Frequency of Field Pea in Rotation: the Issues and Opportunities

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EXECUTIVE SUMMARY

Field pea along with other pulse crops forms an integral part of the cropping system in many parts of the Canadian prairies. Field pea is also very well adapted to no-till cropping conditions in rotation with cereal crops and the benefits of no-till have been observed under a wide range of growing conditions and soil types. There are three key steps for the successful production of field pea. The first is early seeding combined with a plant population in the range of 60 plants per meter square. The second step is proper inoculation with the right combination of bacteria to support nitrogen fixation. Research has shown that soil applied inoculants tend to provide the most consistent results. The third step is the use of an integrated weed management approach combined with early time of weed removal (10-12 days after crop emergence). This means using an aggressive weed control strategy during the 2-3 years prior to seeding field pea to avoid situations of high weed pressures and to take care of hard to control weeds ahead of the year when field pea is seeded. A comparison of different frequencies of field pea in a rotation (continuous pea vs wheat-pea vs wheat-wheat-pea vs wheat-wheat-wheat-pea) has shown that a one year break was all that was required between successive field pea crops to avoid the yield reduction observed with continuous pea with no difference between wheat-pea, wheat-wheat-pea and wheat-wheat-wheat-pea. This means that producers can take advantage of marketing opportunities when they present themselves if it means increasing the intensity of field pea in their rotation. It also means that in the process of re-aligning rotations on the farm as a result of expansion or field consolidation, a one year break is enough to minimize the deleterious effects of higher frequencies of field pea or increasing the frequency when crop rotations in the short-term. Some caution is also warranted as well. Our observation is that short rotations in field pea leads to greater weed problems in the long-term. Our recommendation is to use higher frequencies of field pea in rotations i.e. more than 1 year in 4 infrequently to minimize the build-up of certain root and leaf diseases and also difficult to control weeds.

1.0 INTRODUCTION

Although the merits of including a pulse crop in a cropping system are well recognized, there has to be enough demand for the product to encourage its production. In the case of field pea, its value in the diet of animals and for human consumption is well recognized. Canadian peas are rich in protein, lysine and starch (23%, 1.8% and 44.9% dry matter, respectively), and are able to provide both the amino acids and energy required by animals. Field pea can also act as a green manure crop to enhance the nitrogen fertility of soils because of their ability to convert nitrogen gas into an organic form of nitrogen which the plant can use to grow and reproduce.

Canada has 34M ha of cultivated land and the three prairie province (Alberta, Saskatchewan and Manitoba) account for 87% of all cultivated acres in Canada. Saskatchewan, by itself accounts for 50% of all cultivated in Canada. Also, 40% of the cultivated acres in Saskatchewan have been converted to no-till. In terms of field pea production, there were 807,000 ha seeded to field pea on the Canadian prairies in 1995 and this amount increased to 1.39M ha in 2004. In 1995, Saskatchewan accounted for 61% of the production and in 2004, Saskatchewan accounted for 75% of the total production. As a rule, the majority of the field pea crop is grown on cereal stubble.

The objective of this paper is to provide the latest information on the major components of field pea production under a no-till cropping system and to discuss the potential issues is shorter rotations of field pea.

2.0 COMPONENTS OF FIELD PEA PRODUCTION UNDER NO-TILL

2.1 Seeding Management

2.1.1 Seeding Depth

The current seeding depth recommendation for field pea under no-till conditions is 5-7 cm (www.saskpulse.com). We conducted a series of studies spanning the major field pea growing areas of Saskatchewan which also covers the major soil agro-ecological zones of Western Canada over a two year period for a total of 8 site years. The study involved measuring the effects of seeding depth over different seeding dates. In the range of 2.5 – 8.8 cm seeding depth, there was no effect on plant establishment or grain yield (Table 2.1.1). The results support the current recommendation that when seeding field pea, the producer should ensure that the seed is placed in moist soil rather than on moist soil. Under no-till conditions, this can easily be obtained with a depth of 5-7 cm. It is important to note that deeper seed placement did not result in a lower number of established seedlings which means that changes in seeding rate are not required if deeper seed placement is necessary to put the seed in moisture. In this study, seeding depth had a significant effect on yield 50% of the time in favour of the deeper placement. When seeding depth had a significant effect, highest yields were achieved at depths of 6.5 to 7.5 cm which supports the current recommendation of a 5-7 cm seeding depth. Other more recent research also supports these conclusions. In this case, there was no difference between a 5 and 9 cm depth (Hwang et al. 2006). They also found that deeper seed placement did not increase the incidence of *Mycosphaerella* blight, an important plant disease in field pea. Growers should be able to achieve adequate field pea plant populations even under relatively dry soil conditions since they can seed to depths of up to 7.5 cm or even 9 cm without a grain yield penalty or suffering a reduction in plant populations or increasing the potential for Mycosphaerella blight.

Table 2.1.1. The effects of seeding depth on plant populations and grain yield in field pea. Each value represents the mean of 96 observations.

Depth (cm)	Plant emergence (#/m^2)	Yield (kg/ha)
2.5	66a	2087a
5.0	67a	2108a
7.5	67a	2124a
8.8	67a	2024a
From Eric Johnson, unpublished information		

2.1.2 Seeding Date

The other factor of interest is the optimum seeding date for field pea. The current recommendation is for field pea to be seeded during the April 15-May 5 time frame in the drier parts of the prairies and early May for the other agro-ecological zones (www.saskpulse.com). These recommendations suggest that field pea should be the earliest crop sown. The study described in section 2.1.1 confirms the recommendation. Seeding date had a consistent effect on field pea yield with yields declining dramatically as seeding was delayed past May 15 (Table 2.1.2). It is interesting to note the small decline in plant populations as seeding date is delayed. Producers should strive to seed as early as possible. Other more recent research in Alberta also supports the practice of early seeding, last week of April versus the third week of May (Table 2.1.3). This also agrees with research done in drier areas of Saskatchewan during 1994 to 1997 (Miller et al. 1999) where pea seeded in early May typically yielded 18% more than early June seeding.

Table 2.1.2. The effects of seeding date on plant establishment and grain yield in field pea. Each value represents the mean of 128 observations.

Date	Plant emergence (#/m^2)	Yield (kg/ha)
May 1	70	2703a
May 15	66	2279b
June 1	65	1288c
From Eric Johnson, unpublished information		

Table 2.1.3. The effects of seeding dates on grain yield of field pea (kg/ha) in Southern Alberta.

Seeding Date	1998	1999	2000	2001
April	3470a^z	4110a	2560b	1840a
May	2790b	3450b	3220a	1510b
^{z} Means within a column followed by different letters are significant at the 5% level. *From Blackshaw et al. 2005.*				

2.1.3 Packing Requirements

Field pea cultivars grown in western Canada have relatively large seeds of 190 to 300 g per 1000 seeds. Successful germination will require that the seeds be placed in moist soils with proper packing to increase movement of soil water to the seed. A series of field studies were conducted on three different soil types to determine if an optimum packing force exists. The results showed that very little packing force is necessary to successfully establish field pea providing that the seed is placed into moist soils which is usually the case with early seeding and no-till (Table 2.1.4) given the fact that field pea can be seeded relatively deep (5-7 cm).

Although there was very little effect of packing force on plant emergence, some packing is recommended to ensure water movement to the seed via soil capillary action (Johnston et al. 2003). This recommended packing force did not change with various openers or shape of packing wheel used.

Table 2.1.4. The effects of packing force and soil texture on plant establishment and grain yield in field pea.

Packing Force (kg)	Plant Populations (# m^{-2})			Grain Yield (kg/ha)		
	Sandy Loam	Clay Loam	Heavy Clay	Sandy Loam	Clay Loam	Heavy Clay
0	60	55	63	2596	2542	2952
34	61	58	59	2569	2562	3053
56	60	58	62	2549	2576	3053
76	61	58	62	2650	2603	2898
102	62	55	64	2495	2603	2952
	ns	ns	ns	ns	ns	ns

From Johnston et al. 2003.

2.1.4 Row Spacing and Pant Populations

The current recommendation for optimal plant populations in field pea on the Canadian prairies is 88 plants m^{-2} (http://www.saskpulse.com/media/pdfs/quicktips-pea.pdf). More recent field research has shown that a minimum of 50 plants m^{-2} is probably adequate to maximize grain yield (Johnston et al. 2002) and their results suggested that producers strive to obtain plant populations in the range of 50-75 plants/m^2. Hwang et al. (2006) found that plant populations of 30 plants/m^2 or less were too low and resulted in a yield loss even though there was a reduction in the incidence of the disease Mycosphaerella blight. Obviously the reduction in disease incidence was not enough to compensate for the lower plant populations. However results from Alberta showed that plant populations in the range of 90 plants/m^2 yielded about 10-12 % more over a 4 year period than plant populations in the range of 60 plants/m^2 when heavy weed pressure was imposed on the study area (Blackshaw et al. 2005). In situations where heavy weed pressure is anticipated, higher rather than lower seeding rates should be used. A general rule of thumb is that with germination percentages greater than 90%, seeding rates be set to assume 80% emergence. Therefore, to have 88 plants/m^2, 110 seeds should be planted per m^2 (1.1 million seeds per ha). When dealing with field pea varieties that have large seed sizes (>250 mg), it can be very difficult to obtain the currently recommended plant populations of 88 plants m^{-2} due to limitations from pneumatic seed metering and delivery devices and the increase in damage due to handling as seeds get bigger. There is also the issue of seed costs as the size of seeds increases. Therefore, for varieties with large seed sizes, it may be desirable to have lower target population. If using a lower target population, then good, timely weed control is necessary.

Research on row spacing has shown that grain yields and plant populations can be maintained over a wide range of row spacing providing producers with a lot of flexibility in their choice of seeders and row spacing (Table 2.1.5).

Table 2.1.5. The effects of row spacing on plant populations and grain yield of field pea.

Seed Placement	Plants/m^2	Grain Yield (kg/ha)
23-cm distinct rows	75	2334
31-cm distinct rows	65	2245
Sweeps-spread band	65	2298
Level of significance	ns	ns
From Johnston et al. 2002.		

In striving to attain optimum plant populations, another factor has been recognized as reducing the number of seeds that germinate and establish. This has to do with the advent of pneumatic seed delivery systems. Depending on the design and the air velocity used, some seed damage can occur from the impact of the seed within the delivery tubes and during seed partitioning to various openers. Producers are asked to check with their equipment suppliers about appropriate fan speed settings and to adjust seeding rates accordingly to compensate for potential increases in seed damage resulting in a lower germination potential.

2.2 Fertility Management

2.2.1 Inoculant Formulations, Starter N requirements and Herbicide Effects.

The ability of grain legume crops like field pea to fix nitrogen due to its capacity to establish a symbiotic relationship with nitrogen fixing bacteria provides an opportunity to eliminate production costs associated with nitrogen fertilizers. However in order to maximize the benefits of nitrogen fixation, the field pea plant needs to be inoculated with the proper strain of *Rhizobium spp.* bacteria.

Inoculant Formulations and Placement: In the last 10 years, two different inoculation approaches have been researched and compared for effectiveness in Western Canada. The two approaches consist of applying the inoculant on the seed or in the soil. The in-soil application consists of sterile peat granules impregnated with the correct strain of Rhizobium bacteria. The peat granules are then metered separately and placed directly in the seed-row. More recently, we have seen the introduction of clay based particles impregnated with Rhizobium bacteria. The products commonly used for the on-seed application are either liquid or peat powder formulations applied directly to the seed as close to time of seeding as possible, usually the same day.

Results for field pea in the thin-black and black soil zones of Western Canada have shown that the in-soil applications tend to be equal or better than the on-seed applications when measured as grain yield. The site at Indian Head, which has soil organic matter levels of 3.5%, demonstrated the benefits of using inoculants and also the superiority of in-soil as opposed to the on-seed inoculation (Table 2.2.1). The site at Melfort which has 7.5% soil organic matter demonstrated the benefits of using an inoculant in one of two years of testing but no effect due to the formulation. The soils at Melfort would have high levels of indigeneous Rhizobia bacteria and when combined with the high nitrogen mineralization potential due to high soil organic matter levels, this in turn would mask the effects of inoculant formulations. The benefits of in-soil inoculants over on-seed inoculants have also been shown for other areas of the prairies (Clayton et al. 2004a; 2004b).

With the advent of one pass seeding and fertilizing no-till systems, there was interest in determining if equivalent performance would be obtained if the granular in-soil inoculant was placed in the fertilizer band as opposed to in the seed-row. Results from Indian Head and Melfort showed both approaches were similar (Table 2.2.2). In terms of rates of granular inoculant, 2.5 – 5.0 kg/ha appears to be enough.

Table 2.2.1. The effects of inoculant formulation and nitrogen fertilizer rate on grain yield (kg/ha) of field pea at Indian Head and Melfort in Saskatchewan for 1996 and 1997.

Inoculant Formulation	**Indian Head**		**Melfort**	
	1996	**1997**	**1996**	**1997**
Liquid (on-seed)	3363	2085	4573	2892
Peat Powder (on-seed)	3968	2287	4775	3094
Granular (in-soil)	4035	2623	4371	3094
Uninoculated Check	3026	2018	3026	2959
Nitrogen Rate (kg/ha)				
6	3699	2152	4708	2959
20	3632	2152	4573	3161
40	3430	2287	4573	3026
80	3632	2421	4573	2825
From Lafond et al. 2002a.				

Table 2.2.2. The effects of granular inoculant rate and placement on grain yield (kg/ha) of field pea at Indian Head and Melfort in Saskatchewan for 1996 and 1997.

Granular Inoculant Placement	**Indian Head**		**Melfort**	
	1996	**1997**	**1996**	**1997**
In the Seed-Row	4371	1547	3901	2623
In the Side-Band	4371	1547	4102	2825
Inoculant Rate (kg/ha)				
0	2757	1480	4035	2556
2.5	4371	1480	3901	2623
5.0	4304	1749	4237	2690
7.5	4371	1614	4102	2690
10.0	4237	1614	4102	2623
From Lafond et al. 2002b				

<u>Recropping of Field Pea:</u> Another important agronomic factor is the effect of granular inoculants on field pea grain yields the second year after the use of the inoculant. At Indian Head, in 1998, we only saw a response to inoculant on those plots that had been seeded to a non

N-fixing crop, in this case canola in 1996 and 1997 (Table 2.2.3). In 1999, we observed a benefit from using an inoculant even though field pea had been grown two years previous. At the Melfort site with the high levels of soil organic matter, we observed no effect to added inoculant in 1998 or 1999 (Table 2.2.2).

Table 2.2.3. Effects of previous inoculant and rate of granular inoculant on the grain yield (kg/ha) of recropped field pea on land seeded to field pea two years previous at Indian Head in 1998 and 1999.

Previous Inoculant	Rate of granular inoculant (kg/ha)			
	0	2.5	5.0	10.0
	1998			
Liquid (on-seed)	4035	3833	3564	3968
Peat Powder (on-seed)	4237	4237	4102	3497
Granular (in-soil)	3833	3968	4102	3564
Uninoculated Check	3901	3766	3564	3699
Canola	3363	4304	4237	4506
	1999			
Liquid (on-seed)	4035	4708	4573	4573
Peat Powder (on-seed)	3968	4708	4842	4775
Granular (in-soil)	3901	4506	4842	4775
Uninoculated Check	3564	4371	4573	5313
Canola	3766	4775	4371	4573
From Lafond et al. 2002c				

Table 2.2.4. Effects of previous inoculant and rate of granular inoculant on the grain yield of recropped field pea on land seeded to field pea two years previous at Melfort in 1998 and 1999.

Previous Inoculant	Rate of granular inoculant (kg/ha)			
	0	2.5	5.0	10.0
	1998			
Liquid (on-seed)	4371	3968	4506	4170
Peat Powder (on-seed)	4304	4170	4170	4237
Granular (in-soil)	4506	3901	4170	4102
Uninoculated Check	4170	4640	4170	4102
Canola	4371	4170	3901	4439
	1999			
Liquid (on-seed)	2018	2219	2152	2085
Peat Powder (on-seed)	2085	2085	1950	2152
Granular (in-soil)	2152	2085	2152	n/a
Uninoculated Check	1950	1883	2018	2152
Canola	2219	1950	2219	2219
From Lafond et al. 2002c				

Starter Nitrogen: Another issue of interest to producers was whether there are any benefits from using starter nitrogen fertilizers to ensure there is enough nitrogen available to the developing field pea crop early in the growing season before nitrogen fixation starts. The results at Indian Head and Melfort do not support the use of starter nitrogen fertilizers Table 2.2.1. This has also been confirmed at other locations in Western Canada (McKenzie et al. 2001; Clayton 2004a; 2004b). More detailed research by McKenzie et al. (2001) showed that benefits to starter N can be observed if the soil nitrate N contents in the 0-30 cm soil layer are less than 20 kg N ha^{-1}. They found that 33% of their trials (total of 58) with soil N levels of less than 20 kg ha^{-1} showed an average yield response of 11%.

Producers also express concerns regarding the possible antagonism of inoculants with fungicidal seed treatments. Research in Saskatchewan did not show any strong negative effects of using seed treatments in conjunction with either seed-applied or in-soil application of inoculants (Kutcher at al. 2002).

Effects of herbicides: The last issue of concern with the management of inoculants is the possible interaction of herbicides with the nitrogen fixing process. The effects of herbicides on overall nitrogen fixation can be categorized as follows (Walley et al. 2006).

1. Effects on Rhizobial growth.
2. Effects on Rhizobial survival
3. Effects on the ability of the Rhizobium bacteria to recognize the host plant
4. Effects on nodule formulation due to root hair deformation
5. Effects on nitrogenase enzyme activity
6. Reduced plant growth and photosynthate supply to nodules; reduced root biomass reducing infection sites.

The research indicates that most of the observed effects of herbicides on nitrogen fixation are indirect. This means that any herbicide that significantly stresses crop plants like field pea will have an effect on nitrogen fixation because of the reduced flow of photosynthates to the nodules. Producers need to strive to maintain healthy, actively growing plants in order to achieve optimum nitrogen fixation.

2.2.2 Inorganic Fertilizer - P-K-S Nutrition

Because field pea is from the legume family it is capable of forming a symbiotic relationship with *Rhizobium spp.* bacteria to fix nitrogen gas. This means that when nitrogen fixation is combined with residual soil nitrogen and nitrogen mineralized from soil organic matter during the growing season, there is no requirement for supplemental N fertilizer. This then leaves the plants requirement for phosphorus (P), potassium (K) and sulfur (S). A grain yield of 3000 kg/ha will remove 110 kg/ha of nitrogen, 13 kg/ha of P, 31 kg/ha of K and 8 kg/ha of S.

Although only a limited amount of P, K and S fertility research has been conducted in field pea relative to cereals and oilseed crops like canola, the research conducted on the prairies indicates that unless soils are very deficient in K and S, we seldom, if ever observe a response to these nutrients. Research over a two year period across Saskatchewan found essentially no response to a P-K-S blend of fertilizer with the analysis 13-20-10-10 (Lafond et al. 2002d).

With regards to P fertility, a response will only be observed if the soils are extremely deficient in phosphorus. When soils are cropped continuously with some phosphorus added every year and when combined with no-till which reduces to almost zero the potential of soil loss due to erosion, we seldom observe or expect a response of field pea to phosphorus. Karamanos et al. (2003) found from extensive field trials across Western Canada that when soil test levels for P were less than 10 mg/kg of soil using the Modified Kelowna method for extraction, a response was observed for all situations. When soil test levels for P were >10 mg / kg of soil, no response to added phosphorus fertilizer was observed (Karamanos et al. 2003).

2.3 Weed Management

Field pea is not very competitive against weeds. A survey of producer fields grown to field pea in 2001 in the Northwestern part of the Canadian prairies revealed that 67% of the fields were experiencing yield losses due to weeds (Harker 2001). The other well known fact is that early emerging weeds have the largest negative impact on crop yield. Research by Harker et al. (2001) showed that early time of weed removal had the greatest benefit on field pea yields. A series of studies (14 in all) were conducted across the major agro-ecological zones of the Saskatchewan in 1999 and 2000 to test more fully the concept of time of weed removal (May et al. 2003). A summary of results is presented in the table 2.3.1.

Table 2.3.1. Time of weed removal on grain yield in field pea. Timing is based on the number of weeks after visual crop emergence.

Weed Removal	Indian Head	Swift Current	Melfort	Outlook	Redvers	Scott	Canora
	1999						
1 week	2394a	5206a	3009a	3523a	1747a	3993a	5379a
2 week	2516a	4945a	3113a	3325a	1714a	4246a	5042a
3 week	2610a	4350b	2767b	2352b	1918a	3788a	4426a
weedy check	2700a	5071a	2741b	2230b	1851a	2886b	2275a
Contrasts							
Linear	ns	**	*	**	ns	ns	*
Quadratic	ns	ns	ns	*	ns	*	ns
	2000						
1 week	2730a	4577a	2866a	5178a	3202a	2394a	2486a
2 week	2974a	4335ab	2446a	5481a	3189a	2516a	1316b
3 week	3005a	3894b	2699a	4634a	2885ab	2610a	1638b
weedy check	2608a	4688a	2741a	2752b	2575b	2700a	1384b
Contrasts							
Linear	ns	*	ns	ns	ns	ns	**
Quadratic	ns	ns	ns	ns	ns	ns	**

a-c Values for cultivar or weed removal within a column followed by the same letter are not different at P≤0.05 using a protected LSD.
From May et al. 2003. Can. J. Plant Sci. 83:423-431.

The results showed very clearly that early time of weed removal was important in field pea and that if weed removal was done about 7-10 days after crop emergence, no yield loss was observed. Currently we have excellent choices for both broadleaf and grassy weed control in field pea. The majority of the broadleaf weed control in field pea on the prairies is obtained with the herbicide imazamox and/or imazethapyr. There is soil residual activity observed with some of these products thereby extending the control period. We also observed that there was less crop injury when the products were applied early. Crop injury 3 weeks after later applications tended to be associated with hot and dry conditions.

Producers are encouraged to develop an integrated weed management approach to minimize weed problems in field pea. This involves paying close attention to weed management in the years previous to the year where field pea is grown to avoid areas with high weed populations.

2.4 Disease Management

Field pea has been grown on the Canadian prairies for over 50 years. The widespread production of field pea in the drier areas of the prairies is more recent (<10 years). During that long period of time, we have developed a good understanding of the more economically important fungal diseases in field pea. Most plant pathologists and agronomists would agree that powdery mildew (*Erysiphe pisi*) and the blights and foot rots caused by the *Aschochyta sp* complex are the most limiting fungal diseases. The root rot diseases *Fusarium solani var pisi* and other *Fusarium sp* are the most widely observed on field pea across the prairies but would not be considered the most limiting or the most economically serious disease in field pea. In the wetter areas of the eastern prairies, the root rot organism caused by *Aphanomyces eutreiches* can be very serious, especially on the heavy clay textured soils, when the soils remain wet for long periods of time during the early part of the growing season. Disease surveys in field pea conducted in 2004 in Manitoba revealed that *Mycosphaerella pinodes* was the most common leaf disease and *Fusarium solani* f. sp. p*isi* was the most prevalent root disease and to a lesser extent Fusarium wilt (*F. oxysporum*) and rhizoctonia root rot *(Rhizoctonia solani*) (McLaren et al. 2005).

As a rule, root rots and seedling diseases are not a serious problem if a 4-5 year break between field pea crops is allowed.

The effects of powdery mildew can be very significant but in more recent years, good sources of genetic resistance have been incorporated into a large number of newly released varieties. Early seeding in the absence of genetic resistance tends to minimize the negative effects of powdery mildew.

The most important field pea disease faced by all producers is *Mycoshaerella* blight. The two most important causal agents are *Mycosphaerella pinodes* and *Phoma medicaginis var pinodella*. The latter disease organism is also known as foot rot. The major source of inoculum is infected crop residues and to a lesser extent from infected seed. As the area devoted to field pea production increases in a region, inoculum will build up such that even though a 4-5 year break is used between field pea crops, infections can be expected from air borne spores originating from neighboring fields and from the general area.

2.4.1 Seed Treatments

The current recommendation is that systemic fungicidal seed treatments in field pea be used where spring conditions favor disease development or when inoculum levels are high. The problem with these recommendations is that there is no easy way of determining if inoculum levels for one or more of the important pathogens are high in a particular field or soil and it is very difficult to predict what the environmental conditions will be after the seed has been planted. There is agreement that cold soils combined with wet soil conditions for prolonged periods of time are conducive to root diseases. It should be noted that more recent work has shown that low soil temperatures do not necessarily increase the severity of *Pythium* root rot and seedling blight in field pea (Hwang et al. 2000) Research in Saskatchewan involving 13 site-years of information showed that in situations where fields had no previous history of field pea production, there was no benefits to using a seed treatment providing that a sound seed source was used *i.e.* only a small percentage of cracked seed and limited signs of weathering (Kutcher et al. 2002).

Work by Hwang et al. (2001) showed that the negative effects of *Pythium spp.* increased as the amount of inoculum added to the soil increased. When soil was inoculated with *Pythium spp.,* a seed treatment increased the emergence and grain yield under both field and controlled growing conditions. The continual problem for farmers is to determine the soil inoculum level to decide whether a seed treatment is warranted. Hwang et al (2001) also showed that seed treatments could not improve the emergence of mechanically damage seeds to the levels observed with the same seed lot that was not damaged. Other work looking at seed infections of field pea with *Mycosphaerella pinodes* showed that the seed treatment thiram was successful in improving the emergence of field pea but did not reduce foot rot severity or increase grain yield under field conditions (Xue 2000). The evidence in favor of seed treatments for field pea is not very encouraging but the overall results to date would indicate that producers should strive to use sound seed as much as possible ensuring low levels of seed born diseases and paying careful attention during handling to minimize mechanical damage. Producers need to also take into consideration the number of years between successive field pea crops. The greater the time interval between successive field pea crops, the less the requirements for fungicidal seed treatments.

2.4.2 Foliar Fungicide for Disease Control

Determining the requirements of foliar fungicides is probably easier to monitor than the need for seed treatments. One can observe the state of the disease at the time of flowering and determine if the level of infections warrants the need for a foliar fungicide. However, if dry conditions persist after the start of flowering, the effects can be greatly diminished and it is very difficult to predict weather over a three to four week period. Although there is evidence to show the positive benefits of foliar fungicides in field pea (Bailey et al.2000; Kutcher et al. 2002), the researchers state some caution in the interpretation of the results due to the close proximity of plots with different levels of disease inoculum which easily move from one crop rotation treatment to the next masking the true effects of cultural practices. A general rule for the Canadian prairies is that producers are encouraged to seed their field pea crop as early as possible in order to get the crop as advanced as possible before the onset of foliar diseases which corresponds with warm days combined with extended dew periods in the evenings and in the morning. If foliar diseases like *Mycoshaerella* blight start invading the field pea crop well into the later stages of flowering or even pod fill, the disease tends to have minimal impact on grain yield. In general, prairie producers find it difficult to justify the use of foliar fungicides if the above general recommendations are followed. A rule of thumb is that if the disease has progressed 1/3 of the way up the plant by the start of flowering, there may be some merit to use a fungicide. But if dry conditions persist, the economic benefits of the fungicide may not materialize. More recently, Wang et al (2006) found that when lodging in field pea was prevented, there was a decrease in the incidence of *Mycoshaerella* blight. This means that choosing cultivars with better lodging resistance will tend to reduce the development and severity of the disease on field pea. Choosing semi-leafless genotypes is one way of reducing lodging.

2.4.3. Tillage System Effect on Plant Diseases

Research in the thin-black and black soil zone of the Canadian Prairies showed conclusively that adopting a reduced or no-till production system did not increase root or foliar diseases in field pea (Bailey et al. 1992; Bailey et al.2000; Bailey et al. 2001; Gossen et al 1997). More recently, Miller et al. (2002) reported how well field pea was adapted to the Northern Great Plains of North America.

2.4.4. Cropping System/Rotation Effect on Plant Diseases

With respect to cropping system/rotation, two aspects are important. The first one is the diversity of the rotation and the second is the frequency of occurrence of a particular crop in a rotation. Most cropping systems research for crops like field pea focus on diversity rather than frequency. Research in the black soil zone of the Canadian prairies showed that with field pea, foliar disease levels were similar between a canola-pea-flax-barley rotation and a canola-wheat-pea-barley rotation (Bailey et al. 2000; Kutcher et al. 2002).

Work conducted at Indian Head, Saskatchewan in the thin-black soil zone showed that in terms of plant establishment, plant numbers after 11 years without the use of seed treatments and by using no-till were similar among a wheat-wheat-pea, a wheat-pea and a continuous pea rotation (Lafond, unpublished data). This would indicate that maybe root diseases are much less important than anticipated for field pea production on the Canadian prairies. No quantification of root or foliar diseases was done on this study to date. It should be noted that although grain yields for field pea in the two and three year rotation were similar, there was an observed decrease in yield for the continuous pea which supports recent observations (Johnston et al. 2005).

In conclusion, providing some break between successive field pea crops greatly reduces production risks and foliar diseases and probably slows down the build-up of root pathogens. The exact time frame is debatable; at least one year is required but three years may be preferable. Regarding extended rotations with low pea crop frequency, weed control considerations may be more important than root and/or foliar disease considerations.

2.5 Cropping System Effects on Field Pea Production

2.5.1 Tillage Effect

Of interest is the response of field pea production to changes in tillage practices. Extensive work on the Canadian prairies has shown that field pea is well adapted to no-till (Lafond et al. 1992; Borslap and Entz 1994; Lafond et al. 2006). The increases in grain yield can be explained in large part to more water available with no-till and to higher water use efficiency with no-till. Other benefits derived from no-till on field pea production would be the lower daily fluctuations in surface soil temperatures which in turn would favor nitrogen fixation. The other interesting observation of field pea grown under no-till is that the benefits have been observed over a wide range of growing season conditions as indicated by the lack of a tillage system by year interaction (Lafond et al. 2006).

2.5.2 Stubble Effects

Research involving the effects of stubbles on field pea production indicates that the stubbles showing the least risk to field pea production are cereals (wheat and barley) followed by canola stubble (Johnston et al. 2005). The stubbles showing the least promise were flax and field pea stubble. However the research also showed that depending on the year, sometimes there was no difference between the no-till stubbles mentioned above. The effects of growing season on disease development during the previous year and current year would have a large influence on the effects of stubbles on field pea production.

More recent research has shown that field pea production in the drier areas of the Canadian prairies was enhanced when seeded into 30-35 cm tall stubble (Cutforth et al. 2002). Their research showed that yields were increased as a result of greater water use efficiency. The tall stubble reduced the wind speed at the soil surface reducing soil moisture loss through evaporation allowing more water to be used by the plants to enhance growth and grain yield. The use of no-till allows for this opportunity.

2.5.3 Rotation Length

Very little research has been conducted to determine an acceptable time interval between field pea crops to minimize problems with plant diseases and weeds on a given piece of land. The current recommendation is to allow three full years between field pea crops (www.saskpulse.com). Although producers would be reluctant to seed field pea every year, they are nonetheless interested in knowing what the risks are if the time interval between successive crops is reduced from three to two or even one year for practical reasons and also for economic opportunities. A study is currently under way at the Indian Head Research Farm to determine the risks associated with time intervals of less than three years. A summary of the yield information is provided in Table 2.5.1. These results are similar to observations made at 2 other locations in Saskatchewan (Kutcher and et al 2004, and Kutcher and Brandt 2006). In these studies, pea yield was similar in a wheat-pea, a canola-wheat-pea and a wheat-canola-wheat-pea rotation but 25% greater than a continuous pea rotation when averaged across 12 location years.

Table 2.5.1. The effects of time interval measured in years between successive field pea crops on grain yield (kg/ha) in field pea.

Year	Continuous Pea	Wheat-Pea	Wheat-Wheat-Pea	Wheat-Wheat-Wheat-Pea	Significance[z]
1995	2757a	2892a	-	-	ns
1996	2421b	3026a	-	-	*
1997	1412a	1412a	-	-	ns
1998	2623b	3228a	-	3497a	*
1999	3228b	3699a	-	3632a	*
2000	1816b	2488a	-	2892a	*
2001	1278a	1749a	1614a	-	ns
2002	2085b	2959a	2959a	-	*
2003	1345a	1749a	1614a	-	ns

[z] ns and * refers to not significant or significant at the 5% level. Means followed by the same letter in a row are not significantly different at the 5% level. From Lafond unpublished data

The results indicate that a one year break between successive field pea crops appears to be adequate for field pea. In dry years, as indicated by the years with yield levels of less than 2000 kg/ha, there was no difference whether field pea was grown with zero, one, two or a three year break. The results indicate that producers have flexibility in their cropping systems when it comes to frequency of field pea in the rotation. Although continuous field pea is not recommended, a one year break doesn't appear to increase production risks substantially allowing producers to take advantage of marketing opportunities or to consolidate fields that have different histories of field pea production. In the 6 years where we compare a one year break to a two or three year break, we did not observe any differences in yield. Producers are cautioned that increasing the frequency of field pea in the rotation tends to encourage weed growth because of the fewer number of herbicides registered for field pea relative to cereals. However, some producers in the drier parts of the Canadian prairies have been successful in using a pulse (lentil or field pea) – cereal rotation for many years with careful attention paid to weed management.

A summary of the plant population data is provided in Table 2.5.2. Even after 11 years, plant populations were essentially the same regardless of the frequency of field pea in the rotation. Significant differences were only observed in 3 of the 11 years and plant populations were always as high or higher with the continuous pea rotation. It would appear that shortening the rotations has little impact on plant populations. The plots are always seeded as early as the soil conditions permit under no-till conditions, even if it means seeding in April. No seed treatments were used in any of the years.

Table 2.5.2. The effects of time interval measured in years between successive field pea crops on plant populations (#/m^2) in field pea.

Year	Continuous Pea	Wheat-Pea	Wheat-Wheat-Pea	Wheat-Wheat-Wheat-Pea	Significance[z]
1995	60a	60	-	-	ns
1996	68a	70a	-	-	ns
1997	73a	76a	-	-	ns
1998	65a	56b	-	72a	*
1999	70a	68a	-	56b	*
2000	108a	104a	-	95a	ns
2001	87a	61b	70a	-	*
2002	75a	79a	82a	-	ns
2003	91a	87a	86a	-	ns
2004	48a	47a	43a	-	ns
2005	62a	69a	59a	-	ns

[z] ns and * refers to not significant or significant at the 5% level. Means followed by the same letter in a row are not significantly different at the 5% level. From Lafond unpublished data

2.5.4 Pulse Benefit in Crop Rotations.

The benefits of pulse crops to a following crop whether it is an oilseed or a cereal crop can be described as direct and indirect. The direct effects refers to the effects crops like field pea have on the overall nitrogen dynamics of the soil. The indirect effects refer to the positive effects of pulses for reducing root and leaf diseases root in subsequent cereal and oilseed crops and certain influences on soil physical properties.

There is general agreement that field pea has a direct effect on the response of a subsequent cereal crop to nitrogen fertilizer (Wright 1990; Beckie and Brandt 1997; Stevenson et al. 1995; Stevenson and van Kessel 1996a,b and 1997; Gan et al. 2004). Although the grain yields are higher, the response to nitrogen fertilizer is not as dramatic such that at low rates of nitrogen fertilizer, the overall grain yields of cereals on pulse stubble like field pea are higher than for cereals on cereal or oilseed stubbles. It is important to note that these benefits were observe regardless of the whether tillage was used or not. This means that these same benefits will also be observed in a no-till system (Beckie and Brandt 1997). Beckie and Brandt (1997) also estimated that field pea contribute about 15 kg/ha of N for every 1000 kg/ha of field pea grain yield to the subsequent crop in the moister areas of the field pea growing areas of the prairies and 5-10 kg/ha of N in the drier field pea growing areas. A number of reasons have been put forth regarding the direct effect of pulse crops on subsequent cereal crops. They include higher residual N levels following a field pea crop, enhanced nutrient cycling due to faster breakdown of pulse residues releasing not only nitrogen but other nutrients as well, better and deeper root growth due to improved soil properties, release of growth promoting substances during the decomposition of pulse residues enhancing photosynthesis and nutrient uptake in cereals.

The indirect effects of a pulse crop like field pea on the subsequent yield of cereal crops have been well documented. Cereal crops following a field pea crop tend to yield higher than on cereal stubble and show higher water use efficiency (Lafond et al 1992; Lafond et al. 2006) and show less root and leaf diseases (Bailey et al. 1992; Bailey et al. 2001). However as noted by Beckie and Brandt (1997) and Beckie et al (1997), the observed effects of field pea in reducing plant diseases in a subsequent cereal crop can also be observed in a cereal crop following an oilseed crop like canola. Pulse and oilseed crops provide a very good break between cereal crops (Lafond et al. 2006). Other positive and indirect benefits ascribed to a pulse crop like field pea have also been related to certain soil physical characteristics. Grant and Lafond (1993) found that the inclusion of field pea in a four-year rotation had a moderating effect on soil bulk density and penetration resistance relative to a crop like flax which tended to increase penetration resistance and soil bulk density.

More recently, Lupwayi et al. (2004) found that spring wheat, barley and canola crops grown on legume stubble like field pea had more endophytic *Rhizobium* bacteria in their roots than when the crops were grown on non-legume stubbles. They found a positive relationship between the presence of these bacteria in the roots and crop N uptake and grain yields in certain instances. These bacteria are thought to increase grain yields by stimulating plant growth, increasing disease resistance, or improving the plants ability to withstand environmental stresses like drought (Sturz and Nowak 2000; Dobbelaere et al. 2003). These types of observations suggest that practices like direct seeding and growing a diversity of crops can enhance soil and crop health. To date advances in agronomy have been largely focused on managing pests with rotation, pesticides and genetic resistance while using fertilizers to ensure adequate crop nutrition. In future it is probable that advancements will come as a result of understanding other soil and plant processes that enhance the health of both the soil and the crop.

2.6 Harvest Management

The harvesting of field pea is probably the most challenging part of the entire production cycle. Depending on the disease load, the potential yield (weight of developing seeds in high yield situation pulling the plant down), heavy rainfall events combined with wind during the maturation process and variety used, field pea tends to fall down as the crop matures meaning that the cutter bar of the harvester has to operate close to the ground increasing the risk of picking up foreign material which can interfere with the harvester and/or stain the pea seeds resulting in lower seed quality as they are being harvested and slowing the overall harvesting operation and potentially downgrading the seed. If there is a high incidence of foot root combined with early infections, the crop will fall down earlier and lodging will be more intense. Fully leafed varieties tend to fall more than semi-leafless varieties and some of the newer varieties currently in use with the semi-leafless characteristic have stiffer stems helping with the harvesting process. Field pea growers on the Canadian prairies have included rolling the land after seeding in their field pea production practices to smooth the surface of fields by crushing clods and pushing stones into the soil. This accelerates the harvesting process and minimizes problems with foreign material being picked up by the harvesters. Following are some of the suggested guidelines for rolling as provided by the Pulse Production Manual (www.saskpulse.com).

• Rolling can be done anytime from immediately after seeding up to the 5-leaf stage.
• All rolling should be carried out on dry days to lessen the spread of disease.
• Post-emergent rolling or harrowing is best done on warm days or late afternoons when plants are partially wilted and more flexible.
• In heavy clay soils, where rolling before emergence can cause crusting problems or reduce oxygen movement to the seed, allow one to two days for the seed to take up moisture in the presence of oxygen before rolling.
• On light sandy soils or under low residue conditions, such as summerfallow, rolling can increase the probability of wind and sand blasting of the seedlings. Under these conditions delay the rolling operation until the 5-leaf stage.
• Increased crop injury can occur if rolling occurs immediately before or after herbicide application.
• Most pea producers prefer to roll before the pea crop emerges.

There are two approaches to harvesting field pea, swathing and direct harvesting. The guidelines for optimum time of swathing and direct harvesting are provided in Table 2.6.1.

Table 2.6.1. Timing for swathing and direct harvesting.

Crop Type	**Swathing Stage**	**Direct Harvesting Stage**
Yellow	Bottom third of pods are ripe, middle third of pods and vines are yellow colored and upper third of pods are turning yellow.	Straight Cut when seed has moisture content of 20% or less
Green	Vines are yellow colored and seed has good green color.	Direct harvest when pea seeds have a moisture content of 20% or less.
Feed	Vines are yellow colored and vines are prostrate or leaning over.	Direct harvest at 20% or less seed moisture content.
Taken from the Saskatchewan Pulse Growers manual. Visit www.saskpulse.com		

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