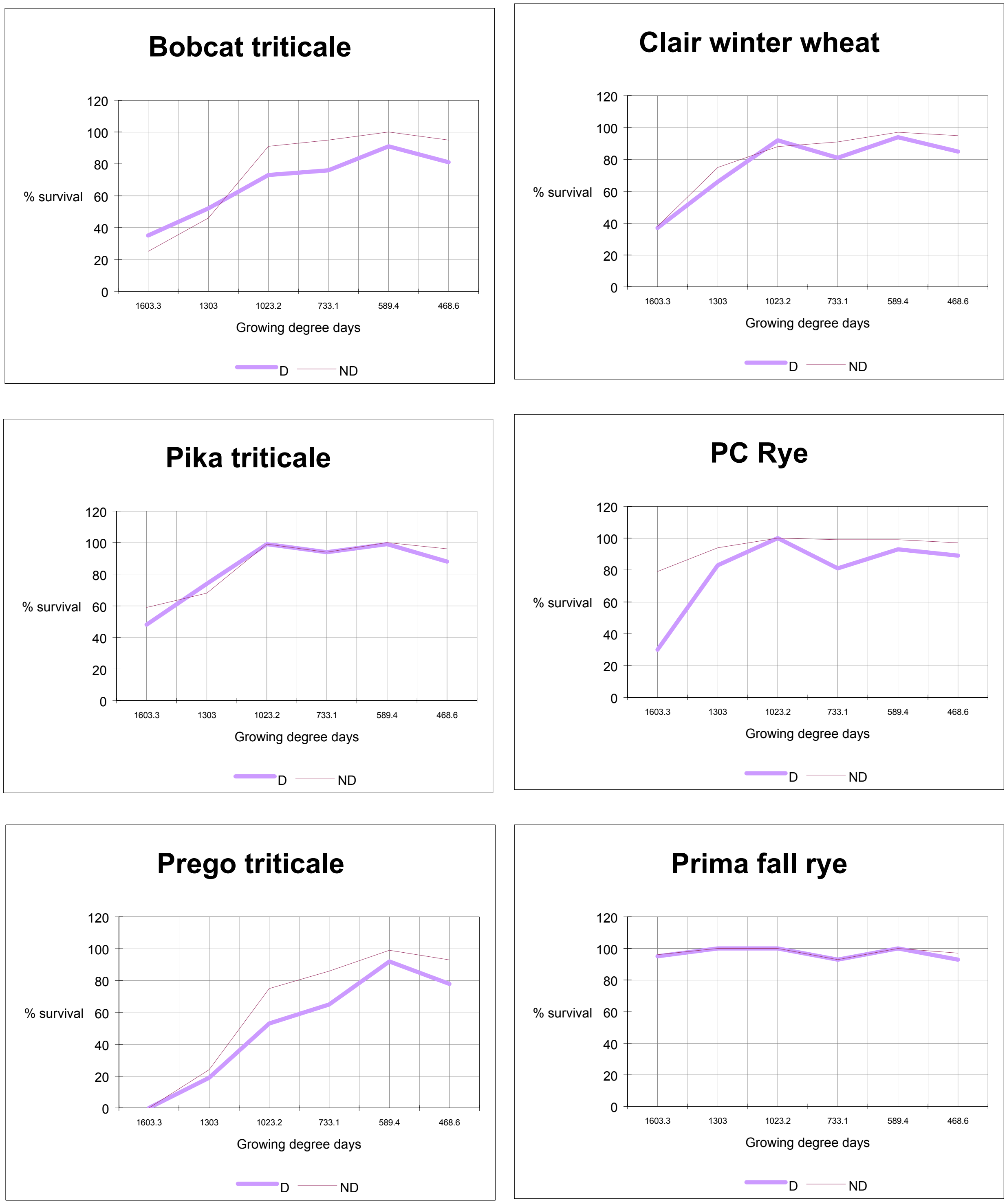

Figure 2. Percent survival of plants in the field for the 6 seeding dates (seeding dates shown as growing degree days accumulated prior to freeze-up) at Swift Current, SK for defoliated (D) and non-defoliated (ND) plants of each forage variety.