EFFECT OF SEEDING DATE, RATE AND DEPTH ON WINTER WHEAT GROWN ON CONVENTIONAL FALLOW IN S.W. SASKATCHEWAN

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(An ERDA Funded Project)

INTRODUCTION

Winter wheat production has occurred in S.W. Saskatchewan for a longer period than in the more northerly areas of the province. This is likely due to the high incidence of Chinook winds in the south which moderate winter temperatures and reduce the chance of winter killing (Fowler et al. 1976). In the southwest, as in the adjacent area in southeastern Alberta, a large proportion of the winter wheat is grown on summerfallow because moisture is a major limiting factor restricting crop production. Furthermore, if winter killing of winter wheat does occur the producer still has the option of replacing this crop with spring wheat.

Based on a 2-year study carried out in the early 1970's throughout Saskatchewan, Fowler et al. (1976) concluded that growing winter wheat on fallow in the Brown soil zone was too risky. They suggested that there was a greater likelihood of receiving more snow and it was more likely to remain in place in the Dark Brown, Black and Gray soil zones, thus winter wheat on fallow would be more feasible for these regions. It was further suggested that stubble-in winter wheat was a more feasible alternative for the Brown soil zone.

The survival of winter wheat under Canadian prairie conditions depends on the severity and consistency of low temperatures from fall to spring as demonstrated effectively by Fowler et al. (1983). However, several management techniques can be used to increase the chances of winter wheat survival. These include seeding at or near an optimum date (Fowler 1982); seeding shallow (Loeppky et al. 1987); ensuring proper seed-soil contact; having good moisture at seeding time; and providing proper N and P fertilization (Fowler and Gusta 1981; Fowler 1983).

In the Brown soil zone snow cover cannot be guaranteed because not only is it likely to be low in most years, but it might not coincide with the cold spells and further, the incidence of high winds to blow it off fallow fields is high. Thus seeding winter wheat on bare fallow is indeed a risky practice here. Nonetheless, if we stubble-crop, the incidence of receiving sufficient late summer and early fall precipitation can also be quite uncertain in this region. This can therefore lead to very poor plant stands, especially when fertilizer is deep banded with hoe-type implements prior to seeding (Campbell et al. 1984). The presence of good soil moisture in fallow removes the latter problem and guarantees a good strong seedling entering the winter. Furthermore, farmers growing both spring and winter wheat will not be as hard pressed to seed early if the harvest is late in some years.

The objective of this study was twofold: (a) to determine if there were any management techniques that could be used to increase the chances of winter wheat survival over winter when it is seeded in bare fallow in the Brown soil zone, and (b) to demonstrate to producers in this region the risk involved in growing winter wheat on fallow, especially when management is not optimized.

Rationale for Choosing Treatments

1984-85

The three techniques tested in the first year of this study were seeding depth and date, and phosphorus rates. We reasoned that since low temperature is one of the main problems, and since temperature increases with depth, perhaps by seeding deeper than the recommended 2.5 cm more seedlings may escape the excessive cold at the soil surface. However, recognizing that too deep may result in weakened seedlings, a range of depths was tested. Secondly, since winter wheat is hardiest before it germinates, but it can be vernalized even during winter or early spring, it was reasoned that a late date of seeding may allow the crop to survive even very cold winters then make an early start in April. Of course, this may delay development; but by how much, and will it be worth the trade off? Thirdly, it is known that P tends to encourage hardening of plants, thus a range of fertilizer P treatments was used to see what effect this would have on rate of survival while also providing the P fertility usually required by crops grown on fallow.

1985-87

Although the application of P may increase fertility or assist in hardening of the plant, it is difficult to differentiate between these effects. Consequently, in the second and third years we optimized P rates and replaced P treatments with a rate of seeding treatment on the premise that (a) good soil moisture in fallow may allow support of a higher plant density, and (b) since plant stand may be thinned in severe winters, the greater the initial stand the greater may be the chance of having a reasonable plant population left even after sacrificing some to winter kill.

MATERIALS AND METHODS

1984-85

Winter wheat (*Triticum aestivum* L. cv. Norstar) was seeded on conventional (bare) fallow land using a split plot design with four replications. Main plots were three dates of seeding and the subplots were the combination of three seeding depths x three rates of phosphorus. Subplots were completely randomized within each main plot. Plots were 2 x 6 m. Pathways of 5 m were left between the blocks; the pathways were seeded to winter wheat in the spring so as to reduce edge effects.

Three dates (Sept. 17, Oct. 2 and Oct. 15), three depths (2.5, 5.0 and 7.5 cm) and three phosphorus rates (0, 30 and 60 kg/ha P_2O_5) were the treatments used. Norstar winter wheat was seeded at a rate of 60 kg/ha using a small zero till drill which seeds 4 rows spaced 22.5 cm; it made two passes per plot (i.e., 8 rows). The P source was 11-51-0. For the zero P rate the soil was disturbed though no fertilizer P was applied; the 30 P_2O_5 rate was applied with the seed, and the 60 P_2O_5 rate had half seed-placed and half banded mid-row at 5 cm depth. All treatments received 45 kg N/ha as ammonium nitrate (34-0-0), which was broadcast in the spring (19 April 1985).

Soil samples to a depth of 120 cm (soil segments 0-15, 15-30, 30-60, 60-90 and 90-120 cm) were taken before seeding (17 October 1984), in the early spring (18 April 1985) and after harvest (3 September 1985), by means of a Giddings soil sampling truck. Soil samples to as deep as possible (60-90 cm) were also taken by hand coring at heading (25 June 1985). Soil moisture was determined gravimetrically on all soil segments. Chemical analyses (NO_3^- and exchangeable NH_4-N and bicarbonate-P) were carried out only on samples taken before seeding.

Plant emergence and survival were assessed in the spring (10 May 1985) at about 3-leaf stage, by counting the number of plants in eight 1-m sections of row in each plot. Heading date (days after 1 April) was determined based on when approximately 50% of the plants in each row had headed. Grain yield was obtained by harvesting the central 1.5 x 6 m area of each plot. Thousand-kernel weight and grain protein content were determined from the harvested seed.

Analysis of variance was done for each parameter and standard errors were calculated.

1985-86

Three changes to the experiment were made: (a) all plots received 45 kg/ha P_2O_5 seed-placed; (b) the P rates were replaced by 3 seeding rates, viz., 30, 60 and 120 kg/ha; and (c) the dates of seeding were expanded to 5 dates initially, viz., Sept. 11, 20 and 30, and Oct. 16 and 25, and then one unplanned date (Nov. 4) treatment was added just outside the test plots because the weather remained good longer than expected.

1986-87

The experiment and analyses were the same as for 1985-86 with five seeding dates being Aug. 30, Sept. 12, Oct. 13, 21 and 27.

RESULTS AND DISCUSSION

1984-85

Soil Conditions and Weather

Available water in the soil was high in fall 1984 and spring 1985 (Table 1), thus soil moisture was not a problem at seeding nor for the early part of the growing season. The winter was extremely cold for extended periods (Fig. 1) and, together with the later than optimal seeding time, this likely accounts for the complete winter kill of plants from the two earliest date-of-seeding treatments; these plants had emerged before freeze-up. The only surviving plants were those from the treatment seeded on October 15 (two days before freeze-up) which presumably germinated, emerged and vernalized in early spring 1985. Growing season precipitation (May-June-July) was very low, being 73 mm compared to the long-term average of 167 mm and it was poorly distributed (Fig. 2).

Table 1. Soil moisture[+], mineral N and available P in soil in three years of study

Year and date sampled	Soil depth (cm)	Soil H_2O (mm) Fall	Spring	Soil chemical analysis in fall NO_3-N	NH_4-N (kg/ha)	$NaHCO_3$P
1984-85	0-15			16.7	16.3	12.8
(Fall=Sept. 17	‡15-30	59	70	9.9	21.8	8.0
Spring=April 18)	30-60	46	50	11.8	45.4	8.8
	60-90	49	54	14.2	42.7	7.1
	90-120	64	64	43.3	58.6	12.7
	Total	218	238	95.9	184.8	49.4
1985-86	0-15	35	32	23.7	12.5	19.9
(Fall=Aug. 20	15-30	35	34	11.9	13.9	18.1
Spring=April 2)	30-60	54	56	13.4	25.2	15.0
	60-90	55	56	11.1	31.9	9.8
	90-120	63	61	12.1	38.8	11.5
	Total	242	239	72.0	122.3	74.3
1986-87	0-15	34	35	10.6	17.1	30.8
(Fall=Oct. 28	15-30	38	37	13.0	18.4	13.7
Spring=April 14)	30-60	66	75	25.9	31.0	19.3
	60-90	65	65	22.3	39.4	14.8
	90-120	76	65	22.6	46.2	17.4
	Total	279	277	94.4	152.1	96.0

[+] The lower limit of available moisture in the 0-30, 30-60, 60-90 and 90-120 cm depths is 24.4, 26.6, 31.7 and 56 mm, respectively, for a total 138.7 mm/120 cm.

‡ This moisture is for the 0-30 cm depth in this case.

Plant Density

Plant counts made on May 10, 1985 were significantly affected ($P < 0.05$) by depth of seeding. In this instance there was greater emergence from a depth of 5 cm (Fig. 3), which is deeper than the recommended 2.5 cm depth for winter wheat.

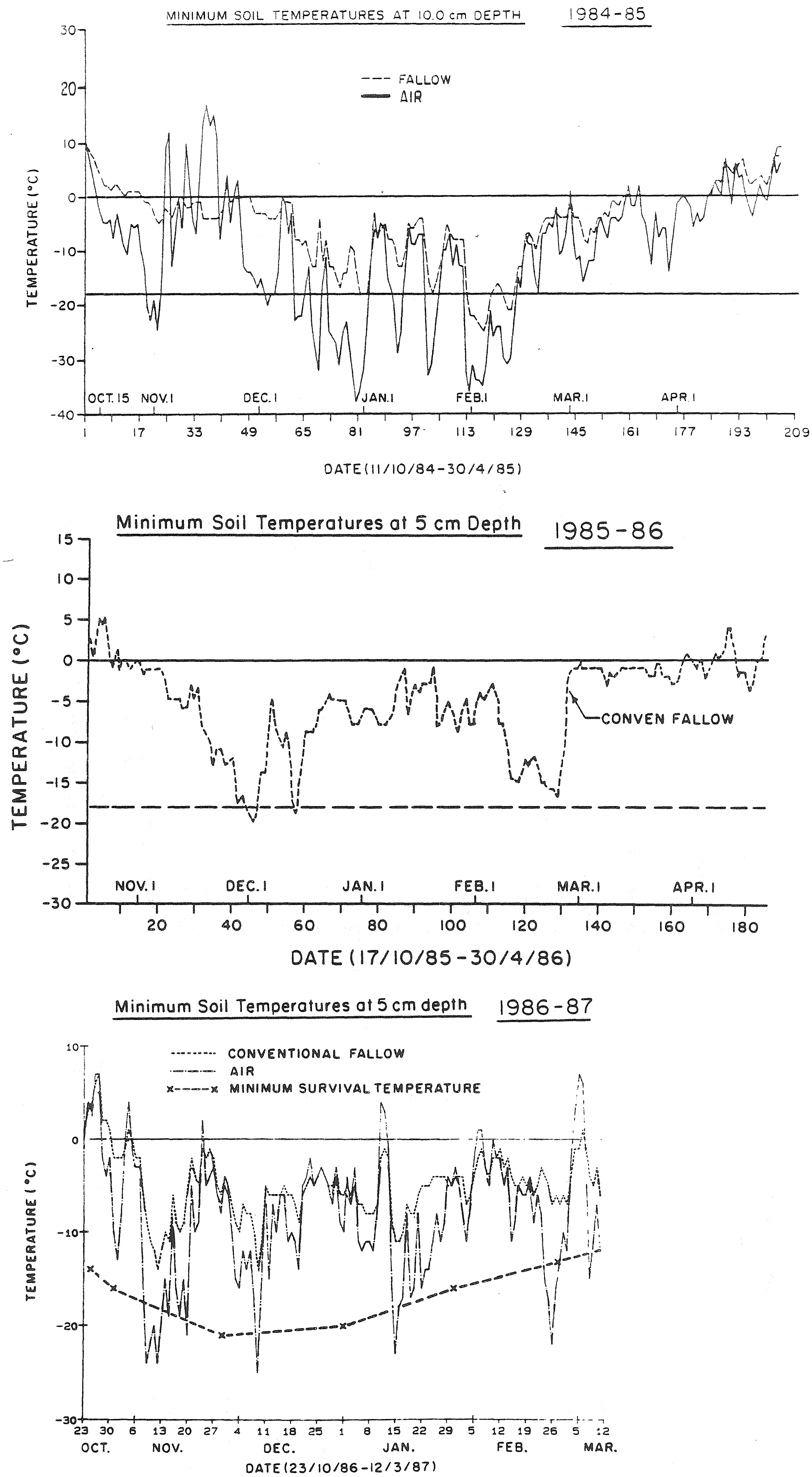

Figure 1. Soil temperatures, fall to spring for 1984-85, 1985-86 and 1986-87.

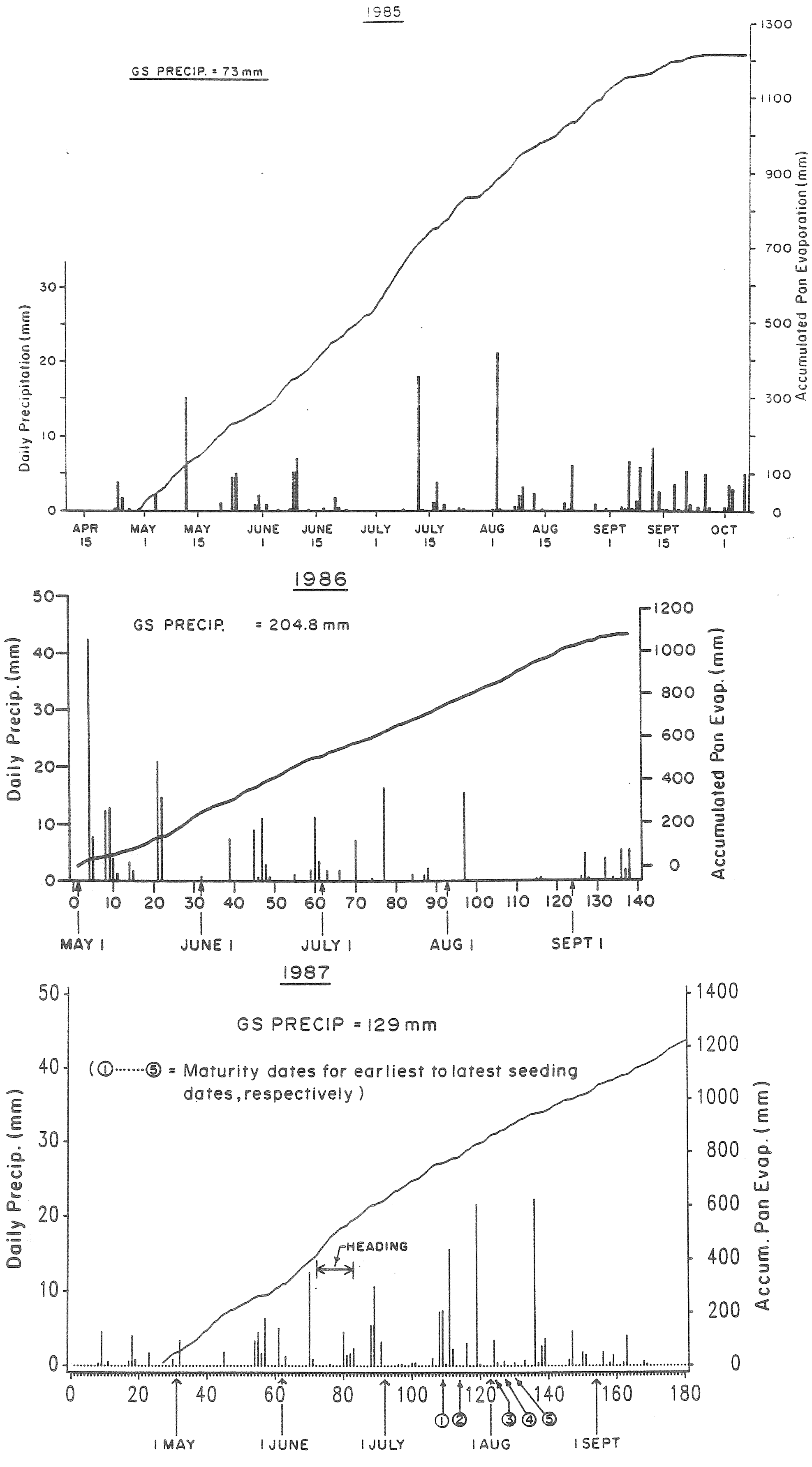

Figure 2. Growing season precipitation and accumulated pan evaporation for 1985, 1986 and 1987.

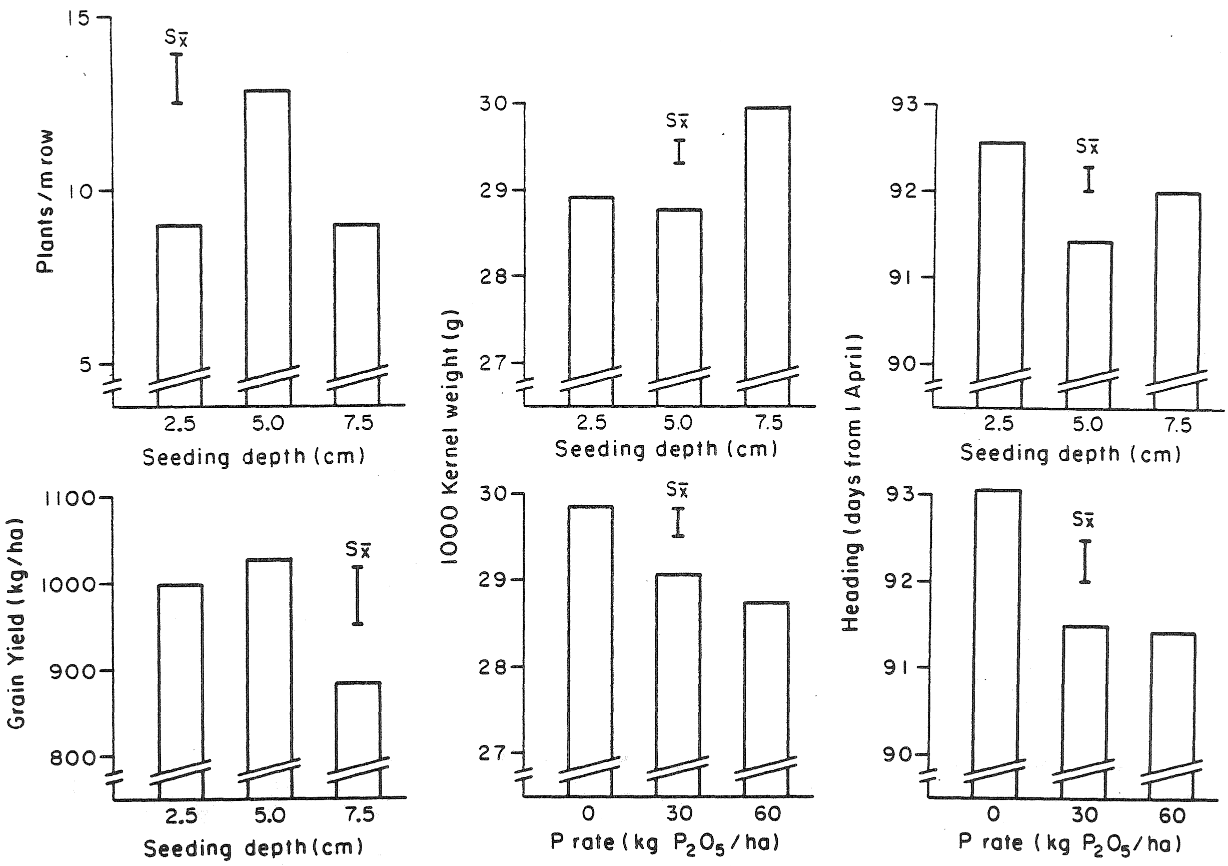

Figure 3. Plant density, grain yield, seed weight and days to head in 1985 (only the third date of seeding survived the winter).

Maturity

Days required to head were significantly reduced ($P < 0.05$) by seeding at the 5.0 cm depth compared to the 2.5 cm depth (Fig. 3) and P also significantly ($P < 0.01$) reduced days to head (Fig. 3). However, in both cases time saved was only about one day.

Grain Yields

Due to the drought, plant population was not reflected in final yield differences (Fig. 3) although yields of the deep-seeded treatment tended to be lower than yields of the 2.5 and 5.0 cm depth treaments. Phosphorus had no significant effect on yield (data not shown).

Grain Protein

Grain protein was unaffected by treatments, the average grain protein being 13.6%.

Seed Weight

Both depth of seeding and P fertilizer significantly ($P < 0.01$) affected seed weight (Fig. 3). Average seed weight was 29.2 mg. Seed weight response to treatments was the opposite to grain yield response as far as seeding depth was concerned indicating a possible compensating effect in a system of limited soil moisture.

1985-86

Soil Conditions and Weather

Soil moisture at seeding time was very good (Table 1) being well above the lower limit of available moisture. Nitrate-N in the top 50 cm was only moderate considering this was fallow (Table 1). This reflects the dry summer of 1985. Bicarbonate soluble P was also moderate in the top 15 cm depth of soil.

Soil temperatures at the soil surface dipped to below -18°C for a few days in late November, for a couple days in early December, and approached -18°C again in late February (Fig. 1). However, it was generally a mild winter for this region.

In the early fall, growing season precipitation was good (43 mm in September and 21 mm in October) and it was above average for the May-June-July period (205 mm) (Table 2), although there was a fairly dry 3-week period from the last week of May to the middle of June (about 5-leaf to shot blade stage of growth) (Fig. 2). The latter dry spell contributed to the crop not reaching its full yield potential. All plants of the first five seeding dates had germinated and most had emerged before winter set in. The sixth seeding date (Nov. 4) did not germinate until early spring.

Table 2. [+]Precipitation received during previous Aug. 1- Oct. 31 and during growing season for various seeding date treatments in 1985-86 and 1986-87

1986			1987		
Seeding Date	Maturity Date	Precip. received April 1-maturity (mm)	Seeding Date	Maturity Date	Precip. received April 1-maturity (mm)
Sept. 11	Aug. 5	219	Aug. 30	July 17	92
Sept. 20	Aug. 9	236	Sept. 12	July 22	117
Sept. 30	Aug. 14	236	Oct. 13	Aug. 2	142
Oct. 16	Aug. 14	236	Oct. 21	Aug. 5	147
Oct. 25	Aug. 15	236	Oct. 27	Aug. 8	147
Nov. 4	Aug. 17	236			

[+] Precipitation during April 1-July 31, 1986 = 219 mm and 1987 = 142 mm; precipitation during May 1-July 31, 1986 = 205 mm and 1987 = 129 mm; precipitation during Aug., Sept., and Oct., 1985 = 39, 43 and 21 mm, respectively; precipitation during Aug., Sept., and Oct., 1986 = 16, 81 and 26 mm, respectively. Long-term avg. precipitation for Aug., Sept., and Oct. = 42, 31 and 19 mm, respectively.

Plant Density

Plant counts in early May (Fig. 4) showed good plant survival, with the early September-seeded treatment having as good a plant population as obtained for comparable stubble-seeded crops (data not shown). Plant population decreased linearly with delayed seeding from September 11 to September 30, then levelled off to October 15 and increased slightly for 5 and 7.5 cm seeding depths of October 16 seeding. This type of response follows that outlined by Fowler and others. Plant population increased with seeding rate and decreased with seeding depth below 5 cm when the crop was seeded prior to October 26, but it increased with depth when seeded very late. The turnaround with late seeding may be due to the deeper seeded material germinating later which reduces their chance of being winterkilled (M.B. McLelland, Alta. Agri., Field Crops Branch, Lacombe, Agdex 112/20-3).

Grain Yield

Grain yield was significantly affected by time, rate and depth of seeding and the interaction of time and depth of seeding. Yields were highest for wheat seeded on September 11 (average 2250 kg/ha), decreased by 17% when seeded on September 20, and by 62% (847 kg/ha) when seeded on September 30 (Fig. 4). Yields then levelled off when wheat was seeded on October 15 and then increased when seeded later at depths of 5.0 or 7.5 cm; at a depth of 2.5 cm, yields were constant for the final 3 dates of seeding. This suggests that if the producer is seeding late, it may be to his advantage to seed very late rather than mid-late; however, he has the problem of deciding how late is very late. If seeding late on fallow it may be advantageous to seed a little deeper than the generally recommended "as shallow as possible". In fallow, a seeding depth of 5 cm produced as good or better yields than 2.5 cm. The 7.5 cm seeding depth was as good as the other two depths at the earliest seeding date, but from September 20 to october 15 the 7.5 cm depth gave the poorest yields. Generally, the yield responses mimicked the plant population results. Yields increased, though not linearly, with seeding rate (Fig. 4). These results might be less positive in a dry year, while after a very cold winter the relative yields might favour the higher seeding rates more (this remains to be determined).

Grain Protein

In contrast to 1985, protein was very low (i.e., < the desirable 11%) in spite of the application of 45 kg N/ha on fallow. Protein was only affected in this experiment by seeding rate, averaging 9.4, 9.3 and 9.2% for seeding rates of 60, 90 and 120 kg/ha, respectively.

Seed Weight

Seed weight responded to the three treatments in a manner generally similar to yield (Fig. 4 and Fig. 5). Rust played a significant role in reducing the seed weight of the later-seeded plants (Fig. 6). Later-seeded plants looked as robust and the heads as big as earlier-seeded plants, but rust infestation greatly affected the later-seeded plants while hardly affecting early-seeded plants. As with yield, seed size increased with rate of seeding (Fig. 5), but only slightly compared to effect of seeding date.

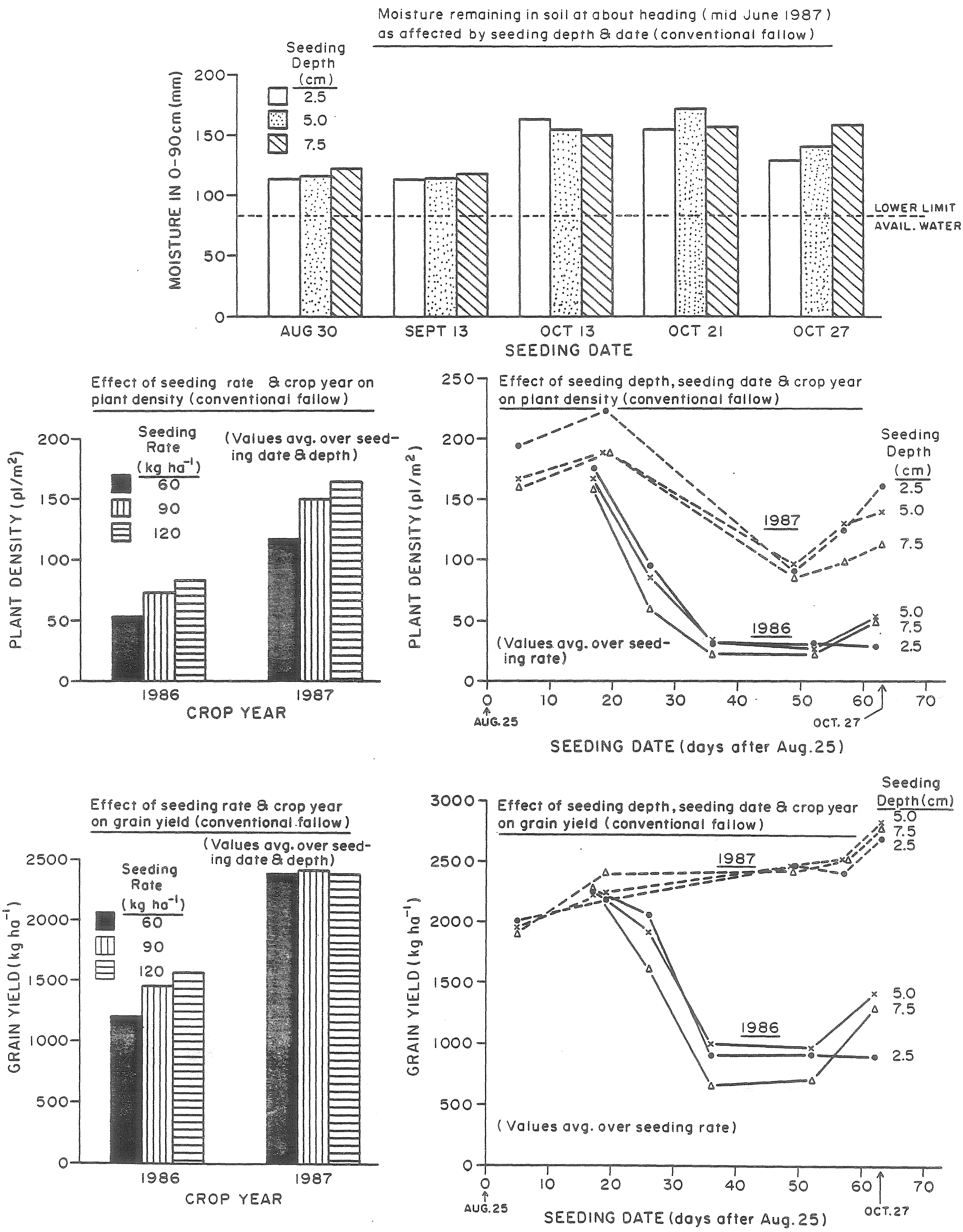

Figure 4. Top: soil moisture at heading 1987; Middle: plant density (1986 & 87); Bottom: grain yields (1986 & 87) (data for the 2 years pooled and analysed).

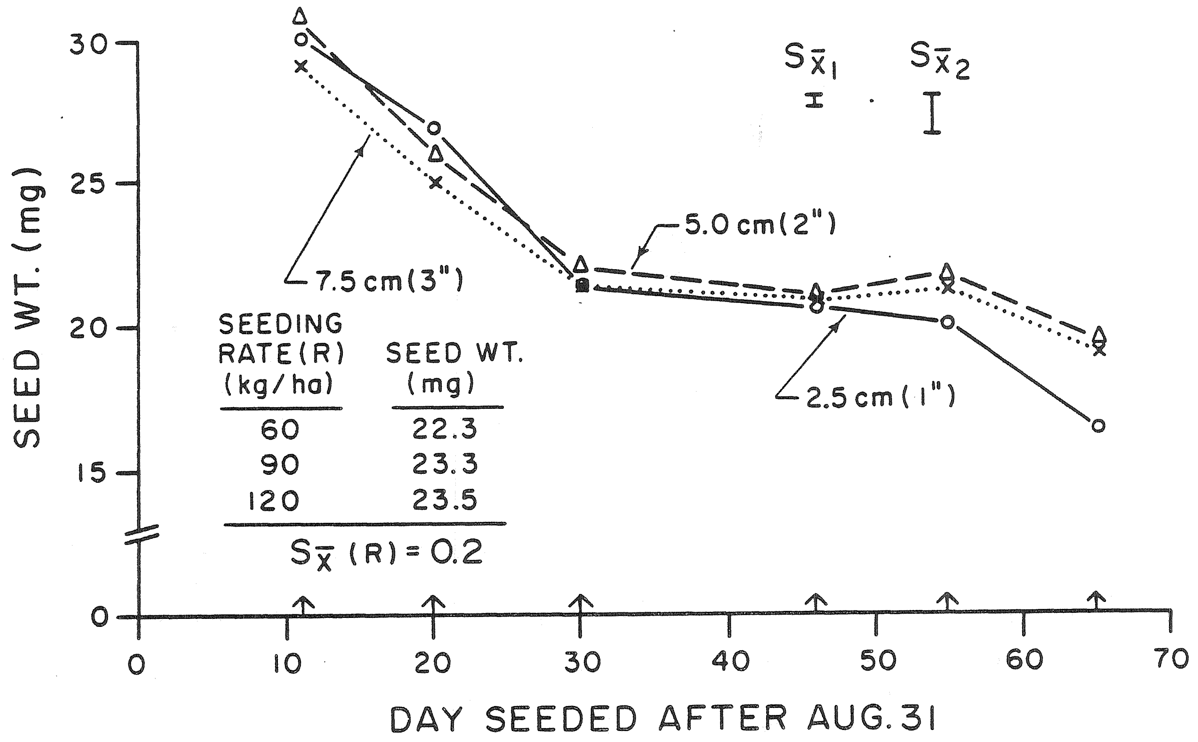

Figure 5. Effect of date, depth and rate of seeding on seed weight (1986). ($S\bar{x}_1$ is standard error used to compare depth of seeding means at a given date of seeding; $S\bar{x}_2$ is for comparing date of seeding means at the same depth or at different depths of seeding).

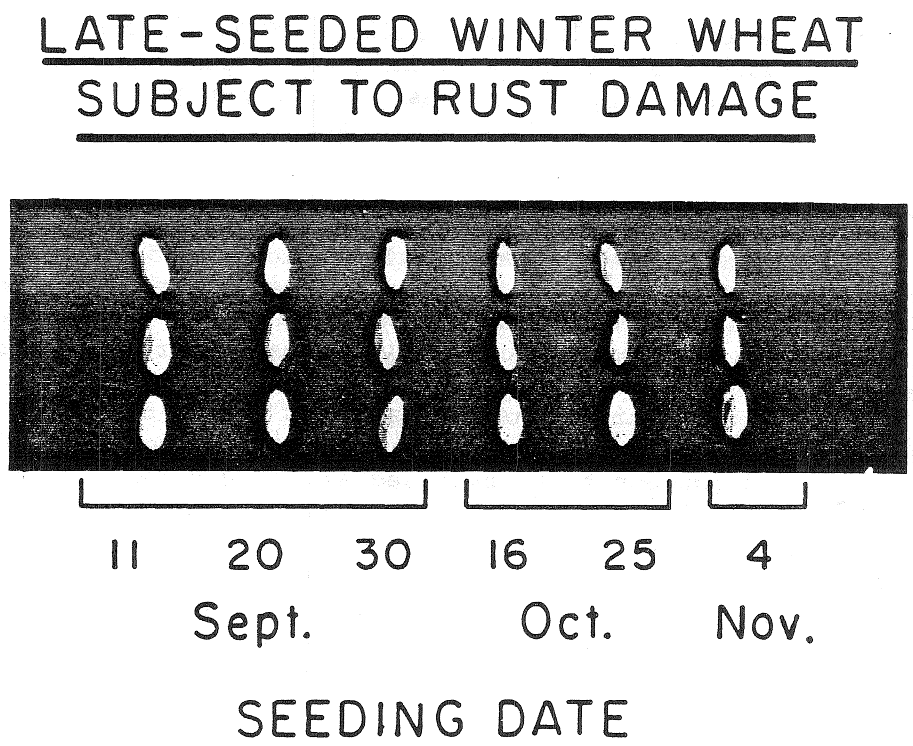

Figure 6. Effect of seeding date on rust damage to grain in 1986.

Maturation was delayed as seeding was delayed (Table 2). Thus, maturity was reached on August 5, 9, 14, 14, 15 and 17 for plants seeded on September 11, 20, 30, October 16, 25 and November 4, respectively (maturity was not assessed for the various subtreatments).

1986-87 and Combined 1985-87

Soil Conditions and Weather (1986-87)

Precipitation between August 1, 1986 and end of October, 1986 was 124 mm which was well above the long-term average of 86 mm for this period a Swift Current (Table 2). This precipitation was well distributed (data not shown) which played havoc with our attempt to establish dates of seeding tests on predetermined dates, but provided excellent moisture for the germinating seedlings (Table 1). Winter precipitation (data not shown) was low, thus soil moisture was not changed over winter (Table 1).

Temperatures between fall and spring were the mildest experienced on a continuous basis during the 3 years (Fig. 1). Minimum soil temperatures at 5 cm depth were never lower than -15°C. Thus, there was little likelihood of winter killing and this was reflected in the best plant stands obtained in the 3 years as shown in Figure 4.

Dates of seeding were quite haphazard in fall, 1986 (Aug. 30, Sept. 12, Oct. 13, 21 and 27) compared to the previous year and the two later-seeded treatments had not emerged when the soil froze, nor did they emerge till mid-April, 1987. Consequently, when run-off water eroded a low lying area that runs across these plots, one of the benefits of early seeding was demonstrated (Fig. 7) by the effective erosion control provided by the well rooted early-seeded winter wheat (Aug. 30).

Soil moisture in fall, 1986 and spring, 1987 was 278 mm/120 cm depth (Table 1). This moisture was about 40 mm greater than was found in the same treatment the previous spring. Soil tests NO_3-N was 49.5 kg/ha (the same as in 1986) and soil test P was 30.8 kg/ha, 10 kg/ha more than in 1986.

Plant Density

Since spring soil moisture was ideal (Table 1) and winter temperatures were very moderate (Fig. 1) the plant density even for the late-seeded treatments were quite good in 1987 (Fig. 4). When the plant density data for 1986 and 1987 experiments were pooled and analysed, each years' results showed the same general response to seeding rate (i.e., density increasing with rate of seeding), and an interaction between date and depth of seeding (Fig. 4). Generally, density decreased sharply with dates after mid-September and remained low to mid-October then increased at later dates, but not nearly to the level of the early-seeded wheat. Though significant, seeding depth, like seeding rate had only a moderate influence on plant density. Generally, density was highest when seeding was at 2.5 cm depths and lowest for the 7.5 cm depth (as reported by Fowler and others), though for very late seeding there was little to choose between the 2.5 and 5.0 cm depths in most cases. Finally, plant densities were much higher in 1987 than in 1986 at all dates and at late dates population was about 3 times higher (Fig. 4), no doubt due to the consistently milder winter weather of 1987.

Figure 7. Rill erosion on summerfallow controlled by early-seeded winter wheat but not by late-seeded wheat in 1986-87.

Table 3. Effect of seeding date, rate and depth on yield components and days to mature in 1986-87

		Plant height (cm)	1000 kernel wt. (g)	No. heads/ plant at harvest	No. kernel/ head	No. kernels/ plant	Yield/ plant (g)	No. days to head	No. days to maturity
								(days from April 1)	
Seeding Date	Aug. 30	63.9	28.7	1.76	20.9	36.8	1.06	72	109
	Sept. 12	62.6	27.7	1.56	22.6	35.3	0.98	73	114
	Oct. 13	70.1	33.4	2.89	32.1	93.8	3.15	77	124
	Oct. 21	67.5	31.2	2.34	30.4	71.9	2.25	78	127
	Oct. 27	68.9	30.9	2.21	28.4	62.7	1.95	81	130
	Signif.	**	**	**	*	**	**	ND	ND
Seeding Rate (kg/ha)	60	67.7	30.7	2.48	28.6	73.0	2.31		
	90	66.2	30.3	2.10	26.9	57.5	1.79		
	120	65.8	30.1	1.92	25.1	49.8	1.53		
	Signif.	**	**	**	**	**	**		
Seeding Depth (cm)	2.5	65.6	30.1	2.11	25.1	54.5	1.68		
	5.0	66.5	30.2	2.09	26.6	57.4	1.78		
	7.5	67.6	30.9	2.26	28.9	68.5	2.17		
	Signif.	**	**	NS	**	**	**		

Although the plant density of later-seeded wheat in 1987 was initially much more sparse than the earlier-seeded wheat, by mid-June the late-seeded plants were tillering more and by mid-July they were just as "bushy" and were now taller (Table 3). This was because the later-seeded wheat developed more slowly, used water more frugally initially (Fig. 4, top), and, while the earlier-seeded wheat had depleted most of its available water supply and the plants had dried up by July 15 (data not shown), the slower growing, late-seeded wheat was fortunte to obtain and use the late rains in July and early August to advantage (Fig. 2 and Table 2).

Grain Yields

When yields were pooled for 1986 and 1987 and analysed, the interaction of year x seeding depth x seeding date, and also the interaction of seeding rate x year were significant ($P < 0.01$) (Fig. 4, bottom). In contrast to results in 1986 which showed generally an inverse relationship of yield to date of seeding, in 1987 there was generally a direct relationship between seeding date and yield. The response for the two years emphasize two points: (a) the great uncertainty in yield expectations that can result when winter wheat is grown on conventional fallow and (b) that the overall best yields and least uncertainty in yield will likely be obtained when seeding is done as recommended, i.e., in early September. In 1986, yields of the later-seeded wheat had been decimated by rust; in 1987 there was no rust. Because of the rainfall distribution in 1987, later-seeded plants received more moisture (Table 2) and consequently produced more yield; the correlation between yield and precipitation for the different seeding dates being $r = 0.94^{**}$. The components of yield showed that the greater yields for later seeding dates in 1987 were due to more tillers surviving to maturity and greater seed weight for the later-seeded, longer growing wheat (Table 3). Yields increased with seeding rate in 1986 when rainfall was good and well distributed. However, in 1987, higher seeding rates exacerbated the drought effects, consequently there was no difference in yields due to seeding rate. In 1986 yields were generally higher for the 2.5 and 5.0 cm seeding depths, but in 1987 there was no consistent effect of depth on yield.

Maturity

There was a 3-week difference in days to reach maturity between the earliest and latest seeded wheat and herein lies another shortcoming of late-seeding (i.e., apart from not knowing when freeze up is going to arrive each year).

SUMMARY

In 1985, only the latest seeded treatment of 3 dates (the one that had not germinated in fall) survived the harsh winter of 1984-85. However, in that first year, even the first-seeded treatment was seeded later (Sept. 17) than ideal (Sept. 1-9). Yields of the surviving treatment averaged almost 1000 kg/ha and was lowest for the 7.5 cm depth of seeding and highest for the 5.0 cm depth.

In 1986 and 1987, winter temperatures being more conducive to winter wheat survival on fallow, plant densities and grain yields were more acceptable for summerfallow. Response of plant density to the treatments were

similar in these two years: density decreased with delayed seeding till mid-October then increased slightly if seeds were ungerminated in fall. Plant density also increased with seeding rate and was generally equal for 2.5 and 5.0 cm depth and lowest for 7.5 cm depth. Plant density was greater in 1987 than in 1986 because 1987 had a prolonged mild winter.

Yields in 1986 averaged 1405 kg/ha and in 1987 (a drier year) it averaged 2389 kg/ha. Yields were mainly affected by seeding date and year (weather). In 1986, a year of good rainfall but rust invasion, yields were highest for early seeding and decreased sharply with later seeding since later seeding delayed maturation and exposed these treatments to rust infestation. But, in 1987 there was an early drought and the same delay in maturation proved to be an advantage to late-seeded wheat since these plants were able to use late rains and thus produced the highest yields. Based on 2 years' data, the safest treatment with the least uncertainty appears to be the early-seeded wheat. Rate and depth of seeding affected yields, but only slightly compared to dates of seeding.

Erosion may be a problem on fallow soil; it was demonstrated that it is particularly important to seed early on such soils so the well rooted wheat can help protect the soil.

REFERENCES

CAMPBELL, C.A., NICHOLAICHUK, W., McANDREW, D.W., PARKER, G.E. and BEATON, J.D. 1984. Effect of stubble height and source, rate, time and method of application of N on yield of spring and winter wheat grown under zero till. p. 220-233 In Proc. Soils and Crops Workshop, University of Saskatchewan, Saskatoon, Sask.

FOWLER, D.B. 1982. Date of seeding, fall growth and winter survival of summerfallow-sown winter wheat and rye. Agron. J. 74: 1060-1063.

FOWLER, D.B. 1983. Production of stubbled-in winter wheat: Basic considerations. University of Saskatchewan, Division of Extension and Community Relations, Publ. No. 475, 4 pp.

FOWLER, D.B. and GUSTA, L.V. 1979. Selection for winterhardiness in wheat. 1. Identification of genotypic variability. Crop Sci. 19: 769-772.

FOWLER, D.B. and GUSTA, L.V. 1981. Winter cereal production in Saskatchewan: Oats, Barley, Triticale, Wheat and Rye. University of Saskatchewan, Saskatoon, Division of Extension and Community Relations, Publ. No. 264, 6 pp.

FOWLER, D.B., GUSTA, L.V., BOWREN, K.E., CROWLE, W.L., MALLOUGH, E.D., McBEAN, D.S., and McIVER, R.N. 1976. Potential for winter wheat production in Saskatchewan. Can. J. Plant Sci. 56: 45-50.

FOWLER, D.B., LIMIN, A.E. and GUSTA, L.V. 1983. Breeding winter wheat hardiness in wheat. pp. 136-184 In New Frontiers in Winter Wheat Production. Proc. of Western Canada Winter Wheat Conference. Held at the University of Saskatchewan, Saskatoon, Sask., June 20-22, 1983.

LOEPPKY, H., LAFOND, G. and FOWLER, D.B. 1987. The effect of seeding depth on crown location, plant development, winter survival and yield in winter wheat. pp. 339-348 In Proc. Soils and Crops Workshop, University of Saskatchewan, Saskatoon, Sask.