ND-09F

Annual Report to the Foundation for Agronomic Research

Chloride x Variety Trials, 1996

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I. Introduction

Chloride research conducted in the 1980's in North Dakota confirmed beneficial effects of Cl fertilization on maturity, disease resistance, yield, and kernel plumpness in barley. Research conducted at the same time in South Dakota focused on spring wheat, and discovered strong Cl x variety interactions. Current research in Montana has also revealed striking Cl x variety interactions in winter wheat.

A research effort, coordinated by the FAR, was begun in 1996 to screen currently-grown wheat varieties for response to Cl. Research is under way in South Dakota, North Dakota, and Manitoba. This report concerns the research performed in North Dakota in 1996.

II. Materials and Methods

Chloride x variety trials was performed near Chaffee (40 mi WSW of Fargo) and near Dickinson, North Dakota. Fifteen varieties were used. The varieties chosen, and the rationale behind the choices, are shown in Table 1. Care was taken to include historic varieties of known Cl response characteristics, currently popular varieties, recently released varieties, Canadian varieties, and two durum wheat varieties. Durum wheat was added by both the Manitoba researchers and by us, because of the small amount of data available on Cl response with this crop.

The protocol of the experiment was to apply chloride broadcast and incorporated at 0 and 40 lb Cl/A as KCl. At the Chaffee site, since the background nitrates in the soil were high, a modest rate of N was applied, 50 lb N/A as urea. The KCl and urea were broadcast on the soil surface, and incorporated with a field cultivator the next day. Phosphate was drilled with the seed at a rate of 90 lb/A of 0-45-0. Planting was done with a conventional press drill, so all varieties were planted at a rate of 90 lb seed/A. Individual plot size was 6 x 50 feet.

The soil type at Chaffee was a Fargo clay. These soils often have a high water table and are often naturally high in Cl. However, we have obtained Cl responses on these soils in the past, if there is good artificial or natural drainage. In this case, the soil has very good natural drainage, because of the proximity to the trench of the Maple River. The prior crop was barley. Soil test and dates and weather data are listed in Tables 2 and 3. 'Harmony Extra' was used as the herbicide, and good general weed control was obtained.

The Dickinson site was located on a Vebar sandy loam. This is an old soil derived from residual sandstone. It is well drained and is inherently low in Cl. The prior crop was oat hay. Because the soil tests were so low, ample amounts of N and P were applied. Urea and DAP were applied at 250 and 100 lb/A of product, respectively (133 and 46 lb/A of N and P_2O_5). The KCl, by a decision made by a technician, not by Drs. Goos or Carr, was drilled with the seed, rather than broadcast and incorporated. There was no obvious thinning of the stand, but this regrettable error does cause us concern in data interpretation. Lower rates of KCl can be safely banded with the seed, but this is a marginally high rate with regards to possible seedling damage.

Planting at Dickinson was done with a cone seeder, and the rate was 1.2 million PLS/A. Weed control was accomplished with a combination of Hoelon and Buctril. Good weed control was obtained.

Soil testing for Cl was done using a slight modification of potentiometric titration method used by Fixen and colleagues in their earlier research. The soil (20 g) was shaken with 50 mL of 0.01 M calcium nitrate. Because filter paper often contains more Cl than the soil extract, no filtration was performed. The suspensions were allowed to settle overnight, and a clear aliquot taken with a volumetric pipet. A few drops of 1 N nitric acid were added to acidify the aliquot, and then the aliquot was titrated with 0.005 N $AgNO_3$, using a Cl specific electrode to indicate the endpoint. A small background level of KCl is added to the extracting solution to provide for a "blank" titration of 1 mL in all samples. This provides for a fresh floc of AgCl in all samples, which leads to more stable mV readings. We have confidence in our soil Cl measurements, as the background titration never varied by more than one drop (0.05 mL) of $AgNO_3$, and our soil measurements were equally as reproducible.

Plant samples were taken at the flag leaf emergence/ early boot stage (Chaffee) and in the late boot stage/early heading stage (Dickinson). Random plants were excised at the soil surface, dried at 65 C, ground, and extracted with 0.1 N HNO_3. The suspensions were filtered through filter papers previously rinsed and dried to remove Cl. The filtrates were analyzed for Cl by potentiometric titration, and for K by atomic absorption spectrophotometry.

Heading notes were taken every day during the heading period at Chaffee and every 2 or 3 days at Dickinson. Because the summer was drier than normal at both locations, foliar diseases were minimal. Physiological Cl deficiency symptoms were not observed at either site. Some leaf "firing" due to drought was observed at both sites. Advancement of maturity was the only visual indicator of Cl response observed at either site.

Harvest was by plot combine at both sites. The grain at the Chaffee site was dried for 3 d at 50 ^{o}C, the grain weight determined, and subsamples taken for further moisture correction (as one or two later-maturing varieties still indicated a small amount of moisture). The grain at Dickinson was dried for several weeks at ambient temperatures before weighing. The grain of all varieties was dry at Dickinson before weighing, so no moisture corrections were made.

III. Results

Soil moisture conditions were above normal at both sites, and planting was perhaps 1-2 weeks behind normal at Chaffee and 2-3 weeks behind normal at Dickinson. Rainfall was below normal at both sites (Table 3), but temperatures were not extremely hot. Yields at both sites, as a result, were considerably higher than was expected for the amount of rainfall received. No obvious agronomic problems (stand, weeds, diseases, etc.) were encountered at either site, apart from the apparent water stress at

Dickinson.

Plant Cl levels at the Chaffee site are presented in Table 4. The levels of Cl in the plants not receiving KCl fertilizer (0.21-0.30% Cl) were considerably higher (at least 2-4 times higher) than would have been anticipated based on the initial soil test Cl levels (12 lb Cl/A in the 0-24 inch layer). We have no explanation for this result. We tested the general soil area in the fall of 1995, and the specific plot area both in the fall of 1995 and spring of 1996. We also tested areas adjacent to this plot in the fall of 1996 (while looking for low Cl soil for a 1997 trial), and all samples were similarly low in Cl. Our methods are sensitive to about 1 ppm of Cl in the soil, and reproducible. So, we were expecting a much lower concentration of Cl in the plant tissues without KCl fertilization. The critical level of Cl in wheat tissues at the boot stages is about 0.15%, and all of the varieties were above this value.

Fertilization with KCl dramatically increased the plant Cl level, as expected, averaging 0.9% Cl with 40 lb Cl/A. There was some differences in variety with regards to Cl concentration, but no striking trends could be discerned.

Potassium levels in the plants at Chaffee were extremely high (Table 5), over 5% for most treatments. This indicates the very high potassium availability in such soils. The effects of KCl fertilization were statistically significant, but agronomically negligible. Some variety effects were seen. Guard is a short variety that does not produce a great excess of dry matter. This variety had 5.3% K in the plant tissues in the absence of K fertilization. At the other end, a rapid growing variety like Trenton had 4.5% K in the plant tissues, which is a much lower value than observed for Guard. However, both of these values are well in the "adequate" range.

Chloride concentrations in the plant tissues at Dickinson (Table 6) were in agreement with our expectations. Without KCl fertilization, the concentration of Cl averaged only 0.04%, well below the defined critical level of 0.15% for wheat. Adding Cl fertilization increased the Cl levels dramatically, to 0.84% on the average. Obviously added Cl was effectively taken up by all varieties.

A question is appropriate at this point. If the average concentration of Cl was 0.04% without Cl and 0.84% with 40 lb Cl/A, this means (assuming a linear relationship between Cl rate and % Cl in the tissue), that only about 10 lb Cl/A would have been needed to increase plant Cl levels from the initial low value of 0.04% to 0.20%, a point above the critical level. Thus, are current recommendations for Cl too generous? It should be noted, though, that this site, because of below normal precipitation, did not have a heavy plant canopy, and perhaps the relationship between Cl rate and % Cl in the plant tissue was unusually steep at this site.

It is interesting to note that, with KCl fertilization, that Marshall had the highest Cl levels of any variety at both sites. This is probably not due to any superior Cl scavenging ability of Marshall, but rather due to its slower daylength-restricted early growth. Marshall does not put on as much early growth as more recently released daylength insensitive varieties, as seen many times in our P x variety trials.

The soil at Dickinson was much lower in available K than the soil at Chaffee and this is apparent in the K concentrations in the plant tissues (Table 7). Overall, the potassium levels in the wheat tissues were still in a adequate range (2.3-3.1% K), but much lower than at Chaffee. Adding KCl fertilizer increased the K levels in the plants, as expected. There were some interesting varietal differences. Without KCl fertilization, Guard had the highest K levels at Chaffee and Dickinson (5.3 and 3.1%, respectively), while other varieties, like Hamar had significantly lower levels (4.9 and 2.3%, respectively). North Dakota soils are not likely to become potassium deficient in the near future, but if K deficiencies are ever discovered, some attention to wheat variety may be appropriate.

Heading date, as expected, was significantly affected by KCl fertilization (Tables 8 and 9). Very careful observations were taken at Chaffee, with daily measurements taken throughout the entire heading period. At Chaffee, the heading date of all varieties was advanced by KCl. Photographs of this effect were taken with all varieties and will be forwarded to PPI. The first variety to head was the known non-responder to Cl, Guard. The heading date was clearly advanced by KCl fertilization for this variety. The variety showing the least effect was Grandin. The heading date effect was most strong with the varieties Marshall and Kulm, with an advancement approaching 2 days. On the average, heading was advanced by KCl fertilization by 1 day, across all varieties. It is perhaps important that Marshall, a known Cl responder, gave a 1.7 day advancement in maturity with KCl fertilization.

There are important questions raised from the data in Tables 4 and 8. Without KCl fertilization, the levels of Cl in the plant tissues averaged 0.25%, well above the critical level associated with yield increase. However, the effect of KCl on maturity, as indicated by the heading date, was quite strong. A K effect can be initially ignored, because the K levels were so high and KCl fertilization did not increase plant K levels very much. This implies that the Cl effect on wheat maturity occurs at even relatively high levels in the plant.

At Dickinson, the heading measurements were taken every 2-3 days, so the data are somewhat less precise than at Chaffee. All varieties, except Russ, gave an advancement in maturity with KCl fertilization. Averaged across all varieties, there was a 1 day advancement of heading, as at Chaffee. Perhaps by coincidence, Marshall gave a pronounced KCl effect of 1.4 day. The data did not agree totally with the data at Chaffee, however. For example, Grandin only gave a 0.5 day advancement in heading with KCl fertilization at Chaffee, but gave a 1.3 day advancement at Dickinson.

Leaf disease ratings, a general rating of leaf area spotting, were taken for three replicates at Dickinson (Table 10). However, these ratings were complicated by leaf necrosis attributable to water stress. There was a lot of variability in the data and no effects other than variety were observed. Varietal effects were largely explained by differences in maturity, with lower ratings observed with the later varieties. Overall, no KCl effect was observed. At Chaffee, leaf disease ratings were not taken, as there was leaf necrosis due to some water stress and little true leaf spotting due to disease.

Grain yields at Chaffee (Table 11) were much higher than would have been expected earlier in the season. Yields above 60 bu/A were common. The surrounding field, planted a few days earlier, also had very high yields. Yield response to Cl, as predicted by the plant Cl analyses, were not large. Only three of the 15 varieties gave a yield response large enough to pay for the KCl fertilizer. Marshall gave a 3.56 bu/A yield response, followed by Amidon and Monroe, with about 1.5 bu/A each. Guard gave no response, so the data from the Chaffee site agrees with prior research, that Marshall responds to Cl, while Guard doesn't. Some negative responses were observed, such as a -3.18 bu/A response from Pioneer 2375 to -4.91 bu/A for Hamar. Only further trials will show if these trends are consistent across years. Averaged across all varieties, there was a -0.26 bu/A effect of KCl fertilization.

Grain yields varied by variety at Chaffee. In particular, the two Canadian varieties, Domain and Teal, gave yields 13-17 bu/A less than the highest yielding variety, which appeared to be Russ.

Grain yields at Dickinson were again, much higher than expected earlier in the season. Yields averaged over 30 bu/A, which was attributed to good tillering and early development due to the generous amount of N and P fertilizer applied, followed by a favorable grain filling period. Yields tended to be depressed by KCl fertilization. We are not certain whether this was a true effect of KCl fertilization, or due to damage to the plants resulting from how the KCl was applied (drilled with the seed). Averaged across all varieties, KCl fertilization depressed yields by 1 bu/A.

Kernel plumpness at Dickinson was significantly increased by KCl fertilization (Table 13). This effect has been observed many times in our trials with barley. Kernel plumpness is the major yield component influenced by Cl fertilization. It is perhaps of importance to note that the known Cl non-responder Guard gave a very small response in kernel weight (30.6 to 31.6 g/1000 seeds), while the known Cl responder Marshall gave a larger effect (29.7 to 32.2 g/1000 seeds).

The kernel plumpness data at Dickinson is difficult to interpret, however. If banding the KCl with the seed thinned the stand of the wheat even 5-10%, this would explain the 1 bu/A yield decrease and the increase in kernel plumpness.

We just discovered that the thousand kernel weights have not yet been performed for the Chaffee site. We had a timeslip worker doing these measurements for weeks, and assumed that the Chaffee site had been done also. These are critical data to obtain, and we are currently performing these analyses. These data will be forwarded to PPI-FAR as soon as they are completed.

The kernel weight data are important for many reasons. Grain yield, unfortunately, is the least precise measurement we make in agronomic research. The experimental error associated with grain yield is often 10%, meaning that it is difficult to pronounce a yield increase to have been "statistically significant" unless an effect greater than 10% is obtained. Kernel weight is an important yield component with an experimental error much lower than overall grain yield (typically 1-2%). Even if it is difficult to demonstrate a yield response to Cl, a significant increase in an important yield component, such as kernel weight, suggests that at least small yield increases to Cl are possible, even if not detectable with our present methods of measuring overall grain yield in field trials.

Table 1. Varieties used in the study, 1996.

Variety	Rationale
Historic varieties (2)	
Marshall	Known Cl responder
Guard	Known Cl non-responder
Current varieties (4)	
Amidon	Popular in western ND
Butte 86	Popular statewide
Grandin	Popular statewide and in Canada
Pioneer 2375	Most popular variety, some scab resistance
New varieties (5)	
Hamar	New AgriPro variety
Kulm	New NDSU variety
Russ	New SDSU variety
Trenton	New NDSU variety
Verde	New U of MN variety
Canadian varieties (2)	
Domain	For continuity with Manitoba studies
Teal	For continuity with Manitoba studies
Durum varieties (2)	
Monroe	Popular NDSU variety
Renville	Popular NDSU variety

Table 2. Soil test data for the two Cl sites, North Dakota, 1996

Soil test	Depth	Chaffee	Dickinson
pH	0-6"	7.0	6.4
OM, %	0-6"	5.3	1.6
Olsen P, ppm	0-6"	11	4
Exch. K, ppm	0-6"	385	135
NO3-N, lb/A	0-24"	159	12
	24-48"	78	10
Av. S, lb/A	0-24"	27	16
	24-48"	146	10
Cl, lb/A	0-24"	12	16
	24-48"	15	12

Table 3. Dates of field operations and precipitaiton data, Cl studies, North Dakota, 1996.

	Chaffee	Dickinson
Date fertilized	13 May	14 May
Date planted	15 May	16 May
Date plant sampled	18 June	2 July
Date harvested	13 Aug	19 Aug
Rainfall by month, inches*		
May	1.3	1.4
June	2.6	1.5
July	1.1	2.8
Aug	1.6	1.3
Total	6.6	7.0

*Starting at planting and ending at harvest

Table 4. Plant Cl concentrations as influenced by KCl fertilization and variety, early boot stage, Chaffee, North Dakota, 1996.

Variety	KCl	% Cl
Amidon	Minus	0.26
Amidon	Plus	0.91
Butte 86	Minus	0.29
Butte 86	Plus	0.96
Domain	Minus	0.29
Domain	Plus	0.96
Grandin	Minus	0.25
Grandin	Plus	0.81
Guard	Minus	0.28
Guard	Plus	0.89
Hamar	Minus	0.22
Hamar	Plus	0.89
Kulm	Minus	0.22
Kulm	Plus	0.95
Marshall	Minus	0.23
Marshall	Plus	1.07
Monroe	Minus	0.21
Monroe	Plus	0.77
P2375	Minus	0.27
P2375	Plus	0.90
Renville	Minus	0.26
Renville	Plus	0.81
Russ	Minus	0.23
Russ	Plus	0.86
Teal	Minus	0.26
Teal	Plus	0.78
Trenton	Minus	0.23
Trenton	Plus	1.00
Verde	Minus	0.30
Verde	Plus	0.98
Average	Minus	0.25
	Plus	0.90

Table 5. Plant K concentrations as influenced by K fertilization and variety, early boot stage, Chaffee, North Dakota, 1996.

Variety	KCl	% K
Amidon	Minus	5.1
Amidon	Plus	5.5
Butte 86	Minus	5.0
Butte 86	Plus	5.1
Domain	Minus	5.1
Domain	Plus	5.1
Grandin	Minus	4.9
Grandin	Plus	5.1
Guard	Minus	5.3
Guard	Plus	5.2
Hamar	Minus	4.9
Hamar	Plus	4.9
Kulm	Minus	4.9
Kulm	Plus	4.8
Marshall	Minus	5.2
Marshall	Plus	5.3
Monroe	Minus	4.7
Monroe	Plus	4.6
P2375	Minus	5.1
P2375	Plus	5.1
Renville	Minus	4.9
Renville	Plus	5.0
Russ	Minus	4.9
Russ	Plus	5.1
Teal	Minus	4.9
Teal	Plus	4.7
Trenton	Minus	4.5
Trenton	Plus	5.4
Verde	Minus	5.3
Verde	Plus	5.5
Average	Minus	5.0
	Plus	5.1

Table 6. Plant Cl concentrations as influenced by KCl fertilization and variety, late boot stage, Dickinson, North Dakota, 1996.

Variety	KCl	% Cl
Amidon	Minus	0.04
Amidon	Plus	0.96
Butte 86	Minus	0.04
Butte 86	Plus	0.86
Domain	Minus	0.03
Domain	Plus	0.79
Grandin	Minus	0.03
Grandin	Plus	0.81
Guard	Minus	0.04
Guard	Plus	0.87
Hamar	Minus	0.03
Hamar	Plus	0.91
Kulm	Minus	0.04
Kulm	Plus	0.96
Marshall	Minus	0.04
Marshall	Plus	1.11
Monroe	Minus	0.03
Monroe	Plus	0.74
P2375	Minus	0.03
P2375	Plus	0.72
Renville	Minus	0.02
Renville	Plus	0.78
Russ	Minus	0.04
Russ	Plus	0.83
Teal	Minus	0.04
Teal	Plus	0.70
Trenton	Minus	0.03
Trenton	Plus	0.85
Verde	Minus	0.04
Verde	Plus	0.77
Average	Minus	0.04
	Plus	0.84

Table 7. Plant K concentrations as influenced by K fertilization and variety, late boot stage, Dickinson, North Dakota, 1996.

Variety	KCl	% K
Amidon	Minus	2.5
Amidon	Plus	3.2
Butte 86	Minus	2.7
Butte 86	Plus	2.7
Domain	Minus	2.6
Domain	Plus	2.6
Grandin	Minus	2.6
Grandin	Plus	2.9
Guard	Minus	3.1
Guard	Plus	3.3
Hamar	Minus	2.3
Hamar	Plus	2.9
Kulm	Minus	2.5
Kulm	Plus	2.5
Marshall	Minus	2.8
Marshall	Plus	3.3
Monroe	Minus	2.7
Monroe	Plus	2.9
P2375	Minus	2.3
P2375	Plus	2.8
Renville	Minus	2.7
Renville	Plus	3.0
Russ	Minus	2.8
Russ	Plus	2.8
Teal	Minus	2.4
Teal	Plus	2.5
Trenton	Minus	2.5
Trenton	Plus	2.8
Verde	Minus	2.6
Verde	Plus	2.8
Average	Minus	2.6
	Plus	2.9

Table 8. Heading date (days after planting) as influenced by KCl fertilization and variety, Chaffee, North Dakota, 1996.

Variety	KCl	Days
Amidon	Minus	47.0
Amidon	Plus	46.0
Butte 86	Minus	44.2
Butte 86	Plus	43.2
Domain	Minus	46.0
Domain	Plus	45.0
Grandin	Minus	45.5
Grandin	Plus	45.0
Guard	Minus	45.0
Guard	Plus	44.0
Hamar	Minus	47.5
Hamar	Plus	46.5
Kulm	Minus	43.8
Kulm	Plus	43.0
Marshall	Minus	49.5
Marshall	Plus	48.2
Monroe	Minus	46.0
Monroe	Plus	45.0
P2375	Minus	46.5
P2375	Plus	45.5
Renville	Minus	48.5
Renville	Plus	47.8
Russ	Minus	45.0
Russ	Plus	44.0
Teal	Minus	46.8
Teal	Plus	45.8
Trenton	Minus	46.8
Trenton	Plus	45.8
Verde	Minus	49.0
Verde	Plus	48.0
Average	Minus	46.5
	Plus	45.5

Table 9. Heading date (days after planting) as influenced by KCl fertilization and variety, Dickinson, North Dakota, 1996.

Variety	KCl	Date
Amidon	Minus	51.0
Amidon	Plus	49.5
Butte 86	Minus	48.2
Butte 86	Plus	47.2
Domain	Minus	49.2
Domain	Plus	49.0
Grandin	Minus	49.5
Grandin	Plus	48.2
Guard	Minus	49.8
Guard	Plus	49.2
Hamar	Minus	49.5
Hamar	Plus	48.8
Kulm	Minus	48.0
Kulm	Plus	47.0
Marshall	Minus	52.2
Marshall	Plus	50.8
Monroe	Minus	49.2
Monroe	Plus	48.2
P2375	Minus	49.8
P2375	Plus	48.5
Renville	Minus	51.5
Renville	Plus	50.2
Russ	Minus	49.2
Russ	Plus	49.2
Teal	Minus	49.5
Teal	Plus	48.8
Trenton	Minus	50.2
Trenton	Plus	49.0
Verde	Minus	51.8
Verde	Plus	49.5
Average	Minus	49.9
	Plus	48.9

Table 10. Leaf disease ratings as influenced by KCl fertilization and variety, Dickinson, North Dakota, 1996.

Variety	KCl	%
Amidon	Minus	6.0
Amidon	Plus	6.4
Butte 86	Minus	15.7
Butte 86	Plus	15.6
Domain	Minus	14.4
Domain	Plus	19.2
Grandin	Minus	13.2
Grandin	Plus	12.6
Guard	Minus	15.7
Guard	Plus	25.2
Hamar	Minus	10.0
Hamar	Plus	13.2
Kulm	Minus	17.8
Kulm	Plus	30.6
Marshall	Minus	7.0
Marshall	Plus	7.3
Monroe	Minus	19.6
Monroe	Plus	22.0
P2375	Minus	21.9
P2375	Plus	19.5
Renville	Minus	8.6
Renville	Plus	10.8
Russ	Minus	18.1
Russ	Plus	20.5
Teal	Minus	19.3
Teal	Plus	19.0
Trenton	Minus	12.0
Trenton	Plus	16.2
Verde	Minus	11.2
Verde	Plus	12.7
Average	Minus	14.0
	Plus	16.7

Table 11. Grain yield as influenced by KCl fertilization and variety, Chaffee, North Dakota, 1996.

Variety	KCl	bu/A	Difference
Amidon	Minus	59.58	
Amidon	Plus	61.14	1.56
Butte 86	Minus	63.73	
Butte 86	Plus	64.20	0.46
Domain	Minus	55.50	
Domain	Plus	55.91	0.41
Grandin	Minus	65.62	
Grandin	Plus	65.89	0.27
Guard	Minus	59.74	
Guard	Plus	59.42	-0.32
Hamar	Minus	66.08	
Hamar	Plus	61.17	-4.91
Kulm	Minus	62.05	
Kulm	Plus	60.94	-1.11
Marshall	Minus	61.21	
Marshall	Plus	64.77	3.56
Monroe	Minus	60.23	
Monroe	Plus	61.75	1.52
P2375	Minus	60.80	
P2375	Plus	57.63	-3.18
Renville	Minus	61.46	
Renville	Plus	61.94	0.49
Russ	Minus	69.94	
Russ	Plus	68.38	-1.55
Teal	Minus	51.75	
Teal	Plus	52.50	0.76
Trenton	Minus	63.61	
Trenton	Plus	63.03	-0.58
Verde	Minus	59.56	
Verde	Plus	58.27	-1.29
Average	Minus	61.39	
	Plus	61.13	

Table 12. Grain yield as influenced by KCl fertilization and variety, Dickinson, North Dakota, 1996.

Variety	KCl	bu/A	Difference
Amidon	Minus	34.85	
Amidon	Plus	33.06	-1.79
Butte 86	Minus	34.59	
Butte 86	Plus	33.53	-1.06
Domain	Minus	29.16	
Domain	Plus	30.59	1.43
Grandin	Minus	31.81	
Grandin	Plus	32.41	0.59
Guard	Minus	34.81	
Guard	Plus	32.69	-2.12
Hamar	Minus	32.85	
Hamar	Plus	32.47	-0.38
Kulm	Minus	31.34	
Kulm	Plus	32.09	0.76
Marshall	Minus	33.10	
Marshall	Plus	31.68	-1.41
Monroe	Minus	26.53	
Monroe	Plus	25.16	-1.37
P2375	Minus	34.67	
P2375	Plus	32.43	-2.24
Renville	Minus	34.09	
Renville	Plus	31.18	-2.91
Russ	Minus	36.68	
Russ	Plus	34.91	-1.76
Teal	Minus	32.01	
Teal	Plus	30.04	-1.97
Trenton	Minus	34.94	
Trenton	Plus	33.89	-1.05
Verde	Minus	31.52	
Verde	Plus	32.29	0.78
Average	Minus	32.9	
	Plus	31.9	

Table 13. Thousand kernel weight as influenced by KCl fertilization and variety, Dickinson, North Dakota, 1996.

Variety	KCl	g/1000 seeds
Amidon	Minus	30.7
Amidon	Plus	32.3
Butte 86	Minus	31.3
Butte 86	Plus	33.3
Domain	Minus	28.3
Domain	Plus	31.5
Grandin	Minus	31.8
Grandin	Plus	34.8
Guard	Minus	30.6
Guard	Plus	31.6
Hamar	Minus	32.2
Hamar	Plus	35.3
Kulm	Minus	28.3
Kulm	Plus	31.2
Marshall	Minus	29.7
Marshall	Plus	32.2
Monroe	Minus	36.6
Monroe	Plus	34.8
P2375	Minus	33.8
P2375	Plus	34.5
Renville	Minus	34.7
Renville	Plus	36.1
Russ	Minus	32.0
Russ	Plus	34.1
Teal	Minus	29.1
Teal	Plus	30.8
Trenton	Minus	30.7
Trenton	Plus	33.3
Verde	Minus	30.5
Verde	Plus	33.5
Average	Minus	31.3
	Plus	33.3

Appendix A. ANOVA tables, Chaffee site.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Replicate	3	.138	.046	15.830	.0001
KCl	1	12.623	12.623	4332.457	.0001
Variety	14	.250	.018	6.126	.0001
KCl * Variety	14	.207	.015	5.064	.0001
Residual	87	.253	.003		

Dependent: Plant_Cl

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Replicate	3	2.777	.926	22.649	.0001
KCl	1	.397	.397	9.708	.0025
Variety	14	5.189	.371	9.069	.0001
KCl * Variety	14	2.069	.148	3.617	.0001
Residual	87	3.556	.041		

Dependent: Plant_K

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Replicate	3	.758	.253	1.693	.1745
KCl	1	27.075	27.075	181.310	.0001
Variety	14	303.367	21.669	145.109	.0001
KCl * Variety	14	.800	.057	.383	.9766
Residual	87	12.992	.149		

Dependent: Days to heading

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Replicate	3	22.250	7.417	1.269	.2900
KCl	1	2.049	2.049	.351	.5553
Variety	14	1845.369	131.812	22.556	.0001
KCl * Variety	14	115.318	8.237	1.410	.1660
Residual	87	508.411	5.844		

Dependent: bu/A

Appendix B. ANOVA tables, Dickinson site.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	3	.028	.009	1.607	.1935
KCl	1	19.521	19.521	3414.582	.0001
Variety	14	.339	.024	4.240	.0001
KCl * Variety	14	.319	.023	3.987	.0001
Residual	87	.497	.006		

Dependent: Plant Cl, %

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	3	.411	.137	1.459	.2312
KCl	1	2.080	2.080	22.143	.0001
Variety	14	5.495	.392	4.177	.0001
KCl * Variety	14	1.335	.095	1.015	.4466
Residual	87	8.174	.094		

Dependent: Plant K, %

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	3	7.076	2.359	2.140	.1010
KCl	1	112.889	112.889	102.413	.0001
Variety	14	398.234	28.445	25.806	.0001
KCl * Variety	14	48.329	3.452	3.132	.0006
Residual	87	95.899	1.102		

Dependent: 1000kw

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	3	1.267	.422	.778	.5096
KCl	1	32.033	32.033	59.003	.0001
Variety	14	129.800	9.271	17.077	.0001
KCl * Variety	14	8.467	.605	1.114	.3576
Residual	87	47.233	.543		

Dependent: Days to head

Appendix B. ANOVA tables, Dickinson site (continued).

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	3	41.172	13.724	1.199	.3149
KCl	1	28.072	28.072	2.453	.1209
Variety	14	608.666	43.476	3.799	.0001
KCl * Variety	14	47.907	3.422	.299	.9928
Residual	87	995.547	11.443		

Dependent: bu/A

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Rep	2	2505.068	1252.534	12.297	.0001
KCl	1	288.727	288.727	2.835	.0976
Variety	14	4367.168	311.941	3.062	.0014
Variety * KCl	14	595.563	42.540	.418	.9631
Residual	58	5907.925	101.861		

Dependent: % Disease