A Comparison of Durum and Common Wheat Response to Nitrogen and Seeding Rates

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Introduction

The majority of the world's export production of durum wheat (*Triticum durum*) is grown in Saskatchewan and North Dakota. Basic recommendations from extension bulletins are similar for both common wheat (*Triticum aestivum* L. em Thell.) and durum wheat (Danke et al., 1988; Panchuck, 1988) even though they are different species and used for different end products. This present study was initiated to answer the question, "What substantiates the similar treatment of these different wheat species in crop production?"

The objectives of this study are: 1) to determine the effects of environment, nitrogen, and plant population on wheat and 2) to determine if durum and common wheat respond similarly to these influences.

Materials and Methods

In 1988 and 1989, two separate tests were set up at six locations chosen to represent a cross section of the environments under which durum can be grown. Only four locations were used for the combined analysis because of field variability. Year, location, soil characteristics at seeding are given for each location of the tests in Table 1. At each location of the study, seeding rate and nitrogen rate tests were established. Each test was planned as a cultivar by treatment experiment, with the same cultivars used in all tests.

Six cultivars were selected to represent a cross-section of the spring wheat cultivars currently produced in Saskatchewan. Durum cultivars were selected for their various agronomic characteristics as well as popularity. The durum cultivars included Wakooma, Kyle, Medora, and Sceptre. Katepwa hard red spring, the commercial standard, and HY320 prairie spring, a semidwarf, were chosen as common wheat cultivars for comparison.

Adjustments were made to seeding rates to place 150 ,250, or 350 viable seeds m^{-2} for each cultivar. Each test was set up in a randomized complete block design with 4 replicates in 1988 and 6 replicates in 1989.

Table 1. Location and soil characteristics of experimental environments, 1988-1989.

Location	Texture	Soil Zone	NO_3-N 0-60cm	P 0-15cm	K 0-15cm	SO_4-S 0-60cm
			kg ha^{-1}			
KCRF 88	Loam	Dk Brown	190	42	940	94
KCRF 88[a]	Clay loam	Dk Brown	65	24	810	160
Dinsmore 88	Clay Loam	Dk Brown	24	12	475	81
Rosthern 89	Loam	Black	51	40	500	78
KCRF 89	Loam	Dk Brown	99	22	750	150
KCRF 89[b]	Clay	Dk Brown	33	---- unavailable ----		

a 1988 nitrogen test
b 1989 nitrogen test

Nitrogen rates bracketed recommendations of the Saskatchewan Soil Testing Lab. In 1988, each plot received ammonium nitrate fertilizer, top dressed by hand at the time of seeding, with 0, 30, or 60 kg ha^{-1} of actual N. This fertilizer was in addition to that banded with the seed. In 1989, ammonium nitrate fertilizer was applied at the time of seeding by the same method as in 1988 except that all plots received at least the lowest level recommended by soil test analysis. Each plot received an additional 0, 30 or 60 kg ha^{-1} of actual N, bracketing the normal to wet soil test recommendations.

Seedlings m^2 were estimated about one week after emergence. Maximum tiller number was measured at Zadoks stage 60. The number of fertile spikes were measured at maturity. All values were reported on a square meter basis. Grain yield was harvested from 5.5 m plots with a 1.25 m Hege plot harvester. Kernel weight was estimated from a random sample of 250 seeds from each plot. Kernels spike^{-1} were calculated from yield, kernel weight, and spike number. Protein concentration was measured using the Udy dye method.

All field variables measured were analyzed using analysis of variance procedures on combined locations. Locations from 1988 and 1989 were combined and analyzed as four separate environments. Means comparison were completed using *a priori* contrasts and trend analysis.

Seeding Rate Results and Discussion

Yield

Research on the effect of seeding rate on yield of small grains has shown that yield is not greatly affected by plant population (Guitard et al., 1961; Briggs, 1975) or if differences occurred they were not consistent among environments (Baker, 1982). Recommendations range from 75 seeds m^{-2} in the Brown Soil Zone (Pelton, 1969) to 350 seed m^{-2} in the Black Soil Zone (Guitard et al, 1961; Briggs, 1975; Faris and DePauw, 1981; Wright et al., 1987).

Climatic conditions in 1988, were dry and hot throughout the growing season while 1989 conditions were much improved and closer to normal. Yields varied from 48 g m^{-2} at Dinsmore to 265 g m^{-2} at KCRF 1989 (Table 2). Averaged over cultivars and environments, yield increased linearly by 7% due to increases in seeding rate from 150 to 350 viable seeds m^{-2} (Table 5). Over all cultivars and environments there was no significant difference in yield between planting densities of 150 and 250 seeds m^{-2}. Differences in yield response due to increases in seeding rates varied across environments. Greater yields were attained with increased seeding rate in two environments, but only the Rosthern environment exhibited a significant response (Table 3). Rosthern, in the Black Soil Zone, received the most precipitation over the growing season and was conducive to achieving a yield response to increased seeding rate. These observations are in agreement with Holliday (1960) who found that the more favourable the general conditions, the higher the optimum seeding rate. Although yield responses in the Dark Brown Soil Zone were small or not present, no environment showed a significant negative response. This is in contrast with the findings of Pelton (1969) and Read and Warder (1982). Most research has shown diminishing increases in wheat and durum yield with increases in seeding rate (Guitard et al., 1961; Chatha, 1974; Briggs, 1975; Wright et al., 1987). The linear response achieved may have been due to seeding rates not being high enough to diminish yield increases.

Semidwarf wheats typically out yields red spring wheat under Saskatchewan conditions, which have been documented recently in the literature (Cutforth et al., 1988; Brandt, 1989). Cutforth et al. (1988) found semidwarf cultivars out yielded standard height and the durum wheats slightly out yielded the common wheats under all moisture regimes. HY320, although not different than Medora and Sceptre, Kyle and Wakooma yielded 10% greater than Katepwa (Table 2). There was no significant interaction of cultivars with seeding rate or environment (Table 5) and there should be no reason to expect cultivars to behave differently in response to seeding rate or environment. Black and Siddoway (1977) found little difference in the response of durum and common wheat to seeding rate. The results of this study are in agreement with Wright (1989) that no difference in seeding rates for high yielding semi-dwarf and hard red spring wheat cultivars are required, other than for seed size, although much of the literature has observed seeding rate by cultivar interactions (Pendleton and Dungan, 1960; Briggs, 1975; Faris and DePauw (1981).

Table 2. Treatment means and standard errors for yield and protein concentration from four combined seeding rate tests

	Yield	Protein Concentration
	g m^{-2}	%
<u>Cultivar</u>		
Wakooma	172	19.4
Kyle	175	19.3
Sceptre	178	18.4
Medora	179	19.2
Katepwa	170	17.8
HY320	187	16.5
SE (5, 272 df[a])	NS	0.18
<u>Seeding Rate</u> (seeds m^{-2})		
150	171	18.3
250	177	18.6
350	183	18.5
SE (2, 272 df[a])	3.5	NS
<u>Environments</u>		
Dinsmore 1988	48	16.1
KCRF 1988	64	19.1
Rosthern 1989	248	18.9
KCRF 1989	265	19.5
SE (3, 16 df)	13.9	0.45

a 204 df for protein concentration

Table 3. Average grain yield of six cultivars over four environments seeded at three rates from four combined seeding rate experiments[*].

Seeds m^{-2}	Environment			
	Dinsmore	KCRF 1988	Rosthern	KCRF 1989
	Yield g m^{-2}			
150	43	63	229	269
250	49	61	253	258
350	51	69	262	268

* Standard errors of 6.9 for yield with 272 df

<u>Plant stand</u>

In the present study, increases in seeding rate caused a positive linear response in plant stand (Table 5). This has been observed previously in the literature (Guitard et al., 1981; Faris and Depauw, 1981; Hucl and Baker, 1989; Hunter, 1989). The cultivars fell into two distinct groups. Approximately 60% of viable seeds emerged in Katepwa, Wakooma, Medora, and Kyle, while less than 50% emerged in HY320 and Sceptre. Poorer seedling stands in 1988 environments than in 1989 environments may be due to the extremely dry conditions at seeding in 1988. Sceptre appeared to be most susceptible.

Medora durum had a greater positive response to increases in seeding rate than the average of the other cultivars (Table 6). HY320 had a smaller linear response than the average of other cultivars. High yielding semidwarf wheats have not been found to respond differently from standard height cultivars to seeding rates (Faris and DePauw, 1981; Brandt, 1989; Hunter, 1989). Extremely dry conditions at Dinsmore caused a two week delay in emergence which may have been the reason for smaller than average linear increase in seedling stand with seeding rate as compared to other environments (Table 7). In 1988 environments, Sceptre had extremely poor emergence which may have been due to seedling disease, but this was not investigated further.

Table 4. Treatment means and standard errors for agronomic characteristics from four combined seeding rate tests.

	Seedlings m^{-2}	Tillers m^{-2}	Spikes m^{-2}	Kernels $Spike^{-1}$	Kernel Weight
					mg
<u>Cultivar</u>					
Wakooma	146	356	219	19	36
Kyle	149	343	215	19	38
Sceptre	122	322	191	24	36
Medora	148	296	194	21	38
Katepwa	152	415	271	20	26
HY320	117	329	194	24	33
SE (5, 272^{+} df)	4.4	15.1	5.8	0.8	0.3
<u>Seeding Rate</u> (seeds m^{-2})					
150	99	287	202	22	34
250	140	353	217	21	35
350	178	389	222	22	34
SE (2, 272^{+} df)	3.1	10.7	4.1	NS	NS
<u>Environments</u>					
Dinsmore 1988	85	150	86	17	34
KCRF 1988	147	229	178	10	37
Rosthern 1989	163	466	263	27	35
KCRF 1989	145	426	274	31	32
SE (3, 16 df)	4.1	18.8	7.5	1.3	0.6

+ 204 df for kernels $spike^{-1}$ and kernel weight

Table 5. Contrasts for cultivar, seeding rate, and environment for all dependent variables from four combined seeding rate tests.

Contrast and Interactions	Seedlings m^{-2}	Tillers m^{-2}	Spikes m^{-2}	Kernels $Spike^{-1}$	Kernel Weight	Yield	Grain Protein
<u>Cultivars</u>							
Common vs durum	*	**	**	**	**	NS	**
HRS vs CPS	**	**	**	**	**	**	**
Wakooma vs new	NS	**	**	**	**	NS	**
Residual	**	**	**	**	**	NS	**
<u>Seeding rates</u>							
Linear	**	**	**	NS	NS	**	NS
Quadratic	NS	NS	NS	*	NS	NS	NS
<u>Environments</u>							
1988 vs 1989	**	**	**	**	**	**	**
1988 envs	**	**	**	**	**	**	**
1989 envs	**	**	**	**	**	**	**
<u>Interactions</u>							
Cv * SR	**	NS	NS	NS	*	NS	NS
Env * SR	**	**	**	NS	NS	*	NS
Env * Cv	**	*	**	**	**	NS	**
Env * SR * Cv	NS	NS	NS	NS	NS	NS	NS

NS, *, ** represents non-significant, significant at the 0.05 probability level, and significant at the 0.01 probability level

Table 6. Average seedling number of four environments for three seeding rates and six cultivars[a].

Seeds m^{-2}	Cultivars					
	Wakooma	Kyle	Sceptre	Medora	Katepwa	HY320
			Seedlings m^{-2}			
150	106	107	79	98	110	93
250	145	142	139	151	148	115
350	186	196	150	197	196	141

* Standard error=7.5 (272 df)

<u>Tillering</u>

Tiller number averaged over cultivars and environments ranged from 287 to 389 seedlings m^2 as seeding rate increased (Table 4). The positive linear response shown in Table 5 agrees with Faris and Depauw (1981), but tiller number usually increase at a decreasing rate (Guitard et al., 1961; Puckridge and Donald, 1967; Hucl, 1986;

Hucl and Baker, 1989). Katepwa consistently initiated the most visible tillers, while Medora initiated the fewest. Poor seedling stands of HY320 and Sceptre resulted in low tiller number. Medora, which developed a good seedling stand appears to be a cultivar of limited tillering potential. Tiller mortality increased linearly with increases in seeding rate (data not presented), which is in agreement with Puckridge and Donald (1967) and Hucl and Baker (1989). Higher tiller mortality in 1989 than 1988 environments may be due to higher numbers of tillers being produced in the moist early part of the growing season that could not be supported later.

As was observed for plant stand, smaller responses to increases in seeding rate were observed in 1988 than 1989 (Table 7). Changes in rank order of cultivars occurred in different environments causing a significant cultivar by environment interaction (Table 5). Sceptre compensated for poor plant stand by producing more tillers plant^{-1} due to reduced interplant competition, tillers m^{-2} remained significantly fewer than other cultivars.

Table 7. Average seedling and tiller number of six cultivars for four environments seeded at three rates[a].

Seeds m^{-2}	Environments			
	Dinsmore	KCRF 1988	Rosthern	KCRF 1989
	Seedlings m^{-2}			
150	69	106	112	100
250	82	150	162	149
350	104	184	216	184
	Tillers m^{-2}			
150	122	195	370	376
250	146	226	487	443
350	181	266	540	460

* Standard errors of 6.2 and 21.4 for seedlings m^{-2} and tillers m^{-2} with 272 df for error.

Yield components

Yield components were measured to help explain yield responses. The only yield component significantly affected by seeding rate was spikes m^{-2} (Table 4). Spikes m^{-2} has been documented as the yield component most sensitive to seeding rate (Pendleton and Dungan, 1960; Guitard et al., 1961; Bremner, 1969; Scott et al, 1975). The linear increase in spikes m^{-2} in response to increases in seeding rate agrees with that reported in the literature (Pelton, 1969; Faris and De Pauw, 1981; Chatha, 1974; Hunter, 1989). The linear response observed was highly significant (Table 5). The significant seeding rate by environment interaction was attributed to a negative response at KCRF 1989 (Table 8). Good conditions for tillering earlier in the growing season followed by drought caused high tiller mortality (data not shown), particularly in the greater plant populations with increased competition. Kernel weight and kernels per head were not affected by seeding rate. No change in kernel size has been previously documented (Briggs, 1975).

Table 8. Average spikes m^2 of six cultivars over four environments, seeded at three rates*.

Seeds m^{-2}	Environment			
	Dinsmore	KCRF 1988	Rosthern	KCRF 1989
	Spikes m^{-2}			
150	72	155	243	280
250	93	183	267	271
350	92	197	280	270

* Standard errors of 8.2 for spikes m^{-2} with 272 df

Katepwa was consistently the most prolific producer of spikes, and had the lightest kernel weight and among the fewest kernels $spike^{-1}$ (Table 4). Faris and DePauw (1981) and Cutforth et al. (1988) found similar characteristics for Neepawa. Durum cultivars typically had the fewest spikes m^{-2}, largest seed size, and variable numbers of kernels $spike^{-1}$. Semidwarf wheats have more kernels $spike^{-1}$ than standard height wheats (Bremner and Davidson, 1978; Fischer and Stockman, 1986; Cutforth et al., 1988). This trend was also seen in the present study and more than offset the low production of spikes.

Campbell et al. (1977) documented lower kernel weights and kernels $spike^{-1}$ under dryland than irrigated conditions. Kyle and HY320 had lower kernel weights at KCRF in 1989 than in the other (data not shown). These two cultivars have particularly long growing season requirements. Moist conditions early in the growing season followed by dry conditions during the filling period may have hastened maturity and due to limited moisture and the last yield component was stressed.

Protein

The protein content of wheat varies with the type of wheat and the location in which it is grown. The 40-year average protein content for hard red spring wheat in the areas represented by this test would be 14-14.9% (Evans, 1986). Percent grain protein was higher than normal in all environments, ranging from 16.1% at Dinsmore to 19.5% at KCRF in 1989 (Table 2). Heat and moisture stress during grain filling occurred in all environments of this study reduced yield and indirectly increase protein content. Findings in the present study support the work of Pendleton and Dungan (1960) that saw no effect of seeding rate on protein in winter wheat.

Nitrogen Rate Results and Discussion

Many of the observations for the main effects of cultivars and environments on the variables studied were similar to that observed in the seeding rate section. Only important differences from what has already been stated will be discussed here.

Yield and protein

The combined effect of increases in spike density and kernels head^{-1} contributed to positive yield responses, while decreased kernel weight contribute to diminishing and negative grain yield responses to nitrogen under irrigated (Gardner an Jackson, 1976) and rainfed conditions (Bruckner and Morey, 1988). The results of the present study generally agree with these assumptions. A 6% increase in yield from applying 30 kg ha^{-1} of nitrogen was observed (Table 9). The significant increase from 30 kg ha^{-1} of was mainly due to a positive linear relationship with spikes m^{-2} (Table 10). The application of 60 kg ha^{-1} showed no advantage from not applying any additional nitrogen due to the decreased kernel weight, although that decrease was less than 1 mg. Sceptre and Katepwa had the greatest negative response in kernel weight from applying 60 kg ha^{-1} nitrogen.

There was no interaction for yield between the important interactions of cultivar by nitrogen rate or environment. This has been observed in previous studies of spring wheat (Kosmolak and Crowle, 1980), and common and durum wheat (Black and Siddoway, 1977) in previously reported literature.

5.2.2 Protein concentration

In the review of Henry et al. (1986), it was concluded that with low available soil N levels and no moisture stress, the effect of N at rates up to 100 kg ha^{-1} will be almost entirely to increase yield. At intermediate moisture stress, the addition of N will increase both protein and yield. Under conditions of severe moisture stress grain protein will be high and yields will be low.

Direct positive increases in protein concentration due to increases in nitrogen applied occurred in all environments of the present study (Table 10). At Dinsmore in 1988, increases in protein concentration of 2% from application of 60 kg ha^{-1}, while only 1% increase was observed in 1989 (Table 9). This difference may be due to decreased yield and increased protein due to drought in 1988. In 1989, available nitrogen was utilized to increase yield as well as protein due to improved moisture conditions.

5.2.3 Tillering

In the present study, no effect of N was observed on tiller numbers (Table 9). Results of the present study agreed with Bremner (1969), who found that a spring wheat cultivar with low tillering potential did not respond to increases in N rate. The cultivars utilized in the present study have similar tillering potential as low tillering cultivars described by Bremner.

Table 9. Treatment means and standard errors for yield components and protein concentration for four combined nitrogen rate tests.

	Spikes m^{-2}	Kernel Weight	Yield	Protein Concentration
		mg	g m^{-2}	%
Cultivar				
Wakooma	170	35	155	20.3
Kyle	177	38	159	19.4
Sceptre	162	35	150	18.9
Medora	158	38	172	19.3
Katepwa	218	25	158	18.2
HY320	158	33	175	16.9
SE (5, 204[a] df)	5.2	0.2	4.8	0.18
Nitrogen rate kg ha^{-1}				
0	169	34	158	18.1
30	175	34	167	18.9
60	177	34	159	19.5
SE (3, 204[a] df)	NS	NS	NS	0.13
Environments				
Dinsmore 1988	86	33	57	16.5
KCRF 1988	97	38	107	-
Rosthern 1989	226	34	232	20.4
KCRF 1989	231	31	197	19.6
SE (3, 12[b] df)	11.7	0.5	14.0	0.6

a 272 df for error for spikes m^{-2} and yield
b 16 df for error for spikes m^{-2} and yield

Table 10. Contrasts for cultivar, nitrogen rate, and environment for maximum tiller number and yield components from four combined nitrogen rate tests.

Contrast and Interactions	Spikes m^{-2}	Kernel Weight	Yield	Protein Concentration
Cultivars				
Common vs durum wheat	**	**	NS	**
HRS vs CPS	**	**	**	**
Wakooma vs new cvs.	NS	**	NS	**
Residual	**	**	**	**
Nitrogen rates				
Linear	*	*	NS	**
Non-linear	NS	NS	*	NS
Environments				
1988 vs 1989	**	**	**	**
1988 environments	*	**	**	--
1989 environments	NS	**	**	**
Interaction				
Cv * NI	NS	NS	NS	NS
Env * NI	NS	**	NS	**
Env * Cv	**	*	NS	**
Env * NI * Cv	NS	NS	NS	NS

NS, *, ** represents non-significant, significant at the 0.05 probability level, and significant at the 0.01 probability level

Conclusions

Yield differences were significant for both nitrogen and seeding rates, among six cultivars and among four environments. The important interactions of cultivar with seeding rate, cultivar by nitrogen rate and cultivar with environment were not significant from the combined analysis of the nitrogen and seeding rate experiments. This indicates that separate cultivar recommendations would not be necessary. The interaction of seeding rate with environment was significant for seeding rates, with only one of four tests showing a positive yield response to higher seeding rates.

Environments in the present study could be characterized as extremely dry throughout the growing season in 1988, while 1989 was closer to normal but during the grain filling period conditions were very dry. There was a five-fold difference in yield from the worst test at Dinsmore in 1988 to the best at KCRF in 1989. These conditions delayed emergence at Dinsmore by two weeks. The number of emerging seedlings was significantly lower in 1988 than 1989. It is also evident that many died soon after emergence. Formation of tillers was 150% higher in 1989 and similar findings were observed for spikes m^{-2} and kernels $spike^{-1}$. Good conditions during the vegetative phase in 1989 promoted good tiller development, drought later in the season caused high tiller mortality.

Seedlings m^{-2}, tillers m^{-2}, and spikes m^{-2}, and yield all increased linearly with increases in seeding rate. Increases in yield were due to increases in spikes m^{-2}. There was no effect of increases in seeding rate on kernel weight but there was a significant non-linear decrease in kernels $spike^{-1}$. Katepwa was the most prolific producer of tillers and was not higher in tiller mortality than other cultivars. HY320 was the highest yielding cultivar due to greater numbers of kernels $spike^{-1}$. There was no effect on protein concentration.

Only the application of 30 kg ha^{-1} of N was beneficial to yield. This increase was due to the beneficial effect on spikes m^{-2} while decreased kernel weight and kernels $spike^{-1}$ resulted in no yield benefit due to 60 kg ha^{-1}. Direct positive effects on protein concentration were observed.

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