Chickpea in Semiarid Cropping Systems

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INTRODUCTION

Relative to other pulse crops such as dry-pea (*Pisum sativum* L.) and lentil (*Lens culinaris* L.), chickpea (*Cicer arietinum* L.) is still new in western Canada. In 1999, there were 350,000 acres of chickpea seeded in Saskatchewan with more than 75% of the seeded area being located in the districts of Swift Current, Shaunavon, Moose Jaw, Rosetown, and Assiniboia (Noble 2000). Approximately 93% of the seeded chickpea area was harvested in Saskatchewan in 1999 (Statistics Canada, 1999). Due to abundant rainfall and generally cooler than normal growing conditions in 1999, some late-seeded chickpea fields did not reach full maturity. The best production success came in the southwest corner of Saskatchewan where the growing season (May to August) precipitation usually is less than 8 inches. The deeper rooting habit and the tolerance to water stress makes chickpea a winner under these adverse drought conditions.

The objective of this study was to develop agronomic information for the inclusion of chickpea in cropping systems for the semiarid prairie region. The focus has been on aspects pertaining chickpea water use characteristics, stubble effect, re-cropping constraints, and other rotational considerations.

MATERIALS AND METHODS

Two field experiments were conducted, one at Swift Current on a loam soil, and the other at Stewart Valley on a clay soil, from 1996 to 1999.

Experiment 1. *D*esi chickpea, treated with *Crown and/or Apron FL* fungicides (Hwang et al. 1998), was planted at a rate of 60 viable seeds per m^{-2}, which was compared with two other commonly grown pulse crops (lentil and dry pea). *Laird* lentil treated with *Crown* fungicide was planted at a rate of 140 viable seeds m^{-2}, and *Grande* yellow pea treated with *Apron FL* fungicide was planted at a rate of 85 viable seeds m^{-2}. The study also included oriental mustard which was treated with *Vitavax RS* and was planted at a rate of 230 viable seeds m^{-2}, and *Katepwa* hard red spring wheat which was treated with *Vitavax Dual* and was planted at a rate of 250 viable seeds m^{-2}. Chickpea and the two other pulse crops received no fertilizer N aside from that in the 30 lb of 11-51-0 ac^{-1} that was applied with the seed. Granular inoculant was applied to each of the pulses at a rate of 7 lb ac^{-1} (Walley 1999). The amount of fertilizer-N applied for mustard and wheat was based on fall soil tests and ranged from 35 to 65 lb actual N ac^{-1}, including the amount of N from the 11-51-0. All five crops were planted on tilled fallow to ensure a full soil moisture profile and were grown with good agronomic practices regarding seeding date and weed control. The treatments were compared in a three-replicate, randomized complete block design.

In the following year, three types of crops (oriental mustard/canola, dry pea/lentil, and spring wheat) were re-cropped on each of the five previous crop stubbles. In the re-cropping of canola and wheat, fertilizer N was applied such that total soil available N was equal to 60 to 65 lb N ac^{-1}, based on fall soil tests and the targeted yield level. Crops grown on pulse stubbles were fertilized by adjusting for pulse stubble N credits in the soil profile. The crop sequences were repeatedly studied for three successive cycles.

Experiment 2. A four-replicate field study was conducted at Swift Current in 1998 and 1999 where kabuli chickpea, 'Sanford' and 'B-90', and desi chickpea 'Myles', were grown under different levels of fertilizer-P using different seed sizes. Phosphorous fertilizer was applied with the seed at the rate of 0, 15, and 30 lb P_2O_5 ac^{-1}. Two sizes of kabuli seed, large (>9 mm in diameter) and small (<9 mm in diameter), were obtained by separating the seed sizes from the same seedlot of Sanford. All plots received 5 lb ac^{-1} of "Nitragin soil implant" granular inoculant (Lipha Tech Inc., Saskatoon). All seed was treated with Crown at 600 ml and Apron at 16 ml per 100 kg of seed. Bravo 500 was applied at early flowering and/or podding stages to control Ascochyta blight.

RESULTS AND DISCUSSIONS

Response of Chickpea to Fertilizer-P

The response of chickpea to fertilizer-P application was inconsistent between the two years (Table 1). In 1998, chickpea yields increased 7 to 11%, by using fertilizer-P at the rate of 30 lb P_2O_5 ac^{-1}, compared to the check treatment. In 1999, however, no yield differences were found between the fertilizer-P treatments, although the application of P fertilizer at the high rate slightly increased dry matter production at flowering (data not shown). Overall, chickpea seed yield in 1998 was 850 lb ac^{-1}, about half of the 1999 seed yield. Greater soil moisture in 1999 favoured rhizobial activity, symbiotical N-fixation, and plant growth, which might have masked the possible response from fertilizer-P. Studies by Walley et al. (1999) also indicated that application of P_2O_5 conferred a seed yield advantage at some sites, but not at all sites.

In both years, a strong correlation was found between fertilizer-P application and seed size proportion in the harvested seedlot in kabuli chickpea. The highest fertilizer-P rate resulted in the greatest proportion of seed greater than 9 mm in diameter. Chickpea buyers are currently (January 2000) offering a 6¢ per lb premium for seed greater than 9 mm. Although the influence of P_2O_5 on seed yield of chickpea was inconsistent, it is important to note that the proportion of large seed was significantly increased with fertilizer-P. In light of the important role that P plays in root development, stress tolerance, maturity enhancement, and large seed production, we strongly recommend that fertilizer-P be applied in chickpea. We expect a return from the use of P fertilizer. Given the high value of this crop, perhaps this is good insurance all the time. In the present trial, the P fertilizer was applied with the seed. Plant stand was the lowest for the highest P rate in 1998, but not in 1999.

Table 1. Effect of phosphorous fertilizer application on kabuli chickpea yield and seed size fraction of the harvested grain at Swift Current.

Year	Actual P-rate	Seed yield	Seed size fraction > 9 mm	Seed size fraction < 8 mm	Gross income
	---------------------------- lb ac^{-1}			--------------------------------	($ ac^{-1})
1998	0	800 a	296 a	104 a	245
	15	783 a	274 a	102 a	239
	30	891 b	357 b	98 b	277
1999	0	1761 a	1110 a	141 a	578
	15	1708 a	1128 a	120 a	566
	30	1734 a	1214 b	104 b	581

Effect of Seeding Date

Seeding date had a significant effect on dry matter production at flowering for kabuli chickpea (Table 2). Averaged for the two years, the early-seeded B-90 produced 10.8% more dry matter at flowering than that seeded late. Similar results were obtained for the cultivar Sanford, with early seeding producing 16% more dry matter at flowering than the late-seeded Sanford.

Table 2. Effect of seeding date on dry matter production in kabuli chickpea at Swift Current.

Seeing date	**B-90**			**Sanford**		
	1998	1999	2yr mean	1998	1999	2yr mean
		-------------------------------		lb ac^{-1}	----------------------	
early (April 30 - May 5)	281	419	350	317	449	383
late (May 16 - May 20)	262	371	316	244	416	329
early over late, %	7.5%	13.0%	10.8%	30.0%	8.1%	16.1%

The greater dry matter production associated with early seeding also translated into higher final seed yields in chickpea (Table 3). By seeding chickpea early, seed yield increased 10 to 16% for B-90 and 4 to 12% for Sanford. We observed that the earlier seeded plants had a longer period of time between flowering and plant maturity. It is speculated that the increased seed yields with early seeding were partially due to the longer reproduction period during which more seeds were set, and more photosynthetic materials were mobilized from the vegetative organs to the seed. In addition, early seeding resulted in an earlier harvest, reducing the risk of late-fall frost and lower seed quality. Kabuli chickpea grown at Swift Current had an average maturity of 95 days in 1998 and 115 days in 1999. However, for late-April seeding of kabuli chickpea in the southwest Saskatchewan, one should make sure that seed is treated with metalaxyl (i.e. *Allegiance, Apron*) since kabuli seed is highly susceptible to Pythium seed rot, especially at soil temperatures below 12ºC (Hwang et al. 1998).

Table 3. Effect of seeding date on the seed yield of kabuli chickpea at Swift Current.

Seeing date	B-90			Sanford		
	1998	1999	2yr mean	1998	1999	2yr mean
	------------	------------	lb ac^{-1}	------------	------------	------------
early (April 30 - May 5)	945	2007	1476	836	1861	1349
late (May 16 - May 20)	861	1723	1292	802	1660	1231
early over late, %	9.7%	16.4%	14.2%	4.3%	12.1%	9.5%

Seed Size Effect

Seed cost is one of the major inputs for kabuli chickpea production. If small seed (<9 mm) could be planted without affecting plant vigour or final seed yield, then seed cost could be reduced accordingly (Gan et al. 2000). For example, to obtain a plant density of 4 plants per square foot for kabuli chickpea, assuming a 75% emergence rate, growers need to plant 180 to 210 lb ac^{-1} of seed that is over 9 mm in diameter, while 130 to 150 lb ac^{-1} is needed for seed below 9 mm in size. The difference is 50 to 60 lb seed ac^{-1}. This 2-yr field study showed that the size of seed planted had no significant impact on plant growth and development, nor on final seed yield in kabuli chickpea (Table 4). Retaining the small seed fraction could save up to 50 to 60 lb ac^{-1} in seed without sacrificing seed yield, however, the affect on seed size fraction remains uncertain. Further studies are being conducted to elucidate if small seed can be used generation after generation without selecting for a small-seeded genetic version of *Sanford*, or without reducing intrinsic seedling vigour.

Table 4. Relation between seed size in Kabuli chickpea and seeding rate, cost of seed, and resulting plant counts, seed yield and dry matter production in southwest Saskatchewan.

Year	Seed size	Seeding rate	Cost of seed	Plant density	Seed yield	Dry matter
		(lb ac^{-1})	(\$ ac^{-1})	(plants ft^{-2})	(lb ac^{-1})	(lb ac^{-1})
1998	=> 9 mm	210	105	3.4	819	314
	< 9 mm	150	75	3.3	829	331
	difference, %	60	30	NS	NS	NS
1999	=> 9 mm	180	90	3.3	1760	486
	< 9 mm	130	65	3.0	1710	481
	difference, %	50	25	NS	NS	NS

Chickpea Water Use Characteristics

Averaged over six site/years, chickpea used 6 to 8% less water than mustard or spring wheat during the growing season (Table 5). Among the three pulse crops, chickpea used more water than dry-pea or lentil; the latter used only 73% of the water that spring wheat used during the growing season. Chickpea conserved an equivalent amount of water as oriental mustard in the soil profile (120 cm depth) after harvest; they were 5 to 7% more than the amount of water conserved by wheat, but were much less than those conserved by dry-pea or lentil. The shallow rooting habit of dry-pea and lentil, with the majority of their roots being within the top 60-cm depth, contributed to the great water conservation below 60-cm soil depth (Gan et al. 1999). Other researchers have also found that dry pea perform well in water-limited environments (Armstrong et al. 1994; Martin et al. 1994; Ney et al. 1994; Lecoeur and Sinclair 1996; Miller et al. 1998).

Table 5. Water use (inches) during the growing season in chickpea grown in the southwestern Saskatchewan from 1996 to 1998.

Crop	Soil type		Mean	% of wheat
	clay	loam		
	(inch)	(inch)	(inch)	(%)
Dry pea	4.1	3.5	3.8	71
Lentil	4.8	3.4	4.1	76
Chickpea	**5.1**	**4.7**	**4.9**	**92**
Mustard	5.3	4.7	5.0	94
Wheat	5.4	5.3	5.3	100
LSD(0.05)	0.38	0.48	0.30	---

Table 6. Available water (inch) in the soil profile (120 cm depth) at planting in various crop stubble, at Swift Current (loam) and Stewart Valley (clay) from 1996 to 1998.

Crop stubble	Soil type		Mean	% of wheat
	clay	loam		
	(inch)	(inch)	(inch)	(%)
Dry pea	6.7	2.5	4.6	109
Lentil	6.5	2.8	4.7	110
Chickpea	**6.1**	**2.3**	**4.2**	**99**
Mustard	6.2	1.9	4.0	95
Wheat	6.1	2.4	4.2	100
LSD(0.05)	0.36	0.33	0.36	---

Soil water recharge occurred during the winter months and the soil water profile at planting the following spring was influenced by the standing stubble. Adequate amount of available water at the spring planting is the key for successful crop establishment in the semiarid prairie. This study showed that chickpea stubble had an equivalent amount of available water in the 120-cm soil depth at planting the following spring, as did mustard or wheat (Table 6). The available water in chickpea stubble was less than those in dry-pea and lentil stubbles, which was consistent with the water status measured after harvest the previous season. Snow retention was probably higher for mustard and wheat stubbles than pulse stubbles; this may have slightly modified the water status in the soil profile measured in spring.

Grain Yield vs Stubble Type

Averaged over the six site-years, canola or mustard grown on chickpea stubble produced slightly higher (5%) seed yield than when grown on wheat or mustard stubble (Table 7). In comparison, canola or mustard produced over 20% higher seed yield on lentil stubble and over 40% higher grain yield on pea stubble than when grown on wheat or mustard stubble. The oilseed crops grown on wheat or mustard stubble had the lowest seed yield. The chickpea stubble did not seem to provide equivalent benefits to the following oilseed crops as did pea and lentil. Chickpea produced the least residue of all crops, and we had establishment problems on this stubble for the shallow-seeded canola/mustard in the dry early spring of 1998.

Hard red spring wheat grown on the different types of stubbles showed a similar trend as for canola or mustard (Table 8). Wheat grain yield was over 25% higher when grown on any of those the pulse stubbles than on its own stubble. Wheat yield was 17% greater when grown on mustard stubble than on its own stubble. Unlike canola or mustard (Table 7), spring wheat grown on chickpea stubble yielded as much as it did when grown on pea or lentil stubble (Table 8). Spring wheat grown on chickpea stubble had better seedling establishment than the small-seeded crops such as canola or mustard.

Table 7. Seed yield of **canola/mustard** grown on chickpea and other crop stubbles in southwest Saskatchewan (1997 to 1999).

Crop stubble	Site/yr	Seed yield (lb ac^{-1})			% up from wheat stubble
		Mean	Min.	max.	
Wheat	6	942	124	1579	0
Mustard	6	947	497	1416	1
Chickpea	6	992	65	1452	5
Lentil	6	1155	226	1629	23
Dry pea	6	1333	927	1704	41

Table 8. Grain yield of **hard red spring wheat** grown on chickpea and other crop stubbles in southwest Saskatchewan (1997 to 1999).

Crop stubble	Site/yr	Seed yield (lb ac^{-1})			% up from wheat stubble
		Mean	Min.	max.	
Wheat	6	1977	1192	2368	0
Mustard	6	2320	1466	3122	17
Chickpea	6	2469	1377	3518	25
Lentil	6	2559	1413	3527	29
Dry pea	6	2576	1756	3426	30

Averaged over four site-years, yellow pea produced excellent grain yields (over 40 bu/ac) regardless of what crop it followed, except when it was grown on its own stubble. Pea had the highest grain yield when grown on wheat stubble (Table 9). In this study, it appeared that the cooler seedbed provided by wheat stubble was preferred by the pea and lentil seedlings. In another experiment, we found that the pulse crops performed better when planted into standing wheat stubble than when planted into a cultivated seedbed.

Table 9. Grain yield of **yellow pea** grown on chickpea and other crop stubbles in southwest Saskatchewan (1997 to 1999).

Crop stubble	Site/yr	Seed yield (lb ac^{-1})			% up from wheat stubble
		Mean	Min.	max.	
Wheat	4	2597	1511	3617	0
Mustard	4	2297	1226	3558	-12
Chickpea	4	2330	925	3689	-10
Lentil	4	2359	1295	3419	-9
Dry pea	4	2121	1170	3215	-18

CONCLUSIONS

In the semiarid prairie, water is one of the major factors limiting crop production. On average, chickpea used an equivalent amount of water as oriental mustard during the growing season, and used 8% less water than spring wheat. After recharge during the winter months, the amount of available water in the following spring was similar between chickpea and wheat stubble fields. In comparison, dry pea and lentil used only 73% of the water used by spring wheat. Pea and lentil stubbles had 10% more available water conserved in the soil profile the following spring than did wheat or mustard stubble fields. The better water conservation explains, in part, why the highest wheat and canola yields occurred on pea and lentil stubbles. This added to the substantial N credit and other rotational benefits associated with including pulse crops in the rotation with cereals. Canola or mustard produced lower seed yield when grown on chickpea stubble than on pea or lentil stubble, while spring wheat grown on chickpea stubble yielded as good as when grown on pea or lentil stubble. When grown on chickpea stubble, spring wheat had a better seedling establishment than the small-seeded canola or mustard.

It is clear that pea and lentil are exerting the largest rotational benefit, averaging over 30% (8 bu/ac) higher wheat grain yield and 23% higher oilseed grain yield, compared to monoculture wheat stubble. This large rotational benefit occurred despite 20 to 40% lower fertilizer N applied for the crops grown on pea or lentil stubble. In fact, wheat grain yield when grown on pea or lentil stubble has averaged over 80% of wheat grown on the fallow check. This compares with only 65% for wheat when grown on its own stubble. Our limited data (2 site/year) indicate that lentil and pea yielded better when grown on each other's stubbles than when grown on chickpea stubble. Pea and lentil use the same type of rhizobial microorganism for symbiotic N-fixation, while chickpea uses a different rhizobial microorganism for its N-fixation activity, so pea or lentil following each other may improve nodulation and therefore N-fixation in the second crop.

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