Agronomic Characteristics of Spelt Wheat : Seeding Rate Effects

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Introduction

The bread wheat species, *Triticum aestivum* and the pasta wheat species. *Triticum turgidum,* together constitute the staple food of about 35 per cent of the world's population, while providing about 20 per cent of the total calories consumed (Breiman and Graur, 1995). These wheats owe their vast cultivation areas to a wide array range of cultivars with different adaptations, on the one hand. and a vast variety of products, on the other. Spelt wheat is a sub-group of allohexaploid wheat, *T. aestivum.* Spelt has a brittle spike and hulled seed. Limited studies on its cultivation and performance have been conducted in Europe, where crop establishment and productivity of fall-sown spelt under marginal areas have been reported. Fall-sown spelt has a comparable grain yield to common wheat under wet-cool growing conditions. An acceptable grain yield under the above-mentioned conditions has been attributed to an ability to establish and grow in cool environment, while having a longer growth period than common wheat.

All available studies on the growth, development, and production of spelt wheat have been conducted in Europe. In that part of the world, a hulled kernel, along with a relatively low grain yield has limited its production to areas characterized by wet, heavy. poor soils. An acceptable establishment is the most convincing reason for its culture under the above conditions. During the past decade or two, there has been an increasing interest in low-input systems, due, mainly, to ecological concerns. The comparable grain yield of spelt wheat, with common wheat (Rimle, 1995; Ruegger et al., 1990), along with the capability to withstand some pathogenic diseases (Percival, 192 1; Kema, 1992a and 1992c; Iordanskaya, 1996), have attracted the attention of organic farmers in Europe. In Canada, too, ecological concerns, along with a considerable interest in spelt as a specialty crop, have increased interest in introducing spring spelt wheats from Europe. Spelt wheat cultivars are adapted to Northern Europe. Thus they might have some differences in crop performance due to different agronomic practices. Their appropriate seeding rate might be different from common wheats currently being used. Because there are no available records of spelt wheat growth and productivity in western Canada, first attempts in this regard should include some basic agronomic investigations. The main objectives of this study were to compare the agronomic performance of spelt and common wheat with differing seeding rates in Saskatchewan, with the help of growth analysis.

Materials and Methods

Spelt wheat cultivars "CDC Bavaria" and "PGR8801" and common wheat cultivar "Katepwa" were used in this study at seeding rates of 150, 250, 350, and 450 naked seeds/m*. Seeds were sown on 3 May and 2 May in 1995 and 1996, respectively in an approximate 3-4 cm soil depth. The study was conducted at the Seed Farm. University of Saskatchewan, Saskatoon in both years. Amonium phosphate (11-55-O) was applied with the seed at a rate of 57 kg/ha. Each experimental unit, i.e. plot. consisted of 24 rows, 3.6m in length, spaced 0.3 m apart. Weekly measurements were carried out on above-ground biomass and leaf area over a 12-wk period in 1995 and 14-wk period in 1996. Sampling started 30 May and 29 May and ended 15 August and 28 August in 1995 and 1996, respectively. For each sampling two rows, one m in length, were harvested at ground level. One quarter (weeks l-3 and 9- 12 for 1995, and l-3 and 12- 14 for 1996) or one eighth (wk 4-8 for 1995 and 4- 11 for 1996) of the harvested sample was stored immediately in a plastic bag and used for determining LAI. The remaining portion of the sample was dried at 80 °C for 48 h, in order to determine dry matter yield. A border of standing plants was left between harvested areas. Leaf area was measured by a LI-30OOA Portable Area Meter (LI-COR-INC. 4421 Superior Street, P.O. Box 4425, Lincoln, Nebraska). Three growth analysis factors, maximum leaf area index (LAImax), leaf area duration (LAD) and crop growth rate (CGR), were assessed based on above-mentioned weekly measurements. From 12 and 14 LAI values obtained for each plot in 1995 and 1996, respectively, the highest value was chosen for assessing maximum LAI of treatments. For each plot, LAI values were plotted against time. The area under the curve was used for assessing LAD. The area was estimated by integrating the curve between first and last measurements. Dry matter values for each plot for 12 and 14 wk, for 1995 and 1996, respectively, were plotted against time. Linear portion of the curve for each year was chosen. The linear portion of the curve was approximately six consecutive wk from 20th June to end of July for both years. A regression line was fitted to the linear portion and the regression coefficient was used for assessing CGR of different treatments. Seedling, tiller and spike counts were carried out on two labeled rows each 0.5 m in length. Grain yield was measured by combine harvesting four intact rows of each plot. Yield components were measured on 10 spikes, taken randomly from each plot. Harvest index was calculated based on the dry matter measured in the 12th sampling (1995) or 14th sampling (1996). For determining harvest index of naked seeds in spelt cultivars, hulled grains were passed through a de-awner machine 3-4 times. Harvest index for naked grain yield was calculated for each plot as naked grain yield divided by the sum of grain yield and straw yield and expressed as a percentage.

The experimental design was a randomized complete block with four replications, repeated over two y. The treatment design was a factorial with 3 levels of cultivar and 4 levels of seeding rate. Except for replications, the rest of the factors were assumed to be fixed effects. The statistical model was :

Y= Year Replication Cultivar Year*Cultivar Seeding Rate Year* Seeding Rate Cultivar*Seeding Rate Year*Cultivar*Seeding Rate (Error=Residuals)

In order to make sure the error variances of two years were not heterogeneous, a test of homogeneity of variances was carried out. Results of the test for all agronomic characteristics and grain yield in two years of experiment did not provide enough evidence that variances of these years were different. Thus, analyses of variance were combined over years. Despite CGR, the two years error variances for LAImax and LAD were shown to be heterogeneous. Thus, the data for the latter factors were analyzed and presented separately for each year. The SAS General Linear Model (GLM) procedure (SAS, 1988) was used for analyzing all data related to above-mentioned variables.

Results and Discussion

Environmental Conditions

The two growing seasons during which studies were carried out differed markedly for precipitation. The first year, 1995, was chamcterised by a lower than normal precipitation during the early part of the growing season and higher than normal precipitation during July and August. The second year was characterised by a progressively higher than normal precipitation for most of the growing season. Temperatures at two years were not markedly different from long term average, except for May, 1996, where it was approximately 3 °C lower than long term average.

Analvsis of Variance of Agronomic Performance and Growth Analvsis Factors

Year effects were significant for all agronomic characteristics except for number of kernels per spike and 1000-kernel weight (Table 1). This indicates that changes in grain yield due to year were mainly through the spike number, rather than through other grain yield components. Cultivar effects were significant for all agronomic characteristics, except for naked grain yield. Cultivar by year interaction effects were statistically significant for all agronomic characteristics and grain yield, with the exception of 1000-kernel weight. This is evidence that behavior of cultivars, with regard to these variables, depended on the environment under which they are grown. Seeding rate effects were significant for all agronomic characteristics and grain yield. with the exception of 1000-kernel wt. Interaction of year by seeding rate was significant only for hulled grain yield. This suggests that all agronomic characteristics, yield components, and grain yield, when averaged over cultivars, show an almost similar response to seeding rate, irrespective of environments under which these seeding rates are practiced. Interaction of cultivar by seeding rate was significant only for harvest index. This indicates that for all agronomic characteristics, grain yield components and grain yield, all cultivars responded in an almost similar manner to the seeding rate. A three-factor interaction was not detectable for any of the above-mentioned variables.

Table 1. Analysis of variance (Mean Squares) for tillers/m^2, spikes/m^2, kernels/spike, 1 OOO-kerne wt, hulled grain yield, and harvest index.

SOURCE	DF	TILLERS/ M^2	SPIKES/ M^2	KERNELS/ SPIKE	1000-KERNEL WIEGHT	HULLED YIELD	HARVEST INDEX
YEAR	1	1951396**	654556**	2.34	0.1	98496017”	618.14”
REP	6	3403 1**	1550	14.58”	9.6	334232”	15.02”
CULT	2	264183”	253843”	79.40”	800.4”	6701592”	1577.94**
RATE	3	137986”	33756”	107.10”	3.8	693926”	10.29**
C*R	6	17413	3040	3.51	12.1	159072	6.27‘
Y*C	2	37398’	39697”	121.80”	20.1	933612”	17.16”
Y*R	3	2260	SO60	8.50	8.9	588849**	1.31
Y*C*R	6	1639	2642	1.89	8.9	87548	1.91
ERROR	66	7544	...2555	2.76	13.0	98446	2.7s
CV		13	11	7	8	7	4

*, ** F test significant at the 0.05, and 0.01 level of probability, respectively.

Analysis of variance for maximum LAI and LAD indicates a significant e cultivar effects in both years (Table 2). Seeding rate had a significant effect on LAD in 1996 only. For CGR, in addition to significant effect for year, the combined ANOVA indicated significant effects for cultivar and seeding rate. Although no significant effect for cultivar by seeding rate interaction and year by seeding rate interaction was detected. the year by cultivar interaction was statistically significant.

Table 2. Analysis of variance (Mean Squares) for LAImax, LAD, and CGR.

SOURCE	DF	LAI-95	W-96	LAD-95	LAD-96	CGR (MS)
YEAR	1					142882”
REP	3’	0.6445**	1.277	16.057”	47.44”	951**
CULTIVAR	2	1.2054**	15.826”	57.422**	540.90”	4069**
RATE	3	0.0170	0.402	1.164	8.68’	2385”
C*R	6	0.0809	0.478	0.663	s.17	232
Y*C	2					1263**
Y*R	3					96
Y*C*R	6					113
ERROR	33[2]	0.0384	0.257	0.987	2.27	133
c v		14	12	12	6	9

* F test significant at the 0.05 level of probability.
** F test significant at the 0.01 level of probability.
‘DF for Rep(Year) for CGR = 6
[2]DF for Error term for CGR = 66

Comparison of Means of Agronomic Performance and Growth Analvses

Plant establishment for Katepwa was higher than that of the spelt cultivars. when averaged over seeding rates, while an average of approximately 80 per cent of the target numbers for different seeding rates was achieved (data not shown). Spelt wheat cultivars produced heavier kernels than Katepwa, irrespective of year and seeding rate (Table 3).

Table 3. Number of tillers, number of spikes, number of kernels per spike, 1000-kernel weight, hulled grain yield, and harvest index of three wheat cultivars.

CULT	TILLERS/ M^2	SPIKES/ M^2	KERNELS/ SPIKE	KERNEL WEIGHT(g)	HULLED YIELD (kgha^{-1})	HARV. IND. (%)
CDC BAV	563	372	25.0	45.8	4620	36.0
PGR8801	745	418	22.1	46.7	4818	33.9
KATEPWA	664	544	24.7	37.6	3945	47.0
LSD (0.05)	43	25	0.8	1.x	144	4.5

All cultivars showed an increase in tillering in 1996, compared to 1995 (Table 4). The relatively smaller response of CDC Bavaria, than other cultivars, to year, led to a sign&ant year by cultivar interaction. A similar trend was observed for spike production. Kernel number per spike of the spelt wheats was higher in 1996, than 1995. Kernel number per spike of Katepwa in 1996 was lower than 1995, leading to a significant interaction. All cultivars showed a measurable decrease in harvest index in 1996, compared to 1995. A more severe decrease in harvest index of Katepwa, compared to that of spelt wheat cultivars led to a cultivar by year interaction. Harvest indices of spelt wheat cultivars did not change with seeding rate (data not shown). Harvest index of Katepwa, however, decreased with seeding rate, leading to a significant interaction. Harvest index of Katepwa was higher than that of the spelt cultivars, irrespective of seeding rate. Hulled grain yield of spelt cultivars and grain yield of Katepwa increased in 1996, compared to 1995. Gram yield in 1996 was 1.44-. 1.64-. and 1.72-fold of 1995, in CDC Bavaria, PGR8801, and Katepwa, respectively. Due to the above differences in the extent of increase in the yield cultivar rank changed. A higher tillering rate (Ruegger *et al.,* 1990: Ruegger and Winzeler, 1993; Rimle, 1995), along with taller plants (Ruegger and Winzeler, 1993: Beglinger 1995: Rimle. 1995) larger grains (Ruegger *et al.,* 1990; Beglinger 1995; Rimle, 1995), and lower harvest index (Ruegger et *al.,* 1993; Beglinger, 1995; Rimle, 1995), than common wheat are agronomic characteristics which are common to fall-sown spelt cultivars. For some other characteristics and grain yield, however, some contradictions between reports exist. Results of our study show that for many agronomic performance characteristics studied here differences between spring spelt and common wheat agree with those reported by above-mentioned results for fall-sown spelt and common wheat.

Table 4. Number of tillers, number of spikes, number of kernels per spike, harvest index, and hulled grain yield of three wheat cultivars at two years.

CULTIVAR	HARV IND. (%)		TILLER/M^2		SPIKE/M^2		KERNEL/SPIKE		YIELD (kg ha^{-1})	
	(95)	(96)	(95)	(96)	(95)	(96)	95	96	(95)	(96)
CDC BAV	38.0	34.0	459	667	328	416	23.4	26.5	3790	5449
PGR8801	36.1	31.6	576	914	327	so9	21.1	23.1	3652	5985
KATEPWA	SO.3	43.6	so9	818	431	657	26.7	22.6	2902	4988
LSD (0.05)	1.2		61		36		1.2		222	

Number of tillers (including main stem) per m^2 was described by the equation : Y = 0.567X + 487.2 (r^2 = 93), meaning that with increasing seeding rate, number of tillers increased with a rate of, on average, 0.567 tillers/m' per each additional seed sown from 150 to 450 seeds/m*. Number of spikes per m^2 was described by the equation : Y = 0.283X + 360 (r^2 = 95). Number of kernels per spike was described by the equation : Y = -0.0163X + 28.82 (r^2 = 99).

Hulled grain yield increased in 1996, compared to 1995, irrespective of seeding rate (Table 6). A considerable amount of cultivar by year interaction in some of the agronomic characteristics and yield components, led to a measurable interaction of year by cultivar in grain yield. A meaningful cultivar by year interaction in grain yield means that there was a meaningful change in the productivity of cultivars relative to one another in two years. The reason of a Cultivar*Year interaction was, at least partially, a severe lodging in CDC Bavaria in 1996. Lodging in CDC Bavaria led to a lower rate of dry matter accumulation relative to PGR8801, in 1996. Taken together, above-mentioned events led to a change in the rank of the wheat cultivars across years, for grain yield.

The highest and lowest of LAImax in 1995 were produced by CDC Bavaria and Katepwa, respectively (Table 5). LAImax of spelt wheat cultivars, in 1996, was not significantly different, though significantly higher than that of Katepwa. The greatest and the smallest LAD in both years were produced by CDC Bavaria and Katepwa. respectively. Both LAImax and LAD in 1996 were, approximately, 3-fold greater than those in 1995. Spelt wheats had a similar CGR in 1995, while it was higher than Katepwa. PGR8801 had a higher CGR, than other cultivars, in 1996. CGR values increased from 73-99, in 1995, to 158 180 g m^{-2} $week^{-1}$ in 1996, *i.e.* 180 to 2 15 per cent increase. The highest and lowest increase belong to Katepwa and CDC Bavaria, respectively. Another biologically important change in CGR's in two years is a change in the rank of the cultivars. Considering a relatively higher LAD for CDC Bavaria in 1996, than PGR8801, one might anticipate a higher CGR for CDC Bavaria. However. CDC Bavaria plots were severely lodged in 1996. There are no detailed reports on the growth aspects and growth analysis of spelt wheat. The only reference to growth characteristics of spelt is made by Ruegger *et al. (1993),* where a lower LAl for fall sown spelt, than common wheat, was reported.

Table 5. LAImax, LAD, and CGR of three wheat cultivars in 1995 and 1996.

CULTIVAR	LAI-95	LAI-96	LAD-95 (weeks)	LAD-96 (weeks)	CGR (95) (g $m^{-2}week^{-1}$)	CGR (96) ($gm^{-2}week^{-1}$)
CDC BAVA	1.67	4.90	9.85	29.1	99.3	162.0
RGR8801	1.49	4.69	1.93	26.5	95.8	179.9
KATEPWA	1.13	3.08	6.06	18.0	73.4	158.1
LSD (0.05)	0.14	0.36	0.7 1	1.1	8.2	

Table 6. CGR and hulled grain yield of four seeding rates, 1995 and 1996.

SEEDING RATE	CGR (95) (g $m^{-2}week^{-1}$)	CGR (96) (g $m^{-2}week^{-1}$)	YIELD(95) ($kgha^{-1}$)	YIELD(96) ($kgha^{-1}$)
150	99.6	175.0	3887	5500
250	95.2	167.7	3457	5418
350	88.9	170.3	3323	5532
450	74.2	153.7	3126	5445
LSD (0.05)	Y.4		256	

According to Schmid and Winzeler (1990), spelt produces a higher number of spikes than common wheat. Based on Ruegger et al. (1990), however, due to the higher tiller mortality of spelt the latter produced the same number of spikes as common wheat. The number of spikelets per spike was the same, but an overall lower number of kernels per spike in spelt caused a lower grain yield, compared to common wheat.

Ruegger et al. (1993) conducted a study on spelt wheat performance under low and high altitude conditions, using low and high seeding rates. Overall, naked grain yield of spelt was lower than that of common wheat, but the extent of the difference at the high altitude was less than at the low altitude. Hulled grain yield of spelt was greater than that of common wheat cultivars at the high altitude location only. Seeding rate affected, kernel number more than spike number of the common and spelt wheat cultivars. Kernel size of spelt and common wheat was not significantly different, while harvest index of spelt was always lower than that of common wheat (31-36 vs. 43-44 per cent). A comparable grain yield of spelt and common wheat was also reported by Rimle

(1995), where spelt cultivars showed a greater yield stability than common wheat. Meanwhile, according to Ruegger *et al.* (1990) in an unfavorable year for cereal production, naked grain yield of spelt was higher than that of common wheat cultivars. though it was 20 per cent lower in a favorable year. Hulled grain yield of spelt was always higher than the naked grain yield of common wheat. They related the high yield stability of the spelt cultivars to their ability to produce a great number of tillers along with heavier kernels, than common wheat.

In conclusion, lack of a meaningful cultivar by seeding rate interaction in grain yield suggests that within the range of environmental conditions experienced during 1995 and 1996 and within the range of seeding rates examined, spelt wheat cultivars will have the same optimum seeding rate as the common wheat cultivar, Katepwa. Growth analysis factors revealed some interesting results. LAI, LAD, and to some extent CGR, of the spelt cultivars were substantially higher than those of common wheat, Katepwa. Spelt wheat cultivars took advantage of their substantially higher LAI and LAD to produce a higher biological yield. In our experiment, a higher LAD of CDC Bavaria, than PGR8801, did not lead to an advantage over PGR8801. in terms of grain yield in 1996. This is contrary to what Watson (1947) concluded. This contradiction can be attributed to the lodging that occurred in 1996. It seems that allocating a large portion of the biological yield to non-reproductive portions of the plant in spelt wheat cultivars led to a relatively smaller increase in grain yield in 1996, than 1995, when compared to Katepwa.

References

Beglinger C. 1995. Ph.D. Thesis.

Breiman A., and D. Graur. 1995. Wheat evolution. Isreal J. Plant Sci. 43 : 85-98.

Iordanskaya, I. V. 1996. Abstracts. In 5th Int. Wheat Conf. Ankara, Turkey.

Kema. G. H. J. 1992. Euphytica 63 : 207-217.

Kema, G. H. J. 1992. Euphytica 63 : 225-231.

Percival, J. 1921. Duckworth and Co. London.

Rimle R. 1995. Diss.Eth Nr.11242, ETHZ, Zurich.

Ruegger, A.; H. Winzeler. and J. Nosberger. 1990a. J. Agron. and Crop Sci. 165 : 110-120.

Ruegger A., and H. Winzeler. 1993. J. Agron. and Crop Sci. 170 : 289-295.

Ruegger, A.; M. Winzeler, and H. Winzeler. 1993. J. Agron. and Crop Sci. 171 : 124-132.

Schmid, J. E. and H. Winzeler. 1990. J. Genetic and Breeding. 44 : 75-80.

Watson, D. J. 1947. Ann. Bot. 11: 41-76.

Winzeler, and B. Keller. 1994. Theor. Appl. Genet. 88 : 994-1003.

------- 1988. SAS/STAT guide for personal computers. Ed. 6.03. SAS Institute Inc. Gary NC.