WINTER CEREAL SURVIVAL IN SASKATCHEWAN

D.B. FOWLER
Crop Development Center
University of Saskatchewan
Saskatoon, Sask.

A. Advantages of Winter Cereals

Where winter cereals can be successfully overwintered they offer the producer several advantages over spring-sown crops. These advantages include:

(1) Redistribution of farm labor requirements. Winter cereals are seeded in late August or early September. Because of conflicts with the harvest of spring-sown crops, this can be a disadvantage initially. However, with the proper planning of preseeding operations, seeding should be the only operation required during the harvest period. With the seed in the ground the advantage then goes to the winter crop. Problems that occur with the seeding of spring crops are eliminated and the early maturity of winter crops (late July to mid-August) usually means an early start at harvest.

(2) Protection of the soil against wind and water erosion in the fall and spring. Winter crops establish in the fall. Therefore, in areas where erosion is a problem, their leaves and roots help in protecting and anchoring the soil. Where wind erosion is a problem, winter (fall) rye should be utilized. Areas subjected to wind erosion are often free of snow during the coldest parts of the winter and wheat does not have the cold hardiness necessary to survive Saskatchewan winters without a snow cover.

(3) Increased competition with weeds such as wild oats. Winter cereals establish in the fall and resume growth early in the spring. This gives them a competitive advantage over plants which start from seed in the spring, e.g., wild oats. On the other hand, winter annual, e.g. stinkweed and flixweed, and perennial weeds, e.g. thistles, have a growth period which is similar to that of winter cereals. They therefore offer more competition and must be controlled through the use of herbicides or other means.

(4) Early development thereby reducing the risk of loss from disease such as rust. Winter wheat cultivars licensed for production in Saskatchewan do not have resistance to the common strains of rust. However, rust does not overwinter in Saskatchewan and each year must be reintroduced. For most of the province winter wheat reaches maturity before the rust innoculum has a chance to build up to economic levels. However, as rust usually enters the southeast corner of the province first, it may pose a problem in that area on some years.

(5) A pasture and forage potential which should be greater than for spring-sown cereals. Winter cereals start growth early in the spring. The cool temperatures and good moisture supply that usually occur at this time promote rapid growth of winter cereal and, as a result, they can provide excellent early season (May-June) pasture. Winter rye should not be grazed after heading, as ergot can be a problem.

Grazing of rye in the year it is sown (fall grazing) has also been practiced extensively in some areas. The effects of this practice have not been adequately researched and therefore general recommendations are not available. It is recommended that winter wheat not be grazed the fall it is sown.

(6) Early maturity, hence an avoidance of late summer drought and fall frost. Summer droughts can be a factor limiting crop production, especially in the south-western corner of the province, the most critical period usually occuring in late July and early August. By this time, much of the winter crops growth has been made, thereby avoiding this stress period. Early fall frosts are a hazard in the northern part of the Parkland area and, once again, early maturity of the winter crops greatly reduces this risk.

(7) Higher yields than spring-sown cereals. Comparative trials in Saskatchewan have demonstrated a 25 percent yield advantage for Sundance winter wheat over Neepawa spring wheat. Similar studies have shown a 35 percent yield advantage for Puma winter rye compared to Gazelle spring rye.

B. Disadvantages of Winter Cereals

While the advantages listed above are recognized, they have not been reflected in the proportion of Saskatchewan's crop acreage devoted to winter cereals. Two factors, winter survival and market potential, have combined to severely limit production of winter wheat. Market potential has been the main factor restricting the production of winter rye. While both factors are recognized as limitations, this report will deal exclusively with winter survival.

C. Development and Maintenance of Cold Tolerance in Winter Cereals

Without previous exposure to temperatures near freezing, winter cereals, when subjected to subfreezing temperatures, will survive no better than spring cereals (Figure I). However, when exposed gradually to decreases in temperature, such as occur during a normal fall, winter cereals have the ability to cold acclimate or "harden off". Because this hardening process is an active change, the health and vigor of the plant and the sequence of temperature changes to which it is exposed are important. A minimum of approximately six weeks

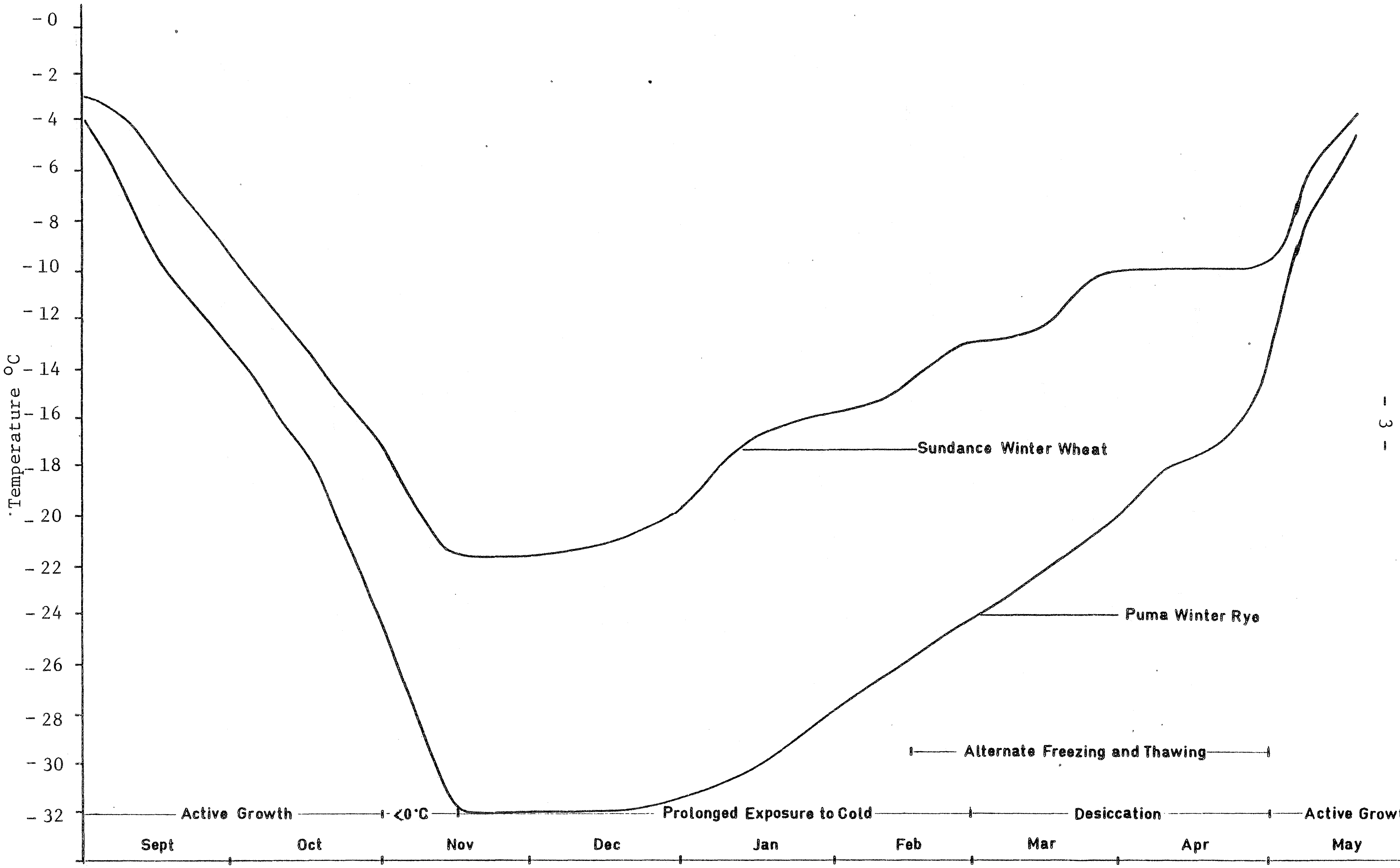

Figure 1. Changes in cold hardiness of winter wheat and rye for the period September to May. The primary factors responsible for these changes are shown at the bottom of the graph.

is required for the development of cold hardiness. The first period is the most active and takes place at above-freezing temperatures (0 to 10°C). At the end of this stage a period of continuous frost (-2 to -3°C) is required to fully harden the plants. Exposure to warm temperatures during this period will result in rapid dehardening. However, at this stage, when dehardened plants are returned to near freezing temperatures, they will quickly reharden.

Once cold acclimation of winter cereals has taken place, a high level of hardiness can be maintained for several months, provided temperatures remain below freezing. Maintenance of hardened plants at temperatures slightly above freezing will reduce their cold hardiness level. Similarly, alternate freezing and thawing or prolonged exposure to temperatures slightly above the killing temperature will reduce the cold hardiness potential. Collectively, these factors often result in a much reduced cold hardiness potential of winter cereals by spring.

Exposure to warm spring temperatures will eventually result in a complete dehardening of winter cereals. Once spring dehardening has been initiated, returning plants to conditions for cold, acclimation will not reverse the dehardening process and loss of cold hardiness will result even if plants are maintained at temperatures below freezing.

D. <u>Environmental Factors Which Determine the Survival of Winter Cereals.</u>

Winter cereals can regenerate from undamaged crown tissue and therefore the temperature to which this part of the plant is exposed is the critical factor in winter survival. Death of the crown tissue will result if the temperature falls below its minimum survival temperature at any time during the winter.

The crown of the plant is below ground and therefore it is the soil temperature to a depth of approximately 5 cm that determines survival. The soil has a tremendous capacity to buffer temperature change, but the extremely low air temperatures that occur during a Saskatchewan winter make it almost a necessity that some form of insulation be present to prevent soil temperatures falling below the minimum required for the survival of most winter cereals. This insulation comes in the form of snow. Snow usually arrives earlier and stays later in the Black and Gray soil zones than in the Brown. For this reason, outside of the chinnook area in the extreme south-west of the province, the greatest potential for winter cereal production lies in the northern part of the agricultural area. However, with effective snow trapping the hardier winter wheat cultivars can be successfully overwintered in most areas of the province. Effective snow trapping for winter wheat means the maintenance of a minimum of approximately 10 cm of snow over the entire field during extended cold periods of winter. This depth of snow is extremely difficult to retain on summerfallow fields, even in the high snowfall areas.

E. Cold-Hardiness Potential of Varieties

Winter cereals do not all possess the same ability to withstand extremes in cold. In addition, there are many stress factors that determine winter survival and the interrelationships among these factors can be extremely complex. Under field conditions there is a confounding of these factors and a lack of opportunity to reproduce their effects. This imposes severe restrictions upon the researcher attempting to determine the relative cold-hardiness potential of cultivars. In addition, field survival trials are often inconclusive due to either complete winterkill or a lack of it. To circumvent some of the limitations inherent in field survival evaluations, laboratory freeze tests have been developed. These tests provide control over many variables, allow for the reproduction of stress factors and provide the opportunity to estimate the minimum survival temperatures of field material at any time of the winter. It is these types of tests which were utilized in determining the survival patterns represented in Figure 1.

The cultivar minimum survival temperatures are greatest just after freeze-up in the fall. Experience has shown that 1°C difference in cultivar minimum survival temperature at this stage is equal to approximately 23 percent difference in field survival estimates made for the same cultivar in the spring. Utilizing minimum survival temperatures and this conversion, Field Survival Indices (FSI) have been estimated for a number of winter cereal species. Cultivars representative of the cold hardiness range within each species are listed in Table 1. These estimates demonstrate that, although there is an overlap among species, cultivars of rye have the best cold hardiness potential. Cultivars of common wheat and triticale are next in line, followed by durum wheat, barley and then oats.

While survival estimates based on laboratory freeze tests are more easily arrived at, reproduction of differences in winter survival potential under field conditions still remains the ultimate final test on which farm recommendations are made. In field trials, the percent survival of each cultivar in a test plot is estimated once growth has resumed in the spring. As indicated in Table 1 there is a wide range in cold hardiness potentials and there are often instances where cultivars will have differences which are greater than 100 percent. However, by utilizing survival data from field trials that have been subjected to different levels of winter stress, comparative field survival indices with a range greater than 100 percent can be determined. The FSIs for winter wheat given in Table 2

Table 1. Winter cereal field survival indices

Cultivar or strain	Species	FSI
a) Unacclimated		
	Spring or winter wheat	70
	Spring or winter rye	90
b) Acclimated		
Random	Spring oats	115
Bonanza	Spring barley	115
Manitou	Spring wheat	160
Gazelle	Spring rye	210
WIR 46870	Winter durum wheat	255
Penium	Winter oats	275
WIR 46870 + Cougar	Winter triticale (6X)	275
Compactum	Winter oats	290
Dover	Winter barley	300
Cappelle Deprez	Winter wheat	306
Dicktoo	Winter barley	355
Novamichurinka	Winter durum wheat	370
Kharkov + Puma	Winter triticale (8X)	460
Ulianovkia + Kodiak	Winter triticale (8X)	480
Kharkov	Winter wheat	501
Ulianovkia	Winter wheat	530
Sangaste	Winter rye	550
Kodiak	Winter rye	575
Cougar	Winter rye	620
Frontier	Winter rye	735
Puma	Winter rye	735

have been derived in this manner. These indices represent average cultivar differences as determined from over 60 field survival trials grown in Saskatchewan during the period 1972-77. This material is representative of cultivars grown in the winter wheat producing areas of North America and Europe and includes the hardiest strains that have been identified to date. It should be noted that recent improvements in winter wheat survival potential have been small and in most of the traditional winter cereal growing areas, if anything, the cold hardiness potentials of the cultivars has been decreasing. The only sources of additional cold hardiness appear to be the two Russian strains, Alabaskaja and Ulianovkia.

Table 2. Winter wheat field survival indices

Year Commercially available in North America	Cultivar or strain	Area of Adaptation or initial release	FSI
NA	Ulianovkia	USSR	530
NA	Alabaskaja	USSR	527
1977	Norstar	Alberta	516
1912	Kharkov 22MC	Quebec	501
1902	Minhardi	Minnesota	501
1971	Sundance	Alberta	494
1932	Yogo	Montana	493
?	Froid	North Dakota	488
NA	Mironovskaja 808	USSR	466
1961	Winalta	Alberta	462
1967	Scout 66	Nebraska	447
1960	Warrior	Nebraska	446
1970	Scoutland	Nebraska	444
1975	Lancota	Nebraska	434
1971	Centurk	Nebraska	433
1922	Cheyenne	Nebraska	427
1946	Rideau	Ontario	405
NA	Besostoja 1	USSR	401
197?	Sprague	Washington	400
1961	Gaines	Washington	388
1973	Tecumseh	Michigan	386
1971	Fredrick	Ontario	361
1968	Yorkstar	New York	360
1965	Nugaines	Washington	360
1967	Blueboy	North Carolina	336
1972	Arrow	New York	337
1969	Ionia	Michigan	337
NA	Cappelle Deprez	Great Britain	306

F. <u>Breeding for Improved Cold Hardiness</u>

In winter wheat the total North American breeding effort expended since the introduction of the Crimean wheats in the late 1800s (Minhardi and Kharkov are selections from Crimean introductions) has produced only a marginal improvement in cold hardiness (Table 2). Inspection of the pedigrees of the successful winter wheat cultivars reveals an extremely narrow gene base suggesting that the main reason for lack of progress has been limited genetic variability for this character. A similar situation appears to exist for barley and oats.

While the opportunity for improving the cold hardiness of winter wheat appears to be limited, there is some evidence that marginal gains through conventional breeding methods are possible. The two Russian strains, Alabaskaja and Ulianovkia, represent potential sources of additional cold hardiness. Part of this variability has been made available to Canadian farmers in the recent cultivar release, Norstar (1977), which was selected from a cross between Winalta and Alabaskaja. In addition, reports out of the USSR indicate that Ulianovkia may not be the best Russian stock avaiable. In any event, the potential for improvement is small and, from what is known of the genetics of cold hardiness, it is expected with the material at hand now an intensive plant breeding effort could result in no more than a 15 percent increase in FSI over that of Norstar.

Related species provide another potential source of genetic variability that has been given consideration in attempts to improve the cold hardiness of cultivated cereal species. The cold hardiness of rye provides proof that the potential of winter cereals to survive cold is much greater than that presently known in wheat, barley and oats. However, the transfer of this potential from one species to a related species is not likely to be an easy task. For example, the cold hardiness advantage of rye is completely surpressed when winter wheat and rye are combined to produce winter triticales (Table 1). Certainly further studies are necessary before access will be gained to this kind of alien genetic variability.

G. The Effect of Cultural Practices on Winter Survival

Optimum cultural practices for winter cereal survival would include seeding with a hoe press or other type of zero tillage drill into a moist, weed-free field of standing stubble or other effective snow trap on the recommended date with the recommended fertilizer levels. Shortfalls on any one of these practices will result in a reduction in cultivar cold hardiness potential or field survival index (FSI). The units (%) used to measure this failure are the same as for the cultivar FSIs (Tables 1 and 2) and therefore the consequences of each management shortcoming can be determined for each cultivar by simple subtraction as shown in the examples that follow. Comparisons with the minimum cultivar FSIs required for undamaged stands (Table 6) will then give a rough estimate of the crops chances for survival under different winter environments.

Seedbed preparation

Seedbed preparation is one of the most important factors affecting winter cereal survival. Hot, dry weather, which often occurs in the late summer, quickly dries out loose, open soils. The result is usually uneven germination and weak seedlings which are extremely prone to winterkilling. The estimated reduction in FSI for plants that enter the winter in this condition is 150 percent (Table 3). On this basis, seeding Norstar deep into a loose seedbed would, in effect, reduce its FSI (516-150 = 366) to that of Fredrick (361) sown under optimum conditions. This would essentially guarantee a crop failure in Saskatchewan. Where a firm seedbed cannot be achieved prior to seeding, the furrow or hoe press drill will usually provide the best stands.

Table 3. Effect of summerfallow seedbed condition on winter survival (Subtract value from cultivar FSI)

	Subtract
Shallow seeding with a hoe press drill	0
Shallow seeding with a disc press drill	30
Deep seeding into a loose seedbed	150

On summerfallow, shallow tillage in late season operations is the best means of maintaining a firm seedbed. Rod-weeding immediately ahead of the drill will also assist in firming the soil and keeping the moisture within seeding depth. Hoe press drills also give the best results on firm moist summerfallow fields as the furrow produced aids in the trapping of snow (Table 4).

Stubble seeding can result in successful winter cereal stands where the previous crop has been harvested at an early date and where moisture conditions are adequate to permit good plant establishment before freezeup. The standing stubble assists in trapping snow and a very firm seedbed is provided. No seedbed preparation is necessary; however, good drill penetration is required. The hoe press drill or other types of zero tillage drills will provide the best stands under these conditions.

On both summerfallow and stubble, the optimum seeding depth is less than 4 cm into firm, moist soil. Deeper seeding often results in delayed emergence and weak plants which are susceptible to winterkilling.

Date of Seeding

Winter cereals should be seeded early enough to allow for the establishment of a healthy, vigorous plant before freezeup. However, seeding too early will result in excessive growth in the fall and plants which are usually less resistant to injury and disease.

The recommended date of seeding for the winter wheat production area of southern Alberta is the first two weeks in September. There, seeding before the first of September has resulted in increased disease problems. However, in more northernly locations, cool fall weather usually arrives sooner and therefore earlier seeding is required. Generally recommended seeding dates in Saskatchewan are August 25 for the north and September 7 for the extreme south of the agriculture area. The effects of earlier and later dates of seeding on winter survival are given in Table 4. As an example, on the basis of these estimates, in the Parkland area seeding the cultivar Norstar on September 25 would reduce its FSI (516-35 = 481) to below that of Sundance (494) seeded on August 25.

Table 4. Effect of seeding date on winter survival (Subtract value from cultivar FSI)

	Subtract
3 weeks early	35
2 weeks early	15
Recommended date	0
2 weeks late	5
3 weeks late	20
4 weeks late	35
5 weeks late	40

Fertilizers

Positive responses have been obtained from fertilizer application on winter cereals. This is especially so for stubble land where nitrogen fertilization will usually produce large yield increases. Phosphate should be applied in the fall with the seed. Nitrogen application may be delayed until spring, after the level of survival has been assessed. Rates of fertilizer application should be based on a soil test.

Field trials have indicated that nitrogen level, for the most part, does not affect a cultivar's cold hardiness potential. In contrast, as shown in Table 5, phosphorous (P) deficiencies will reduce a cultivar's FSI. In this case, the P may act through promotion of spring recovery and not cold hardiness directly. As an example of the magnitude of this effect, a 15 kg/ha P (30 kg/ha 11-48-0) deficiency for the cultivar Norstar would reduce the FSI (516-25 = 491) to that of Sundance (494) sown with the recommended level of P.

Table 5. Effect of Phosphate Fertilizers on Winter Survival
(Subtract value from cultivar FSI)

	Subtract
Minimum requirements met	0
15 kg/ha deficiency P	25
30 kg/ha deficiency P	35

Summation

The importance of utilizing optimum cultural practices in the production of winter cereals cannot be overemphasized. As demonstrated, shortcomings in this area can greatly reduce a cultivar's ability to survive the winter. For a final example, consider the effects of the following cultural practices on the FSI of Puma winter rye: Seeding 4 weeks later than the optimum date into a loose seedbed utilizing a disc-type drill with no provisions for packing and with an uncorrected soil phosphate deficiency of 30 kg/ha. The result is a reduction in the FSI (735 - 35 - 150 - 35 = 515) of the winter hardy rye cultivar to that of Norstar winter wheat produced under optimum cultural practices (FSI = 516).

H. Minimum Cold Hardiness Requirements and Assessment of Winterkill

With the disappearance of snow in the spring, plants may appear severely injured. However, as long as the crown tissue remains healthy (white, not brown, on the inside of the crown), a plant will usually survive. A uniform 50 to 60 percent stand will generally tiller enough to produce a near normal yield. As a rule, one should put off the decision to plow down a damaged stand until it has been exposed to several days of warm spring temperatures. The extent to which newly developed green leaves appear will then assist in final assessment. In most instances a poor looking stand in May will be a normal looking stand at heading.

The most difficult winter damage to assess usually occurs on summerfallow fields. This is due to the drifting of snow from exposed areas. These areas will show up as winterkill patches in which there is a rapid transition from no winterkill to complete winterkill. In winter wheat fields these patches usually will not recover and end up as weed problem areas. Estimates of the magnitudes of these changes have been made utilizing cultivars selected from those listed in Table 2. They were sown in single row plots at test sites with different winter exposures. Survival estimates were made the following spring. Based on the field survival levels, and the survival indices for each cultivar, these plot areas were mapped for winter survival requirements as shown in Fig. 2. The abruptness of the changes in cold hardiness requirements on summerfallow fields can be clearly seen from this survival map. In contrast, similar trials sown into standing stubble indicated that the minimum FSIs required to give an undamaged winter cereal stand were less than 480.

Given the extremes of Saskatchewan winters, snow cover becomes a critical factor in winter cereal production. Table 6 further demonstrates this fact. The indices listed in this table represent mean values from 64 field trials grown at a number of locations in Saskatchewan for the period 1972-1977. Based on these values a cultivar FSI of greater than 650 is required to insure an undamaged stand on bare summerfallow. This means that only the hardiest winter ryes produced utilizing the optimum cultural practices would have a chance of surviving a Saskatchewan winter without snow cover. Five cm of snow greatly reduces the cold hardiness requirement, but the risk for winter wheat is still high. With 10 cm of snow cover, cultivars with a survival index greater than 430 are good risks. This includes Winalta, Sundance, Kharkov and Norstar winter wheats. Test sites where the snow has been greater than 15 cm deep have had Cappelle Deprez survive on occasion. In spite of this, as a general rule, cultivars with survival indices of less than 420 would be considered extremely high risks. Therefore, all presently available cultivars of winter oats, barley and durum wheat do not have sufficient cold hardiness for production in Saskatchewan even under the most optimum conditions.

Table 6. Minimum cultivar field survival indices required for undamaged stands

	FSI
Bare summerfallow	$>$ 650
5 cm snow cover	540
10 cm snow cover	430
$>$15 cm snow cover	$<$ 420 (snow mold hazard)

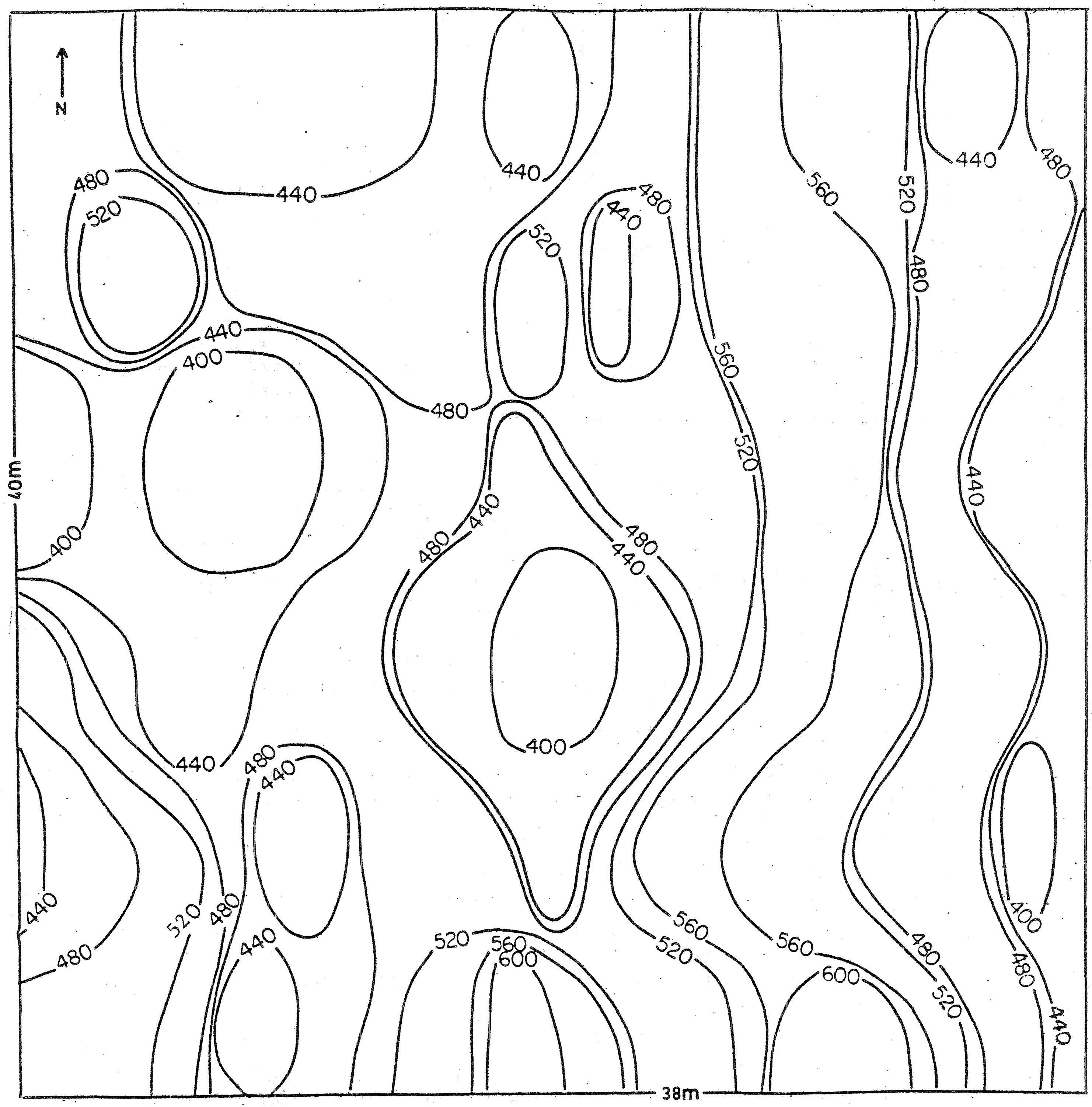

Figure 2. An example of the variation in minimum FSI required to produce an undamaged winter cereal stand on a field with variable snow cover, e.g. most summer-fallow fields. An estimate of the snow cover pattern on this area can be obtained utilizing the values given in Table 6.