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Development of Agronomic Practices for Chickpea Production

2001 Summary Report

by

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1 Comparison of number and size of chickpea nodules on inoculated and uninoculated treatments at the Lethbridge stubble site.

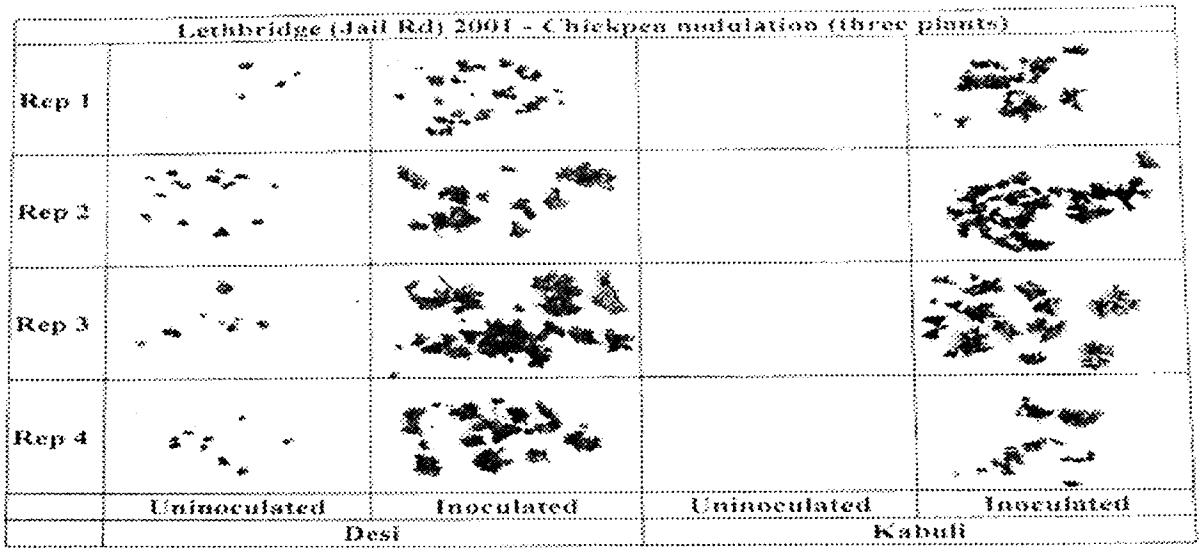

TABLE OF CONTENTS

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 night time 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 2001. 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. 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
Lethbridge	Stubble	Dark Brown
Warner	Stubble	Brown
Warner	Fallow	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) 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 dates for all sites are provided in Table 2. Herbicide application dates, harvest dates and growing season precipitation are provided in Table 3. To avoid serious weed problems, Edge was applied and incorporated in mid-October (2000) at Carmangay, Lethbridge and Warner and in late April at Bow Island. Poast Ultra was sprayed where grassy weeds were present, while Lentigram was sprayed to control broadleaf weeds.

Table 2. Seeding dates at all research locations.

Site	System	1st Seeding	2nd Seeding	3rd Seeding
		Date[1]	Date	Date
Bow Island	Fallow	37008	37018	37026
Carmangay	Fallow	37012	37021	37027
Carmangay	Stubble	37012	37021	37027
Lethbridge	Stubble	37007	37019	37027
Warner	Fallow	37008	37018	37026
Warner	Stubble	37008	37018	37026

1. First Seeding Date - Represents the date which Core 1, 2, and 3 were seeded

Table 3. Herbicide dates, harvest dates and growing season precipitation at all research locations.

Site	System	Herbicide Dates			Harvest	Rainfall[1]	Rainfall[2]
		Edge	Poast	Lentigram	Dates	(mm)	(mm)
Bow Island	Fallow	37007	---	---	Sept 4	95	188
Carmangay	Fallow	Oct. 24	37054	37054	37129	65	236
Carmangay	Stubble	Oct. 24	37054	37054	37129	65	236
Lethbridge	Stubble	Oct. 19	---	37060	37123	61	213
Warner	Fallow	Oct. 19	37054	---	37130	97	173
Warner	Stubble	Oct. 19	37054	---	37130	97	173

1. Rainfall - Growing season precipitation measured from first seeding date to date of harvest.
2. Average Rainfall - Measured from May 1 to August 31 - 30 year average.

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

Table 4. Mean soil analysis results for each research site.

Location	System	Depth	NO_3-N	P	K	SO_4-S	pH	EC
		(cm)	----------ppm----------					
Bow Island	Fallow	0	8	13	514	3.8	6.7	0.3
		15-30	4	4	286	2.8	7.6	0.5
		30-60	3	-	-	2.7	-	-
		60-90	1	-	-	120	-	-
Carmangay	Stubble	0	1	23	511	15	7.1	0.5
		15-30	1	6	257	74	7.6	0.8
		30-60	1	-	-	456	-	-
		60-90	1	-	-	519	-	-
Carmangay	Fallow	0	12	30	632	11.1	6.8	0.5
		15-30	10	6	413	10	7.1	0.5
		30-60	4	-	-	242	-	-
		60-90	2	-	-	685	-	-
Warner	Stubble	0	11	10	335	6.3	7.4	0.6
		15-30	1	3	198	3.2	7.7	0.5
		30-60	1	-	-	80	-	-
		60-90	2	-	-	296	-	-
Warner	Fallow	0	9	15	454	5	6.9	0.5
		15-30	4	4	294	4.2	7.4	0.6
		30-60	4	-	-	2.9	-	-
		60-90	5	-	-	150	-	-
Lethbridge	Stubble	0	7	29	381	8.2	8	0.5
		15-30	4	20	288	20.7	8	0.5
		30-60	3	-	-	290	-	-
		60-90	3	-	-	436	-	-

4.3 Site Overview

In the fall of 2000, the Lethbridge stubble site was irrigated (6" of water) to ensure adequate soil moisture for the spring. Spring and fall soil moisture levels are provided in Tables 5 and 6. Spring soil moisture levels were very good at the Lethbridge stubble, Carmangay fallow and Milk River fallow sites. Although surface soil moisture (0-15 cm) was good at the Bow Island fallow, Carmangay stubble, and Warner stubble sites, sub-surface soil moisture levels were poor to very poor.

During and following spring cultivation and seeding, southern Alberta experienced several weeks of drying winds. This led to an extreme degradation of soil moisture, which ultimately caused uneven germination and emergence. With surface soil moisture conditions being dry, all sites were in desperate need of precipitation.

Precipitation levels were well below normal (Table 3). Growing season precipitation levels were 50% below average at Bow Island, 73% below average at Carmangay, 71% below average at Lethbridge, and 44% below average at Warner.

With two consecutive years of extreme drought, soil moisture was the major limiting factor for crop production. Under drought conditions such as these, the response of chickpeas to inoculant, nitrogen, phosphorus, sulfur, seeding date and seeding rate become less evident or non existent.

Table 5. Pre-seeding spring soil moisture (mm) for all 2001 sites.

Depth	Bow Island	Lethbridge	Carmangay	Carmangay	Warner	Warner
cm	Fallow	Stubble	Fallow	Stubble	Fallow	Stubble
0	39	45.5	49.2	41.6	43.1	42.3
15-30	35.7	43.2	48.4	37.3	47.4	36.7
30-45	26.3	42.7	48.4	23.2	48.7	27.2
45-60	24	41.6	47.8	18.8	43	34.1
60-75	22.1	41	54.9	23	41.7	28
75-90	22.8	40.2	41.7	27.4	40.1	34.6
Total	169.9	254.2	290.4	171.3	264	202.9

Table 6. Post harvest fall soil moisture (mm) for all 2001 sites.

Depth	Bow Island	Lethbridge	Carmangay	Carmangay	Warner	Warner
cm	Fallow	Stubble	Fallow	Stubble	Fallow	Stubble
0	13.9	15.7	24	17.9	20.7	21.2
15-30	23.4	18.7	26.8	21.6	28.8	24.3
30-45	23.3	18.6	26.2	20.3	24.9	25.9
45-60	23	18.8	30.3	22.1	25.1	23
60-75	22.8	22.3	14.8	27.2	27.4	27.1
75-90	24	26.5	34.1	33.1	34.9	35.3
Total	130.4	120.6	130.4	142.2	161.8	156.8

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 8. The results of variety, inoculant, and nitrogen fertilizer on seed Ca content, seed P content, and plant population are provided in Table 9.

Variety - At all research locations except Carmangay, the Desi (Myles) chickpeas significantly out yielded the Kabuli (Stanford) chickpeas by 230 kg ha^{-1} to 430 kg ha^{-1}. However at the Carmangay fallow site, the Kabuli chickpeas yielded higher (although not significant) than the Desi chickpeas. 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 Lethbridge - stubble, Carmangay - fallow and stubble, and Warner fallow), and higher protein content (significant at the Bow Island - stubble, Carmangay - stubble, and Warner - stubble) than the Desi chickpeas. Higher bushel weights and protein content in the Kabuli chickpeas are likely due to the lower yields, thus increasing the bushel weights and protein content. The Desi chickpeas had significantly higher Ca content than the Kabuli chickpeas at all research locations. The only significant P content response was noted in the Kabuli chickpeas at the Carmangay fallow site.

Inoculant - In June, a number of research locations showed an obvious visual response to inoculant in both crop canopy and root nodulation. Nodulation data in Table 7 reveals the difference in the number of nodules in inoculated and uninoculated treatments. Figure 1 shows the difference in noduation number and size between inoculated and uninoculated treatments at the Lethbridge stubble site. Although trends did show increased yields due to applied inoculant at Bow Island fallow, Warner stubble, and Lethbridge stubble, there was no significant yield response at any of the research locations. There was a significant protein response at the Warner fallow site, the Carmangay stubble site (addition of inoculant significantly increased protein content), and the Bow Island fallow site (where the addition of inoculant significantly decreased protein content). There was no significant bushel weight, Ca or P content response to applied inoculant at any of the research locations.

Table 7. Average numbers of nodules per three plants on four check treatments.

Site	**System**	**Desi**		**Kabuli**	
		Inoculated	**Uninoculated**	**Inoculated**	**Uninoculated**
Bow Island	Fallow	8	0	14	0.3
Carmangay	Fallow	54.3	0.3	67.5	0
Carmangay	Stubble	24.3	0	33.8	0
Lethbridge	Stubble	18	9	23.5	0
Warner[1]	Fallow	32.5	0	25.3	0
Average		27.42	1.86	32.82	0.06

1. No data collected at the Warner stubble site.

Nitrogen - There was no significant yield response to nitrogen fertilizer at any of the research locations. However, results did show a strong positive correlation between nitrogen fertilizer rates and protein levels as all research locations responded significantly. The check treatments resulted in the lowest protein content at all research locations, while the 80 kg ha^{-1} treatment resulted in the highest protein at all research locations. There was a significant Ca response to nitrogen fertilizer at the Carmangay fallow site. P content declined significantly with the addition of nitrogen fertilizer at the Bow Island fallow site, and the Carmangay fallow and stubble sites. The addition of nitrogen fertilizer on bushel weight was only significant at the Carmangay stubble site.

Interaction -The variety and nitrogen interaction showed a significant bushel weight response at the Bow Island fallow site, and a significant protein response at the Warner stubble site. The variety and inoculant interaction showed a significant P content response at the Carmangay fallow site while the inoculant and nitrogen interaction showed a significant protein response at the Warner stubble site.

4.5 Experiment 2 - Phosphorus Experiment

The results of phosphate fertilizer on yield, bushel weight, and protein content are provided in Table 10. The results of phosphate fertilizer on seed Ca and seed P content are provided in Table 11.

There was no significant yield or bushel weight response to applied phosphate fertilizer at any of the research sites. At all locations except the Carmangay fallow and Warner stubble sites, the check treatment yielded the highest (although not significant). The Warner fallow site resulted in a significant Ca content response as the check treatment resulted in the highest Ca content. Soil P levels were medium to high at all 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 12. The results of sulfate fertilizer on seed Ca and seed P content are provided in Table 13.

There was no significant yield, bushel weight, protein, Ca or P content response to applied sulfate at any of the research locations. Trends do show, that there was a slight yield response (not significant) to applied sulfate at all locations except Carmangay stubble. Sulfate levels at most research locations were medium to 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, and protein are provided in Table 14. The results of seeding date and seeding rate on seed Ca and seed P content are provided in Table 15.

Seeding Date - There was a significant yield response to seeding rate at the Bow Island fallow, Carmangay fallow, Lethbridge stubble and Warner fallow sites. The third seeding date yielded the lowest at all research locations which directly relates to decreased soil moisture levels through the progression of spring. Bushel weight response to seeding date was significant at the Bow Island fallow, Carmangay stubble and Warner stubble sites. Bushel weights were highest on the third seeding dates due to low chickpea yields. There was a significant P content response to seeding date at the Bow Island fallow site (3^{rd} date resulted in lowest P content), and a significant protein and Ca content response at the Carmangay stubble site (3^{rd} date resulted in the highest protein and Ca content).

Seeding Rate - Plant populations reveal the differences in seeding rates. There was a significant yield response to seeding rate at the Bow Island fallow, Carmangay fallow, and Lethbridge stubble sites. Results show that yield has a tendency to increase to the 40 or 60 plant per m^2 plant population. Bushel weights responded significantly to seeding rate at the Bow Island fallow, and Carmangay fallow sites. Once again, the higher bushel weights are attributed to the corresponding low yields. P content response to seeding rate was significant at the Lethbridge stubble site, Bow Island fallow site, and the Carmangay stubble site (P content was highest on higher seeding rates). The Carmangay stubble site also resulted in a significant Ca response as, the lowest seeding rate resulted in the highest Ca content. There was no significant protein response at any of the research locations.

5.0 Summary

With two consecutive years of extreme drought, soil moisture was the major limiting factor for crop production. Through this drought, chickpeas have shown a high degree of drought tolerance. Yield differences 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, protein, Ca and P content responses, and differences in seeding rates have resulted in yield, bushel weight, Ca and P content response.

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Table 8. Effects of chickpea variety, inoculant, and nitrogen fertilizer on yield, protein, and bushel weight at each research location for Experiment 1.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Warner - Fallow			Warner - 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	414 a	64.4	23.7 b	2296 a	65.6 b	23.3	2245	64.6 b	19.2	539	65.2 b	20.8 b	2333 a	66.0 b	23.1	4 [illegible] a	64.1	24.9 b
Kabuli	181 b	64.7	25.7 a	1889 b	66.7 a	23.9	2574	66.5 a	20.4	408	67.0 a	22.9 a	1904 b	67.1 a	22.9	1 [illegible] b	64.3	25.8 a
Inoc																		
Inoculant	302	64.4	24.4 b	2117	66.2	23.5	2345 a	65.5	20.1	465	66.1	22.4 a	2061	66.6	23.4 a	3 [illegible]	64.4	25.7
No Inoculant	296	64.7	24.9 a	2074	66.1	23.7	2446 b	65.7	19.6	481	66.1	21.4 b	2162	66.5	22.6 b	2 [illegible]	64.1	25.1
N Fertilizer																		
0	334	64.4	23.0 b	1890 b	65.9	21.9 d	2013 b	65.1 b	17.8 d	416 a	65.4 b	19.0 c	1949	66.4	20.3 c	3 [illegible]	64.3	23.1 c
20	256	64.5	24.7 a	2090 a	66.1	22.5 d	2487 ab	65.2 b	18.9 cd	515 a	65.9 a	20.8 b	2142	66.3	22.2 b	3 [illegible]	64.2	25.2 b
40	325	64.7	24.9 a	2132 a	66.1	23.5 c	2467 ab	65.7 ab	20.0 bc	462 a	66.3 a	22.7 a	2196	66.7	23.4 a	3 [illegible]	64.4	25.7 ab
60	295	64.5	25.3 a	2215 a	66.4	24.7 b	2618 a	65.8 ab	20.9 ab	484 a	66.4 a	23.2 a	2257	66.5	24.3 a	3 [illegible]	64.3	26.3 a
80	287	64.7	25.5 a	2157 a	66.3	25.6 a	2338 ab	66.0 a	21.7 a	488 a	66.3 a	23.5 a	2023	66.8	24.6 a	3 [illegible]	64	26.6 a
Significance																		
Rep	<0.0001	<0.0001	0.0023	<0.0001	0.6561	0.2332	0.1450	0.4006	0.1186	0.0075	0.1297	0.0053	0.0008	0.5207	<0.0001	0 [illegible]	0.0036	0.0014
Rep X Var	0.6939	<0.0001	0.9069	0.0003	0.0639	0.3222	0.3140	0.0033	0.0894	0.0275	0.3706	0.2441	0.9570	0.3871	0.3629	0 [illegible]	0.0003	0.6000
Rep X In(Var)	0.5754	0.7806	0.5827	0.7896	0.0127	0.4488	0.7825	0.0256	0.6246	0.3964	0.8154	0.9993	0.6379	0.7092	0.9587	0 [illegible]	0.3464	0.0222
Rep (e=rXv)	0.0180	0.5651	0.0094	0.1107	0.8843	0.4329	0.3629	0.8961	0.5358	0.4052	0.3131	0.1730	0.0033	0.5951	0.0114	0 [illegible]	0.6236	0.0477
Variety	0.0001	0.6350	0.0002	0.0370	0.0100	0.1702	0.1086	0.0176	0.1429	0.0900	0.0009	0.0063	0.0006	0.0057	0.6312	0 [illegible]	0.7939	0.0193
Inoculant	0.9071	0.0217	0.0278	0.2028	0.5344	0.4926	0.1693	0.5368	0.4124	0.6271	0.7702	<0.0001	0.2126	0.9171	0.0037	0 [illegible]	0.2705	0.1642
Fertility	0.3936	0.4954	<0.0001	0.0002	0.0693	<0.0001	0.0604	0.0029	<0.0001	0.2895	<0.0001	<0.0001	0.1146	0.1580	<0.0001	0 [illegible]	0.8248	<.0001
V X I	0.7133	0.9341	0.2028	0.2947	0.7921	0.5326	0.7921	0.9028	0.6215	0.5716	0.2981	0.0005	0.8950	0.9834	0.2296	0 [illegible]	0.1926	0.6954
V X F	0.9103	0.0476	0.2433	0.0133	0.2576	0.0278	0.7656	0.1022	0.3469	0.0128	0.0372	0.0773	0.5943	0.6348	0.9794	0 [illegible]	0.8327	0.0180
I X F	0.3419	0.7424	0.4216	0.4893	0.5718	0.5343	0.8247	0.3767	0.2757	0.1433	0.7079	0.1655	0.5331	0.3110	0.0712	0 [illegible]	0.3600	0.0448
V X I X F	0.7302	0.7027	0.6238	0.9710	0.5272	0.7918	0.5273	0.9722	0.4295	0.3093	0.8103	0.0556	0.1431	0.5542	0.1021	0 [illegible]	0.7623	0.0599
C. V.	37.3	0.8	3.8	8.7	0.8	4.7	22.1	1.1		27.6	0.9	5.2	16.9	1	6.5	4 [illegible]	1.4	4.7

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

on Ca, P, and plant/m^2 at each research location for Experiment 1.

	Fallow		Carmangay - Stubble			Warner - Fallow			Warner - Stubble		
	)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2	Ca (%)	P (%)	Plants /m^2
	6 b	24	0.17 a	0.27	15	0.16 a	0.32	33 b	0.16 a	0.36	31 b
	8 a	27	0.11 b	0.28	16	0.11 b	0.31	48 a	0.10 b	0.35	39 a
	7	23 b	0.14	0.27	14	0.13	0.32	38 b	0.13	0.36	34
	7	27 a	0.14	0.28	16	0.14	0.31	43 a	0.14	0.35	37
	8 ab	27	0.14 b	0.30 a	22	0.13	0.33	33	0.13	0.37	36
	7 ab	26	0.14 ab	0.29 a	15	0.13	0.33	45	0.13	0.34	39
	6 ab	26	0.14 ab	0.27 b	12	0.14	0.30	43	0.13	0.35	34
	8 a	25	0.15 a	0.26 b	14	0.13	0.31	39	0.14	0.36	31
	6 b	23	0.14 ab	0.26 b	15	0.13	0.30	41	0.14	0.35	36
	168	0.8455	0.0009	0.0138	0.0448	0.0202	0.2509	0.7345	0.0075	0.0032	0.5092
	177	0.5647	0.7768	0.2102	0.5092	0.0073	0.0693	0.6095	0.0194	0.0134	0.7997
	971	0.9686	0.7364	0.6287	0.7481	0.6093	0.1622	0.9044	0.0001	0.7400	0.3501
	383	0.7667	0.0367	0.2339	0.1461	0.5714	0.6768	0.6135	0.4335	0.4102	0.2522
	427	0.2699	<0.0001	0.6139	0.7227	0.0042	0.4637	0.0060	0.0025	0.5675	0.0097
	645	0.0236	0.7689	0.8283	0.2221	0.1437	0.4710	0.0296	0.5532	0.3769	0.3569
	384	0.8735	0.4210	<0.0001	0.0236	0.4081	0.0058	0.0823	0.6721	0.1681	0.4088
	209	0.0409	0.3919	0.6109	0.2133	0.1437	0.5793	0.3471	0.1378	0.4443	0.4731
	575	0.7661	0.5885	0.8808	0.3149	0.5747	0.0358	0.2767	0.3946	0.1869	0.3914
	507	0.2767	0.7565	0.8785	0.1017	0.8171	0.5676	0.9031	0.5411	0.7605	0.8697
	817	0.9859	0.5748	0.9743	0.1049	0.3970	0.5041	0.3041	0.1889	0.6629	0.4918
		45.3	6.9	8.2	56.7	9.2	10.2	29.7	10.7	9.4	30.5

s followed by the same letter are not significantly different.

Table 9. Effects of chickpea variety, inoculant, and nitrogen fertilizer

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay -	
	Ca	P	Plants	Ca	P	Plants	Ca	P
	(%)	(%)	/m^2	(%)	(%)	/m^2	(%)	(%
Variety								
Desi	0.18 a	0.30	26 b	0.16 a	0.38	36 b	0.17 a	0.2
Kabuli	0.11 b	0.30	31 a	0.11 b	0.37	46 a	0.11 b	0.2
Inoc								
Inoculant	0.14	0.30	25 b	0.14	0.38	40	0.14	0.2
No Inoculant	0.14	0.30	32 a	0.14	0.37	42	0.14	0.2
N Fertilizer								
0	0.14	0.33 a	29	0.14	0.39	38	0.14 b	0.2
20	0.15	0.30 b	29	0.14	0.38	45	0.14 b	0.2
40	0.14	0.29 a	29	0.14	0.37	37	0.15 a	0.2
60	0.14	0.29 a	26	0.14	0.37	42	0.14 b	0.2
80	0.14	0.29 a	30	0.13	0.36	43	0.15 ab	0.2
Significance								
Rep	0.2225	0.6340	0.0096	0.0016	0.0346	0.3706	0.5806	0.0
Rep X Var	0.7071	0.2841	0.9454	0.6011	0.7210	0.8391	0.4770	0.2
Rep X In(Var)	0.0696	0.3585	0.6319	0.0580	0.3486	0.1263	0.4680	0.9
Rep (e=rXv)	0.1790	0.7409	0.0080	0.0488	0.0720	0.1504	0.5776	0.2
Variety	<0.0001	0.8122	0.0070	0.0002	0.2861	0.2699	0.0002	0.0
Inoculant	0.9021	0.3973	0.0141	0.8449	0.7638	0.4154	0.4592	0.0
Fertility	0.5803	<0.0001	0.8532	0.8112	0.3552	0.4500	0.0326	0.0
V X I	0.3649	0.3070	0.4205	0.8016	0.2568	0.4659	0.1739	0.0
V X F	0.3347	0.0182	0.5696	0.1536	0.4723	0.7281	0.6735	0.2
I X F	0.3192	0.9876	0.9000	0.3275	0.1882	0.4010	0.3511	0.6
V X I X F	0.0489	0.8591	0.9996	0.8444	0.4994	0.5285	0.8477	0.0
C. V.	5.8	7.5	36.6	7.9	10.4	21.4	9.1	7.8

Letters following the mean are Student-Newman-Keuls values. Means

Table 10. Effects of phosphate fertilizer on yield, protein, and bushel weight at each research location for Experiment 2.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Warner - Fallow			Warner - Stubble		
	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein
	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)
P_2O_5 Fertilizer																		
0	515	64.4	23.8	2214	65.7	24.1	2206	64.2	18.8	658	65	20.8	2345	66.2	19.4	521	64.6	22.5
15	454	64.6	23.9	2129	65.7	22.5	2098	63.6	17.9	646	65.3	20.5	2300	65.9	22.0	393	63.9	23.3
30	480	64.5	24.0	2212	65.6	22.7	2267	64.4	17.9	701	64.9	19.9	2238	66	20.3	414	64.2	23.5
Significance																		
Rep	0.5159	0.0610	0.1695	0.0645	0.0141	0.3862	0.2228	0.7274	0.8835	0.1123	0.5788	0.3526	0.4749	0.5167	0.0381	0.5436	0.1342	0.4498
Fertility	0.6335	0.8088	0.9416	0.8131	0.5806	0.1343	0.6942	0.5575	0.3948	0.4342	0.3443	0.5163	0.8893	0.8081	0.0832	0.5876	0.2068	0.7910
C. V.	20.5	0.5	2.8	10.8	0.4	5.0	14.1	2	6.1	9.9	0.7	5.8	15.1	0.9	7.6	46	0.8	10.8

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

Table 11. Effects of phosphate fertilizer on Ca, and P at each research location for Experiment 2.

Trt.	Bow Island-Fallow		Lethbridge - Stubble		Carmangay - Fallow		Carmangay - Stubble		Warner - Fallow		Warner-Stubble	
	Ca	P	Ca	P	Ca	P	Ca	P	Ca	P	Ca	P
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
P_2O_5 Fertilizer												
0	0.18	0.30	0.15	0.36	0.16	0.27	0.17	0.27	0.18 a	0.31	0.18	0.34
15	0.18	0.29	0.15	0.35	0.17	0.26	0.18	0.30	0.16 b	0.31	0.17	0.36
30	0.17	0.29	0.15	0.38	0.17	0.24	0.18	0.28	0.17 b	0.31	0.18	0.36
Significance												
Rep	0.1036	0.1435	0.9214	0.8911	0.6197	0.9043	0.9751	0.1717	0.0007	0.8977	0.6025	0.0054
Fertility	0.1132	0.3626	0.8204	0.1404	0.5075	0.6760	0.9292	0.0901	0.0115	0.9770	0.9399	0.0925
C. V.	3.3	3.7	8.6	5.6	8.4	14.1	4.6	6.3	2.7	9.3	5.0	4.3

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

Table 12. Effects of sulfate fertilizer on yield, protein, and bushel weight at each research location for Exp

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			V
	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Y
	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(l
SO_4-S Fertilizer													
0	447	64.2	23.5	2320	65.5	22.7	2149	63.8	18.1	687	64.8	20.4	2
20	549	64.1	23.1	2407	65.8	22.4	2190	64.8	19.1	658	64.7	19.9	2
30	617	64.5	23.5	2425	65.8	24.0	2229	64.1	18.9	687	64.8	19.5	2
Significance													
Rep	0.6519	0.2196	0.9319	0.1107	0.8782	0.0877	0.9064	0.3604	0.2457	0.0653	0.7167	0.2623	0
Fertility	0.2482	0.6064	0.7332	0.5306	0.7470	0.1995	0.9628	0.4950	0.5510	0.6774	0.6844	0.3403	0
C. V.	27.5	0.8	3.4	6.3	1	5.6	21	2.1	7.8	8.7	0.8	4.6	1

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

Table 13. Effects of sulfate fertilizer on Ca, and P at each research location for Experiment 3.

Trt.	Bow Island-Fallow		Lethbridge - Stubble		Carmangay - Fallow		Carmangay - Stubble		Warner - Fallow		Warner - Stubble	
	Ca	P	Ca	P	Ca	P	Ca	P	Ca	P	Ca	P
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
SO_4-S Fertilizer												
0	0.18	0.30	0.16	0.48	0.17	0.27	0.17	0.29	0.17	0.32	0.17	0.35
20	0.18	0.31	0.15	0.34	0.17	0.24	0.17	0.29	0.15	0.32	0.18	0.34
30	0.18	0.30	0.16	0.35	0.18	0.25	0.17	0.28	0.17	0.31	0.17	0.38
Significance												
Rep	0.9095	0.6738	0.1296	0.4434	0.4363	0.4455	0.8264	0.7755	0.1584	0.6480	0.3564	0.5489
Fertility	0.3830	0.5615	0.7314	0.2820	0.5195	0.2820	0.6204	0.8325	0.8353	0.7501	0.2100	0.3721
							C. V.	4.7	5.9	9.0	34.4	9.2

)eriment 3.

Varner - Fallow			Milk River - Stubble		
ield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)	Yield (kg ha^{-1})	bu wt (lbs/bu)	Protein (%)
177	65.7	18.8	443	63.7	21.3
173	65.8	18.6	496	63.8	21.0
242	65.9	19.2	489	64.0	21.3
.6412	0.6456	0.0092	0.5055	0.7167	0.3812
.8909	0.8839	0.7651	0.9051	0.6844	0.9755
1.4	1.0	6.7	42.6	0.8	12.0

significantly different.

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

Table 14. Effects of seeding date and seeding rate on yield, protein, and bushel weight at each research location for Experiment 4.

Trt.	Bow Island- Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Warner - Fallow			Warner - Stubble		
	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein	Yield	bu wt	Protein
	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)	(kg ha^{-1})	(lbs/bu)	(%)
Date																		
1	554 a	64.1 b	23.2	2721 a	65.7	22.4	2415 a	63.8	18.6	651	64.7	20.5 b	2113 ab	65.3 b	18.9	473	64 b	21.1
2	538 a	64.5 b	23.3	2563 b	66.2	21.9	2124 b	64.2	18.3	620	65.1	20.8 ab	2322 a	65.6 ab	19.7	539	64.4 b	21.0
3	430 b	65.5 a	23.4	2391 c	66	22.3	2061 b	64.4	18.9	568	65.1	21.2 a	1909 b	66 a	19.8	446	65.2 a	20.8
Seeding Rate																		
20	333 b	64.8	23.4	2303 b	65.9	22.3	1849 b	64.3	19.2	572	65.2	21.6	2012	65.7	19.9	418	64.7	20.9
40	525 a	64.9	23.0	2697 a	66.1	22.1	2137 ab	64	19.0	611	64.9	20.6	2208	65.9	19.6	532	64.7	20.6
60	587 a	64.8	23.3	2547 ab	65.7	22.0	2411 a	63.9	18.3	629	65.1	20.7	2136	65.8	20.0	489	64.4	21.4
80	549 a	64.3	23.5	2643 a	66	22.0	2373 a	64.2	18.2	647	65.1	20.5	2107	65.7	19.5	512	64.5	20.6
100	542 a	64.5	23.3	2602 ab	66	22.5	2229 a	64.3	18.4	607	64.9	20.7	2126	65.1	18.4	480	64.4	21.4
Significance																		
Rep	0.2312	0.0817	0.0025	<.0001	0.5147	<0.0001	0.1142	0.0122	0.7203	0.0064	0.0012	0.5765	0.0002	0.5772	<0.0001	0.0824	0.3081	0.0048
Rep X Date	0.9760	0.1897	0.3102	0.8631	0.2023	0.9089	0.8165	0.2479	0.9847	0.0147	0.6834	0.9505	0.1359	0.4073	0.4737	0.7500	0.3009	0.5450
Rep (e=rXv)	0.0178	0.2934	0.0519	0.0010	0.6876	<0.0001	0.0584	0.1155	0.1346	0.2968	0.0096	0.1524	0.0495	0.6201	0.0092	0.0632	0.459	0.0299
Date	0.0060	0.0022	0.6700	0.0053	0.1317	0.1009	0.0108	0.3856	0.1342	0.2796	0.0478	0.0171	0.0161	0.0329	0.2366	0.1123	0.002	0.8935
Rate	0.0162	0.0476	0.7032	0.0295	0.2911	0.7362	0.0058	0.7824	0.4321	0.2860	0.5599	0.1436	0.3395	0.0731	0.1953	0.4852	0.6067	0.7333
Date X Rate	0.2919	0.1307	0.3749	0.9663	0.0765	0.9250	0.5588	0.4848	0.9596	0.3224	0.9740	0.4893	0.9537	0.1680	0.7236	0.8628	0.0854	0.4108
C.V.	36.6	0.9	3.7	11.9	0.8	4.6	17	1.5	7.8	13.9	0.8	5.3	10.7	1.0	8.8	32.6	0.9	9.4

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

ble 15. Effects of seeding date and seeding rate on Ca, P, and plant/m^2 at each research location for Experiment 4.

	Bow Island - Fallow			Lethbridge - Stubble			Carmangay - Fallow			Carmangay - Stubble			Warner - Fallow			Warner - 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
te																		
	0.18	0.31 a	31 a	0.17	0.33	47	0.17	0.26	31	0.17 c	0.29	28	0.17	0.33	40	0.17	0.35	41
	0.18	0.31 a	11 b	0.17	0.31	46	0.17	0.26	25	0.18 b	0.29	22	0.18	0.31	39	0.17	0.35	38
	0.18	0.29 b	24	0.18	0.31	45	0.17	0.25	27	0.19 a	0.28	22	0.18	0.30	37	0.17	0.35	30
ding Rate																		
	0.18	0.29 b	11 b	0.18	0.31 ab	18 d	0.17	0.26	16 b	0.19 a	0.27 b	14 b	0.17	0.30	22 c	0.17	0.32	14 c
	0.18	0.30 ab	15 b	0.17	0.31 ab	33 c	0.17	0.25	22 ab	0.18 b	0.27 b	16 b	0.18	0.30	33 bc	0.17	0.33	28 b
	0.18	0.31 a	20 ab	0.18	0.31 b	47 b	0.17	0.25	36 a	0.18 b	0.28 ab	26 a	0.18	0.31	42 ab	0.17	0.35	33 b
	0.18	0.31 ab	32 a	0.17	0.33 ab	67 a	0.17	0.26	27 ab	0.18 b	0.31 a	32 a	0.18	0.31	44 ab	0.16	0.40	52 a
)	0.18	0.31	33 a	0.17	0.33 a	67 a	0.17	0.27	37 a	0.18 b	0.30 ab	30 a	0.17	0.35	51 a	0.17	0.36	55 a
nificance																		
)	0.3520	0.8540	0.9751	0.0017	0.6641	0.2596	0.0122	0.3681	0.4020	0.1799	0.5072	0.7931	0.7918	0.6364	0.5177	0.7048	0.6782	0.2322
) X Date	0.1947	0.5662	0.8507	0.0575	0.0690	0.3424	0.9621	0.7026	0.3841	0.8220	0.5709	0.0410	0.2984	0.1358	0.7858	0.5409	0.3811	0.4462
) (e=rXv)	0.5698	0.8120	0.9174	0.1380	0.8624	0.3896	0.0020	0.2616	0.4869	0.0843	0.4627	0.9335	0.8421	0.8072	0.3141	0.6643	0.7187	0.3050
te	0.3578	0.0373	0.0019	0.2395	0.0643	0.9489	0.0231	0.2974	0.5119	0.0006	0.3058	0.3660	0.2153	0.2127	0.7076	0.8170	0.9592	0.1829
e	0.3892	0.0196	0.0011	0.2436	0.0221	<.0001	0.4531	0.1474	0.0056	0.0011	0.0188	<.0001	0.6480	0.0846	0.0008	0.3923	0.0712	<.0001
te X Rate	0.2043	0.4618	0.4146	0.8494	0.4557	0.6312	0.8568	0.6585	0.9827	0.9599	0.8086	0.7897	0.5906	0.7491	0.5762	0.5112	0.6327	0.7759
.	5.0	6.7	65.6	6.0	6.6	34.4	7.1	8.7	54.6	4.7	11.0	36.2	7.3	14.4	40.3	7.3	19.3	45.5

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