Apr. 6. 2001

AB: 20F

Development of Agronomic Practices for Chickpea Production

2000 Summary Report
AARI Project
#00M61

by

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Funding Agencies

Alberta Agricultural Research Institute
FFF - On Farm Demo
Alberta Pulse Growers Commission
Westco
Agricore
No-Bull Marketing

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1.0 Introduction

Chickpea (*Cicer arietinum L.*) is a member of the Leguminosae family and is also known as garbanzo beans. Chickpea is a spring seeded, annual legume and is the second highest acreage pulse crop grown in the world. There are two commercial types of chickpea, Desi and Kabuli, which are divided according to seed size and geographic origin. The Kabuli types have a large seed and are of Mediterranean and Middle Eastern origin. The Desi types have a smaller seed and are of Indian origin. Desi chickpea accounts for about 85% of world production, while Kabuli chickpea accounts for 15% of production.

On the Canadian prairies, Chickpea is considered a relatively warm season, moderately drought tolerant, pulse crop. It is a branching, spreading annual legume which has a taproot that is 2 to 6 feet (60 to 180 cm) in length resulting in excellent drought tolerance. They can fix much of their own nitrogen requirements when inoculated. For these reasons, chickpeas have received increased interest by producers across the southern prairies. It has become a significant crop in Saskatchewan in recent years, increasing from 7,000 acres in 1996 to 350,000 in 1999. Some industry estimates suggest that chickpea could approach one million acres over the next five years on the Canadian prairies. The estimated acreage in Alberta in 1999 was 15,000 acres.

Chickpea is the "new kid on the block". There has been very little agronomic research in Alberta to develop agronomic recommendations to assist growers in achieving optimum yield. Only limited agronomic work has been conducted in Saskatchewan, by Dr. F. Walley.

Growing conditions and agronomic requirements of chickpeas are very different from pulse crops such as peas. Peas are a cool season pulse crop that will germinate and grow well under cooler soil and climatic conditions. However, Kabuli chickpea requires soil temperatures of 10°C for rapid germination and emergence. Generally, chickpea requires about 25% more growing degree days to reach maturity than peas. They are best suited to daytime temperatures of 20 to 30°C and nighttime temperatures of about 18 to 20 °C. Generally, Kabuli chickpea varieties are more sensitive to cold than Desi chickpea types.

Chickpea production information has not been developed for Alberta. Information on cultivar performance, inoculation, seeding rates, seeding dates, and fertilizer recommendations has not been available. With new marketing opportunities for chickpeas, coupled with lower cereal and canola prices, producers in southern Alberta in the brown and dark brown soil zones are very interested in this new special crop.

2.0 Objective

The objective of this proposed study is to evaluate the two types of chickpeas under varying management treatments to develop agronomic production practices for the various agro-ecological areas of southern Alberta.

3.0 Materials and Methods

3.1 Experimental Design, Location and Treatments

Field trials were carried out at four locations (Table 1) in 2000. Experiment 1 treatments were arranged as a randomized split-split block design, with the main plots being the varieties, the subplots being the inoculant treatments, and the sub-subplots being the nitrogen treatments. Experiment 2 treatments were arranged as a randomized complete block design (phosphate fertilizer rates). Experiment 3 treatments were arranged as a randomized complete block design (sulfate fertilizer rates). Experiment 4 treatments were arranged as a randomized strip block design, with the main plots being the seeding dates, and the subplots being the seeding rates.

The chickpea varieties used in the Experiment 1 treatments were Desi (Myles) and Kabuli (Sanford). Experiments 2, 3, and 4 treatments used the Desi variety. The inoculant used in Experiment 1 was a self-stick inoculant. The N rates used in Experiment 1 were 0, 20, 40, 60, and 80 kg ha^{-1} using urea. The Experiment 2 phosphate (P_2O_5) rates were 0, 15 and 30 kg/ha^{-1} . The Experiment 3 sulfate-sulfur (SO_4-S) rates were 0, 10 and 20 kg ha^{-1}. The Experiment 4 treatments included three different seeding dates, and targeted five different seeding rates at 20, 40, 60, 80, and 100 seeds/m^2.

Treatments were replicated four times on Experiments 1 and 4 and five times on Experiments 2 and 3. Experiments 1, 2, and 3 were carried out at all research locations while Experiment 4 treatments were only carried out at Bow Island and Lethbridge. Soil samples were taken prior to fertilization in the fall. Five samples were taken in each replicate and combined to get one bulk sample for the 0-15, 15-30, 30-60 and 60-90 cm depths. These samples were air dried and then sent to the Soil and Crop Diagnostic Centre for routine analysis including N, P, K, S, Cu, Fe, Mn, Zn, pH and electrical conductivity. Automatic recording rain gauges were set up at each site during the growing season.

Table 1. Location, cropping system and soil zone of each research site.

Location	Cropping System	Soil Zone
Bow Island	Fallow	Brown
Carmangay	Fallow	Dark Brown
Carmangay	Stubble	Dark Brown
Milk River	Stubble	Brown
Milk River	Fallow	Brown
Lethbridge	Stubble	Dark Brown

3.2 Data Collection and Analysis

Eight rows were seeded with 18 cm row spacings in each treatment. The total area harvested for each treatment was 9.94 m^2. After harvest the following data was determined for each treatment: percent moisture content, grain yield, bushel weight, grain protein (Near Infrared

Spectroscopy) oil content, and P and Ca levels on each variety. Yield samples were adjusted to 9.5% moisture.

Analyses of variance (Statistical Analysis Systems Institute, Inc. 1985) were conducted to determine the significance of treatment differences. Student Newman-Keuls test was used for mean separation, where significant treatment effects were noted.

4.0 Results

4.1 Field Activities

Seeding, harvest, pertinent plot work dates, and growing season precipitation were recorded for each site (Table 2). To avoid serious weed problems, Edge was applied and incorporated second and third week of November (1999), and Poast was sprayed where grassy weeds were present.

Table 2. Plot work dates and growing season precipitation.

Site	System	1st Seeding	2nd Seeding	3rd Seeding	Herbicide Dates		Harvest	Rainfall[2]	Rainfall[3]
		Date	Date[1]		Edge	Poast	Dates	(mm)	(mm)
Bow Island	Fallow	April 28	May 5	May 17	Nov. 8	-	Aug. 28	86	188
Carmangay	Fallow	-	May 8	-	Nov. 10	June 12	Aug. 25	113	236
Carmangay	Stubble	-	May 8	-	Nov. 10	June 12	Aug. 25	113	236
Milk River	Fallow	-	May 5	-	Nov. 14	June 12	Aug. 28	78	173
Milk River	Stubble	-	May 5	-	Nov. 14	June 12	Aug. 9	78	173
Lethbridge	Stubble	April 27	May 4	May 18	Nov.8	-	Aug. 24	139[4]	213

1. Second Seeding Date - Represents the date which Core 1, 2, and 3 were seeded
2. Rainfall - Growing season precipitation measured from date of seeding to date of harvest.
3. Average Rainfall - Measured from May 1 to August 31 - 30 year average.
4. Rainfall total includes 71 mm of supplemental irrigation in May and June.

4.2 Soil Analysis

Mean soil analysis results are provided in Table 3. Nitrogen levels were high at the Carmangay stubble site, medium at the Bow Island fallow, Milk River stubble, and Milk River fallow sites and low at the Lethbridge stubble and Carmangay fallow sites. Phosphorus levels were high at the Lethbridge fallow and Carmangay fallow sites, medium at the Bow Island fallow, Carmangay stubble, and the Milk River stubble sites, and low at the Milk River stubble site. Potassium levels were high at all the research locations. Sulfate sulfur levels were high at all research locations except Bow Island where levels were low. Micronutrient levels were adequate at all sites (data not shown).

Table 3. Mean soil analysis results for each research site.

Location	System	Depth (cm)	NO_3-N	P	K	SO_4-S	pH	EC
			ppm					
Bow Island	Fallow	0-15	13.6	18	398	4	6.1	0.4
		15-30	3.7	5.9	277	4	7	0.8
		30-60	4.8	-	-	6	-	-
		60-90	18.2	-	-	40	-	-
Lethbridge	Stubble	0-15	6.9	40.4	556	23	7.7	0.7
		15-30	3.6	28	507	373	7.6	2.2
		30-60	1.1	-	-	362	-	-
		60-90	0.8	-	-	595	-	-
Carmangay	Fallow	0-15	5.6	31.1	609	20	6.5	0.6
		15-30	1.0	7.4	308	13	7.2	0.7
		30-60	4.0	-	-	721	-	-
		60-90	5.5	-	-	1470	-	-
Carmangay	Stubble	0-15	14.7	19	375	21	7.2	0.8
		15-30	8.0	7.9	169	13	7.7	0.6
		30-60	5.7	-	-	10	-	-
		60-90	4.8	-	-	428	-	-
Milk River	Fallow	0-15	15.5	16.9	550	80	7.1	1
		15-30	3.4	5.1	339	114	7.8	1.5
		30-60	1.7	-	-	3280	-	-
		60-90	2.2	-	-	6530	-	-
Milk River	Stubble	0-15	7.1	11.3	708	48	7	1
		15-30	1.5	7.3	380	42	7.4	0.9
		30-60	7.1	-	-	1070	-	-
		60-90	18.6	-	-	2910	-	-

4.3 Site Overview

After seeding, all plots progressed well with the exception of Milk River where on the fallow plot, water accumulation in a low spot caused severe soil crusting and resulted in very poor emergence. As a result, approximately 50% of reps 1 and 4 were not harvested. Precipitation levels were approximately 60% below average (see Table 2) and as a result yields were slightly lower than what might have been expected.

4.4 Experiment 1 - Variety X Inoculant X Nitrogen Experiment

The results of variety, inoculant, and nitrogen fertilizer on yield, bushel weight, and protein are provided in Table 4. The results of variety, inoculant, and nitrogen fertilizer on Ca content, P content, and plant population are provided in Table 5.

Variety - At each research location, the Desi (Myles) chickpeas significantly out yielded the Kabuli (Stanford) chickpeas by 11% - 143%. On the fallow sites, the yield difference between the Desi and Kabuli varieties were not as great as on the stubble sites. This may indicate

that the Desi chickpeas may be more drought tolerant than the Kabuli chickpeas. Generally, the Kabuli chickpeas had higher bushel weights (significant at Bow Island - fallow, Lethbridge - stubble, Milk River - stubble and Carmangay - fallow), higher protein content (significant at Bow Island - fallow, Lethbridge - stubble , Milk River - stubble, and Carmangay - stubble), and Higher P content (significant at all locations) than the Desi chickpeas. The higher protein and P content in the Kabuli chickpeas are likely due to the lower yields, thus increasing the protein and P concentration. High bushel weights are also likely a result of lower yields. The Desi chickpeas had significantly higher Ca content than the Kabuli chickpeas at all research locations.

Inoculant - In June, a number of research locations showed an obvious visual response to inoculant in both crop canopy and root nodulation. Although trends do show increased yields due to applied inoculant, the Carmangay fallow site was the only site that showed a significant yield response. The chickpeas did show an increase in protein levels (significant at Milk River - fallow, Lethbridge - stubble, and Bow Island - fallow) with the addition of applied inoculant. There was no significant bushel weight, P, or Ca content response to inoculant.

Nitrogen - There was no significant yield response to nitrogen fertilizer at any of the research locations. Results did show however, that increased rates of nitrogen fertilizer did have a significant response on bushel weight (at Bow Island - fallow, Carmangay - fallow, and Milk River - fallow), protein content (all research locations), Ca content, (all research locations) and P content (Bow Island - fallow, Carmangay -stubble and fallow, and Lethbridge - stubble). Bushel weight, protein levels, and Ca content all showed a positive correlation to increased rates of nitrogen fertilizer. P content declined with the addition of nitrogen fertilizer.

Interaction - The variety and inoculant interaction showed a significant bushel weight response (at Milk River - stubble), protein response (at Carmangay - fallow, and Milk River - stubble), Ca response (Milk River - stubble) and P response (Carmangay - stubble). The variety and nitrogen interaction showed a significant yield response (at Carmangay - stubble and Milk River - stubble), bushel weight response (at Bow Island - fallow and Carmangay stubble), protein response (Bow Island - fallow and Carmangay - stubble), and P content response (at Milk River - stubble). The inoculant and nitrogen interaction showed a significant yield response (at Carmangay - stubble) and Ca content response (at Milk River - fallow). The variety, inoculant and nitrogen interaction showed a Ca content response (at Milk River - stubble).

4.5 Experiment 2 - Phosphorus Experiment

The results of phosphate fertilizer on yield, bushel weight, and protein content are provided in Table 6. The results of phosphate fertilizer on Ca and P content are provided in Table 7.

There was no significant yield or Ca content response to applied phosphate fertilizer at any of the research sites. However, there was a trend of yield increase at the Bow Island fallow (significant at 93% interval) and Milk River stubble (significant at 90% interval) sites. There was a significant bushel weight response (Carmangay - fallow) and P content response (Lethbridge - stubble) to applied phosphate fertilizer. Soil P levels were medium to high at most sites, and together with very dry moisture conditions there was a reduced chance of P response.

4.6 Experiment 3 - Sulfate-Sulfur Experiment

The results of sulfate fertilizer on yield, bushel weight, and protein are provided in Table 8. The results of sulfate fertilizer on Ca and P content are provided in Table 9.

There was no significant yield, bushel weight, protein, Ca, or P content response to applied sulfate at any of the research locations with the exception of the Carmangay stubble site where there was a significant yield response to applied sulfate. Sulfate levels at most research locations were very high and therefore, a response to sulfate was not anticipated. Sulfate levels at Bow Island were low, and although yield results were not significant the data does show a trend of increasing yield.

4.7 Experiment 4 - Seeding Date X Seeding Rate Experiment

The results of seeding date and seeding rate on yield, bushel weight, protein, Ca content, P content and plant population are provided in Table 10.

Seeding Date - There was no significant Ca or P content response to seeding date at any of the locations. Results did show however, that there was a significant yield response (Bow Island - fallow and Lethbridge - stubble), bushel weight response (Lethbridge - stubble), and protein response (Bow Island - fallow) to seeding dates. At both sites it was very clear that the first seeding dated out yielded the second and third seeding dates.

Seeding Rate - Plant populations reveal the differences in seeding rates. There was no effect of seeding rates on bushel weight, Ca, or P content. At the Lethbridge stubble site, there was a significant yield and protein response to seeding rates. At the Bow Island fallow site the 40, 60, 80, and 100 seeds/m^2 treatments all yielded very similar. This is likely due to the fact that moisture stress pre-determined yield.

5.0 Summary

In a year of severe moisture stress, it was very evident that chickpeas are a drought tolerant crop. Yield between the Desi and Kabuli varieties show that the Desi's may be more drought tolerant than the Kabuli's. Though the addition of inoculant, nitrogen, phosphate, and sulfate-sulfur resulted in limited yield increase, subsequent years data with average rainfall will be needed to accurately identify benefits of these variables. Differences in seeding dates have resulted in significant yield, bushel weight, and protein responses, and differences in seeding rates have resulted in yield response. This experiment will be expanded to all sites in 2001.

This was the first year of a three year project. Over the next two years this project will provide more data concerning recommendation for chickpea production.

6.0 Acknowledgments

The authors gratefully acknowledge Terry Doran, Chris Wehlage, and Ron Svanes for kindly providing land in these experiments.

We gratefully acknowledge research funding from the Alberta Agriculture Research Institute, FFF- on farm demonstration program, Alberta Pulse Growers Commission, Westco, Agricore, and No-Bull Marketing.

Table 4. Effects of chickpea variety, inoculant, and nitrogen fertilizer on yield, protein, and bushel weight at each research location.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Milk River - Fallow			Milk River - Stubble		
	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)
Variety																		
Desi	2014 a	65.5 b	22.9 b	1870 a	64.5 b	26.3 b	3539 a	66.2 b	21.7	966 a	63.9	24.8 b	919 a	65.2 b	25.6 b	1285 a	64.8 b	23.4 b
Kabuli	1591 b	66.2 a	25.4 a	1209 b	66.0 a	27.7 a	3204 b	69.7 a	22.7	398 b	63.4	26.6 a	442 b	66.9 a	27.2 a	833 b	66.0 a	24.9 a
Inoc																		
Inoculant	1819	65.9	24.5 a	1555	65.2	27.3 a	3386	67.8	22.3	719 a	64.0	25.8	736 a	66.0	26.5	1086	65.5	24.9 a
No Inoculant	1797	65.8	23.8 b	1533	65.3	26.8 b	3362	68.1	22.1	668 b	63.3	25.6	663 b	65.9	26.5	1040	65.3	23.5 b
N Fertilizer																		
0	1816	65.3 c	21.5 e	1559	65.2	25.6 c	3150	67.5 b	20.1	663	63.8 ab	23.5 c	714	65.7 ab	24.8 b	1131	65.1 b	21.9 c
20	1853	65.7 bc	23.2 d	1485	64.9	26.3 b	3370	67.7 b	21.0	697	63.1 b	24.9 b	685	66.3 a	26.6 a	1054	65.3 b	22.9 c
40	1809	65.8 ab	24.3 c	1545	65.4	27.6 a	3407	68.1 ab	22.6	682	63.8 ab	26.4 a	706	66.1 ab	26.7 a	1215	65.8 a	24.1 b
60	1816	66.2 a	25.4 b	1569	65.3	27.5 a	3443	67.9 b	23.1	717	63.5 ab	26.7 a	714	65.9 ab	27.2 a	918	65.4 b	25.2 ab
80	1742	66.1 a	26.4 a	1561	65.3	28.2 a	3507	68.6 a	24.3	710	64.0 a	27.1 a	678	65.7 b	27.4 a	1058	65.5 b	25.6 a
Significance																		
Rep																		
Variety	0.0018	0.0012	0.0001	0.0069	0.001	0.0134	0.0119	0.0037	0.0875	0.0014	0.4714	0.0089	0.0001	0.0070	0.007	0.0045	0.1051	0.0709
Inoculant	0.5198	0.2538	0.0044	0.7353	0.9056	0.0066	0.778	0.3105	0.4939	0.1196	0.1133	0.1539	0.0222	0.0703	0.5645	0.8817	0.2198	0.0011
Fertility	0.3263	0.0002	0.0001	0.6505	0.5659	0.0001	0.2373	0.0012	0.0001	0.9343	0.0834	0.0001	0.2636	0.0786	0.0001	0.4107	0.0268	0.0001
V X I	0.0623	0.941	0.3813	0.1285	0.9767	0.2207	0.2736	0.1887	0.0239	0.0579	0.2174	0.3348	0.5360	0.0018	0.0067	0.9387	0.4468	0.1265
V X F	0.099	0.0233	0.001	0.0744	0.5871	0.0839	0.1003	0.8148	0.5829	0.0455	0.0001	0.0001	0.0156	0.0686	0.2791	0.1555	0.5399	0.5956
I X F	0.5392	0.5492	0.1248	0.2279	0.7014	0.0926	0.6513	0.4681	0.0798	0.0619	0.3086	0.6647	0.7081	0.8005	0.425	0.1668	0.0855	0.1789
V X I X F	0.5407	0.6312	0.7341	0.4379	0.8193	0.8702	0.9944	0.502	0.1965	0.1636	0.075	0.2762	0.5702	0.9153	0.8562	0.2320	0.5868	0.7955
C. V.	8.7	0.8	2.8	10.7	1.3	3.7	13.1	1.1	4.5	20.5	1.3	4.2	19.7	0.8	3.8	29.0	0.6	5.2

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 5. Effects of chickpea variety, inoculant, and nitrogen fertilizer on Ca, P, and plant/m^2 at each research location.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Milk River - Fallow			Milk River - Stubble		
	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2
Variety																		
Desi	0.22 a	0.31	38 b	0.22 a	0.31 b	37 b	0.21 a	0.27	51 b	0.21 a	0.33	24 b	0.24 a	0.29 b	35 b	0.19 a	0.29 b	51 b
Kabuli	0.14 b	0.30	51 a	0.15 b	0.34 a	52 a	0.15 b	0.26	74 a	0.13 b	0.34	59 a	0.15 b	0.34 a	51 a	0.13 b	0.34 a	68 a
Inoc																		
Inoculant	0.18 a	0.30	51 a	0.18	0.33	43	0.18	0.26	63	0.17	0.33	40	0.20	0.31	43	0.16	0.32	63
No Inoculant	0.18 b	0.31	38 b	0.18	0.33	47	0.18	0.27	62	0.17	0.33	43	0.20	0.31	44	0.16	0.31	57
N Fertilizer																		
0	0.17 d	0.32 a	46	0.18	0.34	47	0.17 c	0.28 a	69 a	0.16 b	0.34 a	44	0.18 c	0.32 a	45	0.14 b	0.32	59
20	0.17 c	0.32 a	44	0.18	0.34	45	0.17 b	0.27 ab	58 b	0.16 b	0.35 a	40	0.20 b	0.32 a	49	0.16 a	0.33	57
40	0.18 b	0.31 b	45	0.19	0.33	40	0.18 a	0.27 b	61 b	0.18 a	0.33 ab	41	0.21 a	0.31 ab	42	0.16 a	0.33	55
60	0.19 a	0.29 c	45	0.19	0.32	46	0.18 a	0.26 bc	64 b	0.17 a	0.33 ab	41	0.21 a	0.30 ab	40	0.17 a	0.31	64
80	0.19 ab	0.29 c	43	0.19	0.32	45	0.19 a	0.24 c	62 b	0.18 a	0.31 b	41	0.21 a	0.29 b	40	0.17 a	0.30	63
Significance																		
Rep																		
Variety	0.0001	0.1682	0.0171	0.0001	0.0225	0.0007	0.0001	0.1365	0.0029	0.0012	0.0824	0.0003	0.0001	0.0164	0.0128	0.0001	0.0002	0.0226
Inoculant	0.0044	0.754	0.0007	0.5797	0.6829	0.2462	0.8423	0.4903	0.8169	0.2235	0.5728	0.0953	0.3774	0.1357	0.7327	0.0193	0.8026	0.2536
Fertility	0.0001	0.0001	0.9904	0.1001	0.0503	0.5322	0.0001	0.0001	0.0030	0.0030	0.0009	0.4013	0.0001	0.0741	0.4385	0.0052	0.1875	0.4462
V X I	0.3744	0.3696	0.0001	0.7375	0.6251	0.2630	0.4378	0.888	0.9903	0.8985	0.0044	0.1739	0.0518	0.2360	0.4567	0.5789	0.2116	0.0670
V X F	0.1735	0.0852	0.531	0.7757	0.3899	0.1994	0.5103	0.2683	0.0139	0.4870	0.0861	0.1369	0.9540	0.0066	0.9731	0.2765	0.6024	0.0525
I X F	0.2912	0.7732	0.9553	0.2904	0.9827	0.0715	0.9843	0.6027	0.4316	0.9574	0.5412	0.2823	0.5937	0.3552	0.7883	0.0087	0.1560	0.3234
V X I X F	0.0824	0.3198	0.901	0.2933	0.565	0.4135	0.1006	0.7854	0.654	0.5966	0.4184	0.1629	0.9977	0.0137	0.9036	0.6586	0.3843	0.7154
C. V.	3.4	4.9	30.8	5.9	7.6	27.7	3.5	7.7	11.9	6.9	5.6	22.1	5.2	6.1	38.7	6.1	8.3	26.7

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 6. Effects of phosphate fertilizer on yield, protein, and bushel weight at each research location.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Milk River - Fallow			Milk River - Stubble		
	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)
P_2O_5 Fertilizer																		
0	1891	65.5	22.9	2265	65.3	25.6	3398	66.0 ab	22.6 a	924	65	27.2	818	64.2	25.7	1410	64.9	20.9
15	1852	65.4	22.3	2095	64.8	25.5	3665	65.7 b	21.9 ab	867	65.5	27.4	990	64.7	26.4	1521	65.3	20.8
30	1842	65.2	23.1	2006	64.9	25.4	3946	66.3 a	21.6 b	908	65.2	28.1	915	64.5	26.6	1389	65.4	21.0
Significance																		
Rep																		
Fertility	0.8761	0.3777	0.5880	0.4981	0.2785	0.8852	0.0713	0.0264	0.0473	0.4184	0.2609	0.2584	0.1039	0.1825	0.2139	0.8087	0.5436	0.9035
C. V.	7.8	0.5	4.9	15.9	0.7	3.0	8.6	0.4	2.6	8.7	0.7	2.9	12.1	0.6	2.7	23.5	1.0	3.4

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 7. Effects of phosphate fertilizer on Ca, and P at each research location.

Trt.	Bow Island- Fallow		Lethbridge - Stubble		Carmangay - Fallow		Carmangay - Stubble		Milk River - Fallow		Milk River - Stubble	
	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)
P_2O_5 Fertilizer												
0	0.21	0.32	0.21	0.31 b	0.21	0.26	0.23	0.30	0.25	0.26	0.18	0.29
15	0.21	0.32	0.21	0.33 ab	0.21	0.26	0.23	0.29	0.24	0.30	0.20	0.28
30	0.21	0.32	0.20	0.35 a	0.21	0.26	0.22	0.30	0.25	0.29	0.20	0.28
Significance												
Rep												
Fertility	0.9037	0.9140	0.2157	0.0409	0.2557	0.3076	0.6300	0.9074	0.2625	0.8165	0.1318	0.6354
C. V.	3.2	4.5	5.1	5.9	3.0	6.7	4.8	4.1	3.6	7.5	7.9	6.7

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 8. Effects of sulfate fertilizer on yield, protein, and bushel weight at each research location.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Milk River - Fallow			Milk River - Stubble		
	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)
SO_4-S Fertilizer																		
0	1919	65.2	22.5	2008	64.6	25.4	3214	65.3	20.3	626 b	65.5	28.5	1006	64.4	25.3	1994	65.2	20.0
20	2039	65.1	22.5	2076	65.3	26.0	3353	65.6	20.6	736 b	65.3	28.3	960	64.4	25.8	1541	64.5	20.6
30	2091	65.1	22.6	2047	65.5	26.8	3384	65.8	20.8	684 a	65.5	28.5	905	64.0	25.4	1913	64.6	20.6
Significance																		
Rep																		
Fertility	0.3404	0.7927	0.9886	0.9170	0.5483	0.392	0.7874	0.5104	0.7943	0.0057	0.8625	0.6526	0.6491	0.4565	0.5609	0.1038	0.203	0.2868
C. V.	8.8	0.6	3.3	12.9	1.8	5.8	12.3	0.9	4.9	5.5	0.7	1.5	17.5	0.8	3.1	17	0.9	3.0

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 9. Effects of sulfate fertilizer on Ca, and P at each research location.

Trt.	Bow Island- Fallow		Lethbridge - Stubble		Carmangay - Fallow		Carmangay - Stubble		Milk River - Fallow		Milk River - Stubble	
	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)	P (%)
SO_4-S Fertilizer												
0	0.21	0.32	0.21	0.31	0.21	0.27	0.23	0.30	0.24	0.29	0.19	0.28
15	0.21	0.31	0.21	0.32	0.21	0.26	0.24	0.29	0.24	0.29	0.18	0.29
30	0.21	0.32	0.22	0.31	0.21	0.26	0.23	0.31	0.25	0.27	0.19	0.29
Significance												
Rep												
Fertility	0.6088	0.5907	0.1225	0.7465	0.1561	0.403	0.1132	0.0859	0.1836	0.2617	0.1205	0.5610
C. V.	3.8	5.6	4.3	8.3	2.5	6.5	2.6	4.6	2.7	5.6	6.2	5.9

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.

Table 10. Effects of seeding date and seeding rate on yield, protein, bushel weight, Ca, P, and plant/m^2 at Bow Island and Lethbridge.

Trt.	Bow Island- Fallow						Lethbridge - Stubble					
	Yield ($kg\ ha^{-1}$)	bu wt (lbs/bu)	Protein (%)	Ca (%)	P (%)	Plants /m^2	Yield ($kg\ ha^{-1}$)	bu wt (lbs/bu)	Protein (%)	Ca (%)	P (%)	Plants /m^2
Date												
1	2046 a	65.3	22.9	0.21	0.32	52	2124 a	64.8 b	25.5	0.21	0.31 b	59 ab
2	1989 a	64.9	22.9	0.22	0.32	46	1951 b	64.9 b	26.1	0.22	0.33 a	45 b
3	1658 b	65.1	23.2	0.22	0.32	59	1982 c	65.8 a	26.2	0.22	0.32 a	64 a
Seeding Rate												
20	1549 b	65.2	23.0	0.22	0.31 b	20 e	1865	65.1	25.6	0.21	0.31	23 d
40	1904 a	65.3	23.5	0.22	0.31 b	33 d	2105	65.2	25.8	0.21	0.32	40 c
60	2018 a	64.9	22.5	0.21	0.33 a	55 c	2068	65.3	26.0	0.22	0.32	55 b
80	1981 a	65.0	22.8	0.22	0.33 a	70 b	2008	65.4	26.2	0.22	0.32	77 a
100	2037 a	65.1	23.2	0.22	0.32 ab	84 a	2071	64.9	26.1	0.21	0.33	83 a
Significance												
Rep												
Date	0.0001	0.4717	0.0969	0.2197	0.1025	0.8556	0.0143	0.0199	0.2220	0.0932	0.0242	0.0455
Rate	0.0001	0.5075	0.0001	0.0862	0.5604	0.0069	0.0880	0.25	0.1296	0.1204	0.5159	0.0001
Date X Rate	0.7898	0.9041	0.03	0.4309	0.1647	0.0351	0.1208	0.7748	0.7742	0.3159	0.0757	0.0247
C.V.	8.6	1.0	21.8	4.1	3.2	4.9	12	0.08	3.3	4.7	5.5	27.2

Letters following the mean are Student-Newman-Keuls values. Means followed by the same letter are not significantly different.