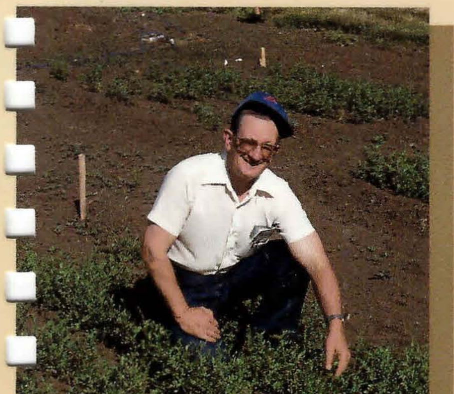
Pulse Production Manual

Produced By: Saskatchewan PULSE CROP DEVELOPMENT BOARD



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PULSE CROP DEVELOPMENT BOARD

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TAN

March, 1997

Congratulations! You are the owner of some of the most advanced information on pulse crop production technology available anywhere in the world.

The "Pulse Production Manual" is an initiative of the Saskatchewan Pulse Crop Development Board and was first printed in 1995. This is the first of what we hope will be many updates to this material.

I would like to express my sincere appreciation to the technical experts who provided the update material and to the Prairie Agricultural Machinery Institute for their editing and production.

This update is being sent to you at no additional cost through the support of our industry partners, BASF and Cyanamid. Please take the time to review their material included in this package.

Replacement Instructions

This update replaces all chapters (Introduction, General Production, Lentils, Peas, Dry Beans and Chickpeas) except Faba Beans.

We are constantly striving to improve this material and would be pleased to entertain any suggestions you may have. Please contact us at our Saskatoon address.

May you enjoy a successful 1997 field season!

Yours sincerely,

Gordon B Cresswell

Gordon Cresswell, Chair
Saskatchewan Pulse Crop Development Board

Acknowledgements

The printing and distribution of this update is courtesy of BASF and Cyanamid.

The *Pulse Production Manual* update is an initiative of the Saskatchewan Pulse Crop Development Board. The 1997 board members are:

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Glenn Annand, Mossbank

Bob Bradley, Stranraer

Garry Meier, Ridgedale

John Serhienko, Blaine Lake

Judy Wooff, Langbank

Their goal was to provide a "farmer friendly" comprehensive guide to the production of pulse crops in Saskatchewan. Funding for the production of the original manual was provided by the Saskatchewan Pulse Development Board though a producer check-off of pulse sales, a grant from the Saskatchewan Agriculture Development Fund, and cost recovery through sales of the manual. The manual will continue to be updated to keep it current with changes in technology.

The original manual was written by Dr. Brenda Frick, Saskatoon in close cooperation with Dr. Al Slinkard and Dr. Bert Vandenberg, both of the Crop Development Centre, University of Saskatchewan, Saskatoon.

This update and the original manual were made possible by the efforts of experts who provided editing advice and information.

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Acknowledgements

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Final editing, coordination, and production services were provided by Mr. P. Leduc, Mr. G. Hultgreen, and staff of the Prairie Agricultural Machinery Institute.

Chapter 1

Introduction

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Chapter 1

Introduction

Saskatchewan Pulse Crop Development Board assumes no responsibility for the accurateness of comments or articles by contributors to this "Pulse Production Manual". Readers are advised to satisfy themselves as to the accurateness and reliability of agronomic and market figures and advice. Articles are provided for the basic information of producers, but the Board assumes no liability for damages a producer may suffer as a result of reliance upon any article or comment.

IMPORTANCE OF PULSES IN THE WORLD

Pulses are the seeds of legumes which are used as food and they include peas, beans, lentils, and chickpeas. These are a very small but very important segment of the 1800 species of the legume family.

The word "pulse" is derived from the Latin "pulse", a thick soup. It is the broad term used to describe all of the dried edible seeds of legumes.

The use of pulses dates back more than 10 thousand years and spans the globe. Records of their use were found in the Egyptian pyramids whereas dry pea seeds were discovered in a village in Switzerland dating back to the Stone Age and some centuries-old pea seeds have been discovered in the ruins of Troy and buried in caves in Hungary. It is said that Aryans from the East introduced peas to the pre-Christian Greeks and Romans. Archaeological evidence suggests that peas were grown in the Eastern Mediterranean and Mesopotamia at least 5 thousand years ago, and in Britain as early as the 11th century.

Lentils originated from the wild lentils that still grow in Turkey and other Middle Eastern countries. Lentils were one of the favourite dishes of the ancient Greeks. About 8 thousand years ago, Indians in what is now the Ancash province of Peru, cultivated the same kind of lima beans and common beans that we know today as navy beans, black beans, and other types of beans.

Pulses are an important source of protein, especially in developing countries. In total, they provide about 10% of the world's total dietary protein. Pulses have two to three times the protein content of cereal grains. In 1996, about 45 million tonnes of pulses were produced annually on 130 million acres (TABLE 1) worldwide.

Peas are now produced mainly in developed countries while chickpeas and lentils are produced and consumed mainly in third world countries. Bean production is more evenly distributed around the world.

HISTORY AND IMPORTANCE OF PULSES IN CANADA

Pulses played a colourful part in the dietary history of North America as well. The hearty "pea soup" was introduced in Canada by the early French settlers and was popular in the diets of pioneers who helped develop the West. Baked beans were considered a staple for ranchers

Table 1. World Crop Area and Production of Pulses (1996).

	Pea	Bean	Chickpea	Faba Bean	Lentil	Total
Total Area (000 ac)	18,105	68,419	28,080	7,064	8,359	130,027
Total Production (000 tonnes)	11,364	18,467	8,748	3,356	2,800	44,735
Source: FAO						

riding the winter trail. They froze beans in batches, carved off their daily portion and heated it over an open fire. To this day, baked beans are an important part of the menu at rodeos and barbecues.

Peas were a leading crop in eastern Canada at the turn of the century with an average of 720 thousand acres grown each year from 1883 - 1902. Production in eastern Canada gradually declined. By 1970, only 62 thousand acres were grown in all of Canada with about 70% of the production in Manitoba.

Pulses did not play a significant commercial or economic role in Western Canada prior to the 1970's when the wheat glut encouraged farmers to diversify into cash crops such as rapeseed, lentils, peas and other special crops. The registration of herbicides, such as Treflan, provided a method of weed control in poorly competitive pulse crops and the development of new well adapted varieties by Dr. Slinkard of the Crop Development Centre, University of Saskatchewan, contributed to the commercial acceptance of lentils and peas.

Since the 1970's, pulse production in Western Canada has increased dramatically, with most of the increase being in peas and lentils (FIGURE 1).

With the opening of the European feed pea market in 1985 and resulting high prices, pea production has exploded with a record 1.99 million acres grown in Western Canada in 1995.

At the same time that technological change and changing markets were encouraging the growing of pulses, other changes including reduced summerfallow acreage, longer crop rotations, continuous cropping, and direct seeding were also occurring. The nitrogen fixing ability of pulses as well as the improved control of disease and weeds through better rotations contributed to the increase in acreage of pulses in the Canadian prairies.

Currently, acreage of pulse crops in Western Canada is at a record high with gross sales over $462 million in 1995 and a similar value in 1996. This trend to increased pulse production will likely continue, even with improved cereal grain prices, as farmers now know how to produce pulses, and pulses are required in economic, sustainable crop rotations.

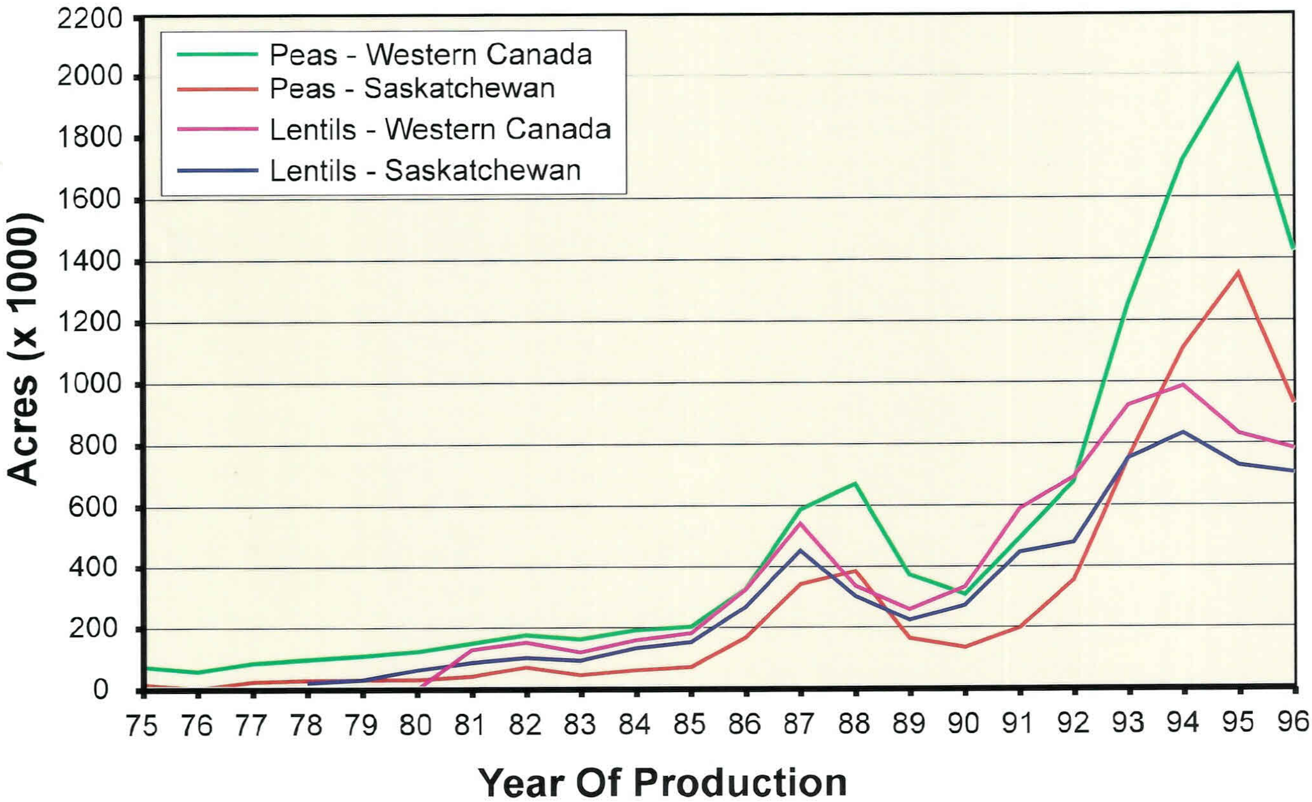

FIGURE 1. Pulse Production in Western Canada.

THE SASKATCHEWAN PULSE CROP DEVELOPMENT BOARD

The Saskatchewan Pulse Crop Growers Association was established in 1976. The association has been active in pulse market development and promoting pulse production since its inception. In 1982, the membership voted to have a plebiscite of all pulse growers in Saskatchewan to determine whether they were in favour of a check-off on commercial sales of pulse crops. This plebiscite lead to the establishment of the Pulse Crop Development Plan in 1984. The mandate of the Saskatchewan Pulse Crop Development Plan is to provide for the effective development of the Saskatchewan pulse crop industry.

The purpose of the plan is:

1. To promote and develop the Saskatchewan pulse industry.
2. To develop procedures to maximize returns to producers.
3. To gather, compile and distribute information related to production, consumption and marketing of pulse crops.
4. To conduct and encourage research on the production, marketing, processing and consumption of pulse crops.
5. To promote and improve communication amongst individuals and organizations within the pulse crop industry.

The Plan is administered by the Saskatchewan Pulse Crop Development Board. The Saskatchewan Pulse Crop Development Board consists of a producer-elected board which controls the direction of the organization.

Through funding from a non-refundable check-off, the Board generates funds for administration, research, promotion and development of the pulse industry. In 1996, $1.2 million in check-off revenue was collected from over $240 million in gross sales of Saskatchewan pulses.

Since 1984, when the Board was established, over $2.38 million has been spent on research and another $1.96 on market development. This major investment in research and market development has been a major factor in the development of the industry and in achieving $462 million in pulse crop export sales for western Canada in 1995/96.

The *Pulse Newsletter* is published six times per year. It contains reports of projects funded by the Board, marketing and growing tips, and other news of interest to pulse growers which may not be found in farm papers or magazines.

The Saskatchewan Pulse Crop Development Board are the owners of this publication *Pulse Production Manual.*

THE CANADIAN SPECIAL CROPS ASSOCIATION

The Canadian Special Crops Association is a trade organization representing firms involved in the merchandising of Canadian special crops. It was formed in 1987 and has been active in various aspects of the industry ever since.

The objectives of the Association are:

1. To encourage the merchandising of Canadian special crops.
2. To acquire and distribute information with respect to special crops and to encourage the establishment and maintenance of uniformity in the business, customs and regulations among persons engaged in the trade.
3. To promote objects and measures for the advancement of trade and commerce respecting Canadian special crops and to fairly adjust, settle and determine controversies and misunderstanding between persons engaged in the said trade, or to submit them to arbitration.

Located in Winnipeg, the Canadian Special Crops Association continually provides its membership with information on special crops. In addition to board and committee meetings, an annual convention is held each year between April and July.

The Association has developed a comprehensive set of Trade and Arbitration Rules which govern the trading of special crops in Canada, and these rules are used by virtually every participant in western Canadian special crops.

The Canadian Special Crops Association is seen by Agriculture and Agri-Food Canada and the Canadian Grain Commission as a spokesman for the special crops trade, actively promoting and advancing the industry's perspective on various regulatory matters and policy issues.

The Association also works closely with the Western Canadian Pulse Growers Association.

Western Canada Pulse Growers Association is an umbrella association composed of the three prairie pulse organizations. The three organizations are the Manitoba Pulse Growers Association, Saskatchewan Pulse Crop Development Board, and the Alberta Pulse Growers Commission. Its role is to assist the provincial groups in developing the pulse industry in western Canada, particularly in cases where work can be done better with a regional rather than a provincial approach. The association is active in liaising with governments and industry to avoid duplication of effort.

Membership comprises individuals, partnerships, corporations or other legal entities engaged in the business of the export and/or merchandising of special crops.

To date, the focus has been primarily on western Canadian special crops. However, the Association is now taking steps to coordinate its efforts with those marketing eastern Canadian special crops. Grower organizations from Alberta, Saskatchewan, Manitoba, and Ontario recently joined forces with the Canadian Special Crops Association to form Pulse Canada. The role of Pulse Canada will be to promote and encourage the increased consumption of Canadian pulse crops on a global scale.

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Chapter 2

General Production Practices

ROTATIONS

The advantages of pulse crops in the rotation are many and not limited to the years in which they are grown. They extend and diversify crop rotations, increase nitrogen availability, improve soil tilth, and contribute to soil organic matter. They also reduce dependence on summerfallow, break cereal disease cycles, offer unique opportunities for grassy weed control, and broaden market opportunities.

Cereal yields following pulse crops are often higher than following cereals. At Swift Current, wheat following lentils yielded the same as wheat following wheat. At Melfort, Scott and Saskatoon, cereals (barley or wheat) following lentils or peas yielded substantially more on average than those following cereals. The amount of advantage gained from a pulse crop over that of a cereal as the preceding crop in the rotation may depend on moisture availability. At Swift Current (Brown soil zone), cereal yields on lentil stubble were approximately 65% of cereal yields on fallow; in the moister sites (Dark Brown and Black soil zones), cereal yields on lentil or pea stubble were approximately 90% of yields on fallow. **When moisture limits production, pulses provide less yield benefit, and may even reduce yield, possibly because they leave very little stubble for snow trapping.**

In a separate study at Swift Current, with a long-term lentil-wheat rotation, nitrate nitrogen in the rooting zone was higher in a wheat-lentil rotation than in any other continuous cropping rotation. This increase in soil nitrogen resulted in a reduction in the fertilizer nitrogen requirements and a consistent 1% boost in the grain protein of wheat. The protein boost was attributed to an improved synchrony between the breakdown of pulse crop residues and wheat crop development.

At Melfort, pulses had a beneficial effect that continued in the third year of the rotation. Barley yielded more following a pulse than following barley, even when fertilizer nitrogen was applied to the required level. In the third year, wheat yields were still substantially higher in the pulse rotation than in the cereal rotation. Different pulses produced their maximum effect at different times. The effect of faba beans was strongest in the second year while peas had the strongest effect in the third year.

In another crop sequence study at Melfort, the yield of a number of crops was higher following a pulse than following a cereal (TABLE 1). However, peas did not yield higher when following a pea crop. Pea yields were highest following a cereal in rotation, and higher following an oilseed in rotation than when following pea or peaola.

TABLE 1. Pulse Rotation Effect in Several Different Crops at Melfort.

Crop	**Yield After Peas as a % of Yield After Wheat**
Flax	126
Barley	140
Wheat	147
Canola	126
Preceding Crop	**Pea Yield as % of Yield After Peas**
Flax	115
Barley	130
Wheat	119
Canola	113
Peaola (Pea-Canola Intercrop)	103
From Townley-Smith 1995.	

A recent study at Indian Head has shown that nitrogen fixation is greater in zero tillage systems than with conventional tillage. Nitrogen fixation was 10% higher in lentil crops and 31% higher in pea crops when the zero tillage system was used. It was also shown that nitrogen fixation was improved for lentils grown in diversified rotations in both zero till and conventional tillage (TABLES 2 and 3). The cause of this improved nitrogen fixation has not been determined but the less stressful crop establishment environment with zero tillage may be beneficial to nitrogen fixation.

TABLE 2. Crop Rotations (the rotations move from right to left e.g., in R5 spring wheat is grown after sunola).

	Phase in Rotation			
Rotation	**Cereal**	**Oilseed**	**Cereal**	**Pulse**
R1: Post-Emergence Herbicide	Spring Wheat	Canola	Spring Wheat	Lentil
R2: Pre- & Post-Emergence Herbicide[a]	Spring Wheat	Canola	Spring Wheat	Lentil
R3: Low-Input Herbicides[b]	Spring Wheat	Canola	Spring Wheat	Lentil
R4: Low-Input Herbicides & Fertilizers[c]	Spring Wheat	Pea (Pulse)	Spring Wheat	Lentil
R5: Highly Diversified I	Canary Seed	Sunola	Spring Wheat	Lentil
R6: Highly Diversified II	Spring Wheat	Mustard	Canary Seed	Lentil

[a] Post-emergence herbicides used in the spring wheat phases and pre-emergence (trifluralin) used in canola and lentil.

[b] In this rotation grassy weeds were not controlled in the spring wheat phases and reduced herbicide levels were used for broadleaf weed control. Wheat seeding was delayed 10 to 14 days compared to other rotations.

[c] This rotation used the same herbicide approach as R3 and the rates of fertilizer used for all crops were half that applied in the other rotations (i.e. one half soil test recommendations).

Derksen et al 1996.

TABLE 3. Net Returns ($/ac) of Specialty Crop Rotations by Tillage Method and Year.

Tillage	Rotation	1992	1993	1994	1995	Total
Conventional	R1: Post-Emergence Herbicide	424	158	78	227	221
	R2: Pre-Emergence Herbicide	465	150	119	261	249
	R3: Low-Input Herbicides	434	195	187	188	251
	R4: Low-Input Herbicides & Fertilizers	231	185	156	190	191
	R5: Highly Diversified I	492	131	24	132	195
	R6: Highly Diversified II	338	57	49	108	138
Mean		397	146	102	184	207
Zero	R1: Post-Emergence Herbicide	505	174	70	191	235
	R2: Pre-Emergence Herbicide	514	153	139	185	248
	R3: Low-Input Herbicides	492	200	155	194	260
	R4: Low-Input Herbicides & Fertilizers	309	246	195	234	246
	R5: Highly Diversified I	493	126	54	129	201
	R6: Highly Diversified II	475	79	86	124	191
Mean		465	163	117	176	230
Overall Mean		431	154	109	180	219

Derksen et al 1996.

Nitrogen fixation by the pulse crop is an important part of the total benefit of growing a pulse in rotation. Pulse crops fix nitrogen (in association with rhizobia) and release it in an available form when their residues decompose. The amount of nitrogen fixed can be substantial and is largely a function of the dry matter yield (about 40 lb of nitrogen per tonne of dry matter). The "pulse effect" can be the equivalent to the boost that the crop would receive if given 50 lb/ac or more of fertilizer nitrogen. Most of the fixed nitrogen is removed as protein in the harvested seed. The pulse residues usually contain only about 1% nitrogen (slightly more than cereal residues), but pulse crop residues do break down very rapidly, releasing this nitrogen and making it available to the succeeding one or two crops. In spite of this, less than 50% of the nitrogen in the pulse crop residue is available to the following grain crop.

The boost in productivity that is not due to nitrogen is termed the "non-nitrogen benefit". Many factors can contribute to this benefit, and these factors work in combination, so the effect of individual factors is difficult to determine. Pulse crops improve soil tilth. Soil organic matter may actually be reduced following pulses, relative to cereals, because less dry matter residue remain, but relative to fallow, organic matter can be greater following pulses. Crop rotations that include pulses can substantially increase soil microbial activity and this may increase nutrient availability (including phosphorus).

A real benefit may be realized in cereal crops that follow a pulse because the pulse year interrupts pest cycles. Most cereal diseases do not affect pulse crops. Soil-borne root rots in continuous wheat (or wheat-fallow) or continuous barley rotations can cause average yield losses of 5 to 10%. These yield losses may be reduced by inserting a pulse crop into the rotation. Insects such as grasshoppers may find pea much less palatable than wheat. Weeds may have different abilities to survive in pulse and cereal crops. For example, a wide range of grassy weeds can be controlled over a wide window of growth stages with herbicides which are only registered for use in pulse crops.

CROP ADAPTATION

The Saskatchewan climate offers many opportunities for quality pulse production. Cold winters and dry summers limit disease and insect problems, and help to keep production costs down. The cereal crops grown on the Prairies are relatively low in value, so pulse crop production provides a promising alternative in spite of higher production costs.

In the Brown soil zone, inadequate moisture is the major limitation to agricultural production. Suitable crops must have good drought and heat tolerance. Chickpea production can be successful with limited water availability. **Lentils, which have slightly less drought tolerance, can be grown effectively in the Brown soil zone on fallow, or on stubble in years with good moisture.**

Chickpeas and lentils have good production potential in the Dark Brown soil zone as well. **Lentils are especially suited to production on cereal stubble in the Dark Brown and moist Dark Brown soil zones of Saskatchewan.**

Faba beans and dry beans are well suited to irrigated production in the long season areas of the Dark Brown soil zone. Faba beans are late maturing so they benefit from the longer season. Dry beans are a drought sensitive warm season crop which yields best under irrigation in the warmer Brown and Dark Brown soil zones of Saskatchewan. Late July rainfall is essential for profitable dry bean production on dryland in the Dark Brown and moist Dark Brown soil zones. Peas also require more moisture than is generally available in dryland production in the Brown and Dark Brown soil zones, but yield well under irrigation or when rainfall is above average.

The Thick Black and Grey soils generally have too much moisture and too short a season for consistent production of quality lentils. In this area, the growing season is generally too short for chickpeas, dry beans, or faba bean seed production (except Orion), but faba beans can be grown for silage.

TABLE 4 gives some agronomic characteristics that may help growers select a pulse crop suitable for their area. This table is a generalization only. For instance, the table indicates that the Black soil zone is too wet for lentil production. This is not intended to imply that lentils can never be grown successfully in the Black soil zone; only that in typical years lentils will be at risk from excess moisture (e.g. they will be less likely to produce seeds, and more likely to suffer from disease).

EQUIPMENT PURCHASES AND MODIFICATIONS

Most existing farm equipment can be used or modified to successfully produce pulse crops. One exception is the need for a roller which is used to smooth the soil surface to make it easier to harvest pulses such as peas, lentils, and dry beans that have pods very close to the soil surface. The roller substantially reduces cutterbar damage and may improve seed quality by reducing earth tag (earth sticking to seeds) and speeds up swathing or direct harvesting.

Swather and combine modifications can also significantly reduce seed loss, increase harvest efficiency, and improve seed quality in some of the pulses. Vine lifter guards, pickup reels and flex headers improve the cutting of plants with pods close to or in contact with the soil surface. Generally, pulse crop production results in higher wear on swathers and combines which increases the cost of repairs and leads to more frequent machine replacement.

TABLE 4. Agronomic Characteristics of Some Pulse Crops.

	Lentils	Peas	Chickpeas	Dry Beans	Faba Beans
Optimal Temperature	cool	cool	cool to warm	warm	cool
Spring Frost Tolerance	tolerant	tolerant	tolerant	none	very tolerant
Drought Response	tolerant	less tolerant	very tolerant	less tolerant	much less tolerant
Maturity	some early varieties	some early varieties	very late	late	very late
Potential on Brown Soil	fallow	irrigated, fair to poor on stubble	excellent on fallow	irrigated	too hot and dry
Potential on Dark Brown Soil	excellent on stubble	irrigated, fair to good on moist stubble	excellent on stubble	irrigated, fair on fallow and moist stubble	excellent on irrigation
Potential on Moist Dark Brown Soil	good on stubble	good	fair on stubble and light soil	fair to good on fallow and moist stubble	too dry
Potential on Black Soil	too wet	excellent	season too short, wet	fair to good in longer season areas with early varieties	using Orion, or for silage
Potential on Moist Black Soil	too wet	excellent	season too short, wet	season too short	using Orion, or for silage
Potential on Grey Soil	too wet	excellent	season too short, wet	season too short	for silage only
Annual Yield (lb/ac)	900 - 1300	1250 - 2400 dryland, 3500 irrigation	1000 - 1800	700 - 1000 dryland, 1500 - 2000 irrigation	1350 dryland, 2500 irrigation

From various sources including SAF 1994, A.E. Slinkard, Personal Communication.

An undercutter may be used to harvest beans, especially under wide row systems. The plants are cut below the surface with a knife, a rod cutter or a knife followed by a rod cutter. Following undercutting the beans are windrowed. The pods of some dry bean market classes, such as Pinto, often touch the soil, and the undercutter reduces losses in the swathing process.

Most pulses require gentle handling to prevent splitting and reduced germination. Even non-visible minute damage to the seed can result in a substantial loss in germination. Seed with low moisture content is particularly susceptible to damage when handled in cold temperatures. To reduce damage during extensive handling of pulses, special conveying equipment should be considered. Refer to PAMI Research Update #660, Conveying Equipment For Pulse Crops for detailed information on handling pulse crops.

Equipment requirements, notes on use, or modifications of equipment for specific pulse crops have been included in the individual pulse crop chapters as many requirements are specific to a particular crop.

FIELD HISTORY

Field history is an important consideration in all pulse production. The decision to grow pulses in a given field is best made one or two years in advance so that the site can be prepared.

Pulses generally cannot tolerate residues of herbicides such as Ally, Amber, Assert, Attain, Banvel (spring or fall application), Curtail, Glean, Lontrel, Muster, Poast FlaxMax, Prevail, Rustler (pre-seed application), Tordon 202C, or Unity. Only peas can tolerate residues of Pursuit. The recommended period following chemical application before pulses can be grown safely varies with the type of chemical, the rate applied, the soil characteristics such as pH and organic matter, and the type of pulse. **Follow label recommendations and, if in doubt, sow a test plot of the desired pulse in the field in the year before the pulse is to be planted.** The plot should be grown to maturity to ensure there are no late season effects on yield or crop quality. A chemical assay can also be conducted to determine residue levels. Accurate spray application records are essential for a grower to evaluate the risk of chemical residues.

Pulse crops are susceptible to diseases that can overwinter in the soil and in stubble. It is best to grow pulses following a cereal, rather than following another crop that may carry pulse diseases.

Pulse crops are not very effective competitors with weeds, and not all weeds can be controlled in pulse fields, so it is best to have a weed management strategy in mind before seeding pulses (see *Weed Management* section). In particular, it is a good idea not to seed pulses on land that has a number of broadleaf perennial weeds. Sowing pulses into clean fields offers the best probability of success, but pulses are frequently seeded on stubble and potential weed competition is often high and can often be complicated by volunteer crop growth.

If pulse crops are zero-till seeded into stubble, the previous crop is very important. Volunteer canola or tame mustard may be especially difficult to control, and may smother a pulse crop. Volunteer cereal control is expensive, and the seeds from any plants which escape can be difficult to separate from small-seeded pulses such as Eston lentil. If pulse and cereal can be separated easily, some level of yield loss in the pulse can be offset by sale of the cereal and ease of harvesting. The cereal yield is unlikely to fully compensate for the pulse yield loss as even a sparse cereal stand will substantially reduce pulse yield, and pulses generally have higher value than cereals.

Pulses are susceptible to damage from drift and off- target movement of phenoxy herbicides such as 2,4-D or MCPA formulations, particularly esters. This should be considered when choosing a field for pulse crop production.

PRODUCTION

Seed Quality

With pulse crops, the quality of the crop is very dependent on the quality of the seed. Seed testing at accredited seed test labs (TABLE 5) can include tests of germination, seedling vigour and disease contamination with *Ascochyta*, *Anthracnose*, and *Botrytis*.

Pulse crop seeds are easily damaged by rough handling. Equipment used to harvest, clean, move, inoculate and plant the seed in the soil can all cause damage. Seeds are especially prone to damage when they are dry or cold. Even the most tiny cracks in the seed coat indicate seed damage and reduced germination, and make the seedling more prone to infection by soil-borne diseases.

Seed that has been frozen, especially when it was damp or tough, may have low germination, or may result in a high proportion of abnormal seedlings. **The seed produced in immature pods that were treated with a desiccant, or with a pre-harvest weed control product (notably glyphosate or glufosinate ammonium), may have reduced germination or seedling vigour.** This effect can be reduced by strict adherence to herbicide label guidelines. Even seed that germinates well may produce seedlings that do not develop normally. Professional seed testing can assist in detecting this sort of problem. Sizing to remove small seeds during seed cleaning helps produce a quality seed for planting.

Inoculation

Most legumes can get a substantial portion of their required nitrogen from the air. This is termed nitrogen fixation, and it is possible because of a partnership between the legumes and rhizobia. Rhizobia are micro-organisms that can live independently in the soil, but only fix nitrogen when in partnership with a legume. The legume supplies the rhizobia with sugars (energy) and mineral nutrients, while the rhizobia supply the legume with nitrogen. The rhizobia penetrate the small root hairs of the legume, and the plant develops a thickened nodule around the infection. If the rhizobia are actively fixing nitrogen, the nodules will be visibly red or pink inside.

The association of legume and rhizobia costs the legume large amounts of energy to feed the rhizobia. If large amounts of available nitrogen (more than 50 lb/ac) are present in the soil, the plant will preferentially use it rather than supply extra energy for nitrogen fixation so the potential benefit of nitrogen fixation is lost if excess nitrogen fertilizer is applied. It usually takes 10 to 15 days after initial infection before the rhizobia are effective. If the pulse has used up the nitrogen reserves in the seed by then, and no soil nitrogen is available, it may suffer some loss of yield. In most instances if the soil test indicates nitrogen levels of less than 30 lb/ac in the surface two feet, application of an additional 30 lb/ac nitrogen fertilizer will be cost effective. **Nitrogen should not be placed with the seed but may be applied before seeding or side banded if good separation from the seed is maintained.** The major exception would be in high organic matter soils (more than 5% organic matter) in the Black soil zone where microbial action plus nitrogen fixation usually supplies adequate nitrogen for optimum yields.

Inoculation of legumes can result in a substantial yield increase in soils that do not contain excess nitrogen (TABLE 6).

Each different type of *Rhizobium* is only capable of inoculating one type of legume. The rhizobia that infect pinto beans will not infect lentils. Although rhizobia occur naturally in the soil, to ensure the appropriate strain of *Rhizobium* contacts each lentil plant as it develops root hairs, the rhizobia must be placed with the seed. **This process of inoculation is carried out each year to ensure that sufficient numbers of the correct strain of highly effective rhizobia are available where they are needed when the seed germinates.**

Inoculant products contain a live culture of rhizobia which can be killed easily by exposure to antibiotics, some fungicides, high concentrations of phosphate fertilizer, heat, drying, or sunlight. Only live rhizobia are effective in nitrogen fixation. As such, inoculant should be used before the expiry date, and stored under refrigeration if not used immediately. If applying inoculant to seed previously treated with fungicides, read the application instructions to determine the safe limits for contact time.

TABLE 5. Accredited Seed Laboratories in the Prairies (1996).

	Purity	Germination	Seedling Vigour	Disease
Accu-Test Seed Lab Box 579 Rivers, MB R0K 1X0 Phone: 204-328-5313 Fax: 204-328-7400	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Ascochyta, Unofficial Advisory on Anthracnose, Botrytis, and Sclerotinia
Alberta Wheat Pool 4722 - 39 St. Camrose, AB T4V 0Z5 Phone: 403-672-5612 Fax: 403-672-6971	Lentil Pea Faba Bean	Lentil Pea Faba Bean	None	Unofficial Advisory on Ascochyta
Alberta Wheat Pool 9728 - 128 Ave. Grande Prairie, AB T8L 4J4 Phone: 403-532-8890 Fax: 403-539-1924	Pea	Pea	None	Unofficial Advisory on Ascochyta
BDS Laboratories Box 363 Qu'Appelle, SK S0G 4A0 Phone: 1-888-237-5227 Fax: 306-699-7190	None	None	None	Unofficial Advisory on Mycotoxins, Moulds, and Bacteria
BioVision Seed Lab 9954 - 67 Ave. Edmonton, AB T6E 0P5 Phone: 403-436-8822	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Ascochyta, Unofficial Advisory on Anthracnose and Sclerotinia
Brett-Young Seeds Ltd. Box 99 St. Norbert Postal Station Winnipeg, MB R3V 1L5 Phone: 204-261-7932 Fax: 204-275-7333	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	None	None
Discovery Seeds Labs Ltd. #4 - 1527 Ontario Ave. Saskatoon, SK S7K 1S7 Phone: 306-249-4484 Fax: 306-249-4434	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Ascochyta, Unofficial Advisory on Anthracnose and Botrytis
Imperial Seed (1979) Ltd. 1038 Arlington Street Winnipeg, MB R3E 2G1 Phone: 204-786-8457 Fax: 204-786-6004	Pea	Pea	None	None
Lenden Seeds Ltd. Box 10 Riceton, SK S0G 4E0 Phone: 306-738-2064	None	Lentil Pea	None	None
Peace River Seed Co-op Box 40 Rycroft, AB T0H 3A0 Phone: 403-765-3737 Fax: 403-765-3800	None	Pea	None	None

continued....

	Purity	Germination	Seedling Vigour	Disease
Peace Valley Seeds Ltd. Box 100 Rycroft, AB T0H 3A0 Phone: 403-765-3069 Fax: 403-765-3960	Pea	Pea	None	None
Priority Lab Services Box 1180 Nipawin, SK S0E 1E0 Phone: 306-862-4212 Fax: 306-862-4440	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Ascochyta, Unofficial Advisory on Anthracnose, Botrytis, and Sclerotinia
Reed Agricultural Services Box 130 Elrose, SK S0L 0Z0 Phone: 306-378-2784 Fax: 306-378-2811	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	Unofficial Advisory on Ascochyta, Anthracnose, Botrytis, and Sclerotinia
Saskatchewan Wheat Pool 605 Lillooet St. W. Moose Jaw, SK S6H 4Z6 Phone: 306-691-3263 Fax: 306-692-0225	None	Lentil Dry Bean Pea Faba Bean Chickpea	None	None
Saskatchewan Wheat Pool Box 1630 Nipawin, SK S0E 1E0 Phone: 306-862-5091	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	None	Ascochyta, Unofficial Advisory on Anthracnose and Botrytis
20/20 Seed Labs Ltd. Suite 201 - 509 11th Ave. Nisku, AB T9E 7N5 Phone: 403-955-3435 Fax: 403-955-3428	Lentil Dry Bean Pea Faba Bean	Lentil Dry Bean Pea Faba Bean	Lentil Dry Bean Pea Faba Bean	Ascochyta, Unofficial Advisory on Botrytis Anthracnose, Sclerotinia, and Fusarium
United Grain Growers 101 Devos Road Winnipeg, MB R3T 5X9 Phone: 204-989-5468 Fax: 204-275-1541	Lentil Dry Bean Pea Faba Bean Chickpea	Lentil Dry Bean Pea Faba Bean Chickpea	None	None
Valley Seed Lab Ltd. Box 72 Morris, MB R0G 1K0 Phone/Fax: 204-758-3207	None	Lentil Pea Faba Bean Dry Bean Chickpea	None	None
From R. McVicar, Sask. Ag & Food, Personal Communication				

TABLE 6. Grain Yields (lb/ac) from Inoculated and Uninoculated Lentils.

	Brown Soil	Dark Brown Soil	Black Soil
Inoculated Lentils*	408	1128	1799
Uninoculated Lentils	351	931	1191

*Average of 4 inoculants; from Bremer et al 1989.

Before 1988, all inoculant products were cultured and packaged in the USA, but today a number of companies in western Canada culture and formulate inoculants (TABLE 7). Single strain products contain rhizobia specific for one crop while mixed strain products contain rhizobia suitable for a number of crops. In general, the single strain products are more efficient, but more costly than mixed strains. Four basic types of inoculant are available: peat based, liquid, self-sticking, and granular. Generally, liquid-based products are more convenient to apply and more costly than peat-based products. The liquid products are also more susceptible to damage from environmental extremes prior to seeding than peat-based inoculants.

Peat based inoculants require the use of a sticker, such as a solution of powdered milk, honey, sugar, corn syrup, wallpaper paste (non-toxic type), or a commercial sticker. Some milk replacers may contain antibiotics that will kill the rhizobia so they should not be used.

The amount of sticker used in not important, provided the seed is completely moistened, and any excess sticker is allowed to drain off. Two pounds of milk powder, or 1 pint of corn syrup in one gallon of solution will cover 1000 to 1500 lb of seed. Once the seed is wetted with the sticker, the inoculant can be added. **A rate of 1 lb of peat inoculant to 300 lb of seed is generally adequate. Inoculant is cheap relative to its potential benefits.** Use of inoculant at 2 to 3 times the recommended rate has no detrimental effect and ensures effective seed coverage, but it costs more.

The seed can be moistened with the sticker and mixed in an auger or cement mixer. The sticker may be applied to the seed with a garden sprayer as it flows from the truck or bin, and inoculant is often sprinkled on the moistened seed by hand. Other systems can be set up depending on a farm's resources and the amount of seed to be inoculated annually.

Bridging in the seed box can be avoided by allowing the moistened, inoculated seed to dry for an hour or so before it is loaded into the drill box. Best results are achieved if the seeding is done soon after inoculation. If seeding is delayed, the seed should be stored in a cool place, away from direct sunlight. If seeding is delayed more than 1 day, check manufacturer's recommendation for reinoculating. Inoculated seed flows through seeding equipment more slowly, so calibration of the seeder is more accurate if it is done using inoculated seed.

Seed placed phosphorus can kill the inoculant. One solution to this problem is to side-band the phosphorus, or apply it before seeding. Provide from Philom Bios is a fungal inoculant that enhances phosphorus uptake by plants. It is a self-sticking liquid product that can be used as a sticker for peat-based rhizobia inoculants. Provide is compatible with Crown and Thiram, but not with Captan. Crown, a seed applied fungicide registered for use with lentil to control ascochyta, does not damage the inoculant. **Captan, Thiram and PCNB fungicides are toxic to inoculants.** Captan at concentrations greater than 30% is especially toxic. The risk to the inoculant increases with the length of time that the fungicide-treated seed is inoculated before seeding.

The effectiveness of inoculation can be checked by examining the pulse crop in early summer. When plants are pulled gently, nodules should show up as swollen bumps that develop near the stem close to the soil surface (FIGURE 1). If nitrogen fixation is active, the nodules will be pink or red on the inside. Lack of nodules indicates that rhizobia did not infect the pulse plant. Lack of a pink colour indicates that the rhizobia are not fixing nitrogen.

TABLE 7. Rhizobium Inoculants.

Company	Product	Crop	Strain	Formulation
Agrium Biologicals Phone: 306-975-3840	RHIZ-UP	Lentils, Peas, Chickpeas or Dry Beans	Single	Liquid
Philom Bios Phone: 1-888-744-5662	N-PROVE	Lentils, Peas	Mixed	Peat, with Sticker
	Tag Team	Lentils, Peas	Mixed	Peat, with Sticker
Imperial Oil Products Div. Phone: 403-449-8655	ENFIX L	Lentils	Single	Liquid
	ENFIX P	Peas	Single	Liquid
Liphatech Inc. Phone: 1-800-558-1003 or 204-435-2260	CELL-TECH C	Lentils, Peas	Mixed	Liquid
	NITRAGIN POWDER C	Lentils, Peas	Mixed	Peat
	NITRAGIN BRAND D	Dry Beans	Mixed	Peat
	NITRAGIN POWDER-GC	Chickpeas	Mixed	Peat
	NITRA-STIK C	Lentils, Peas	Mixed	Peat, with Sticker
	SOIL IMPLANT C	Lentils, Peas	Mixed	Granular
	SOIL IMPLANT D	Dry Beans	Mixed	Granular
	SOIL IMPANT GC	Chickpeas	Single	Granular
Loveland Industries Inc. Phone: 306-721-2201	SOW FAST P/L	Lentils, Peas	Mixed	Peat, with Sticker
	SOW FAST BEAN	Dry Beans	Mixed	Peat, with Sticker
MicroBio Rhizogen Phone: 306-373-3060	BIORHIZ	Peas or Lentils	Single	Liquid
	SELFSTIK st	Peas, Lentils, Faba Beans, Chickpeas, Dry Beans or Lupins	Single	Peat, with Sticker
	MicroFix	Peas or Lentils	Single	Peat
Urbana Laboratories Phone: 816-233-3446	LIQUI-PREP XT	Peas, Lentils, or Faba Beans	Mixed	Liquid
	RHIZO-STIK	Lentils, Peas, or Faba Beans	Mixed	Peat, with Sticker

From: Saskatchewan Agriculture & Food Farm Facts Publication "Inoculation of Pulse Crops"

FIGURE 1. Good Nodule Development on a Pea Plant.

Fertilization

Fertilizer requirements are always best determined by soil test. Additional nitrogen may be required if the soil test nitrogen levels are below 15 lb/ac in the top foot. Excess nitrogen is not beneficial as it encourages the growth of vegetation at the expense of seed production.

Research conducted at Melfort and Watrous has demonstrated reductions in yield due to seed placed nitrogen when using a hoe opener which provides a 2 inch spread pattern on 8 inch centres. Plant stand thinning with increasing nitrogen was visually apparent, but the reduction in yield may also be partly due to reduced nitrogen fixation (FIGURE 2). **Nitrogen should not be placed with the seed, but may be applied before seeding, or it may be side banded as long as there is good separation from the seed during seeding.**

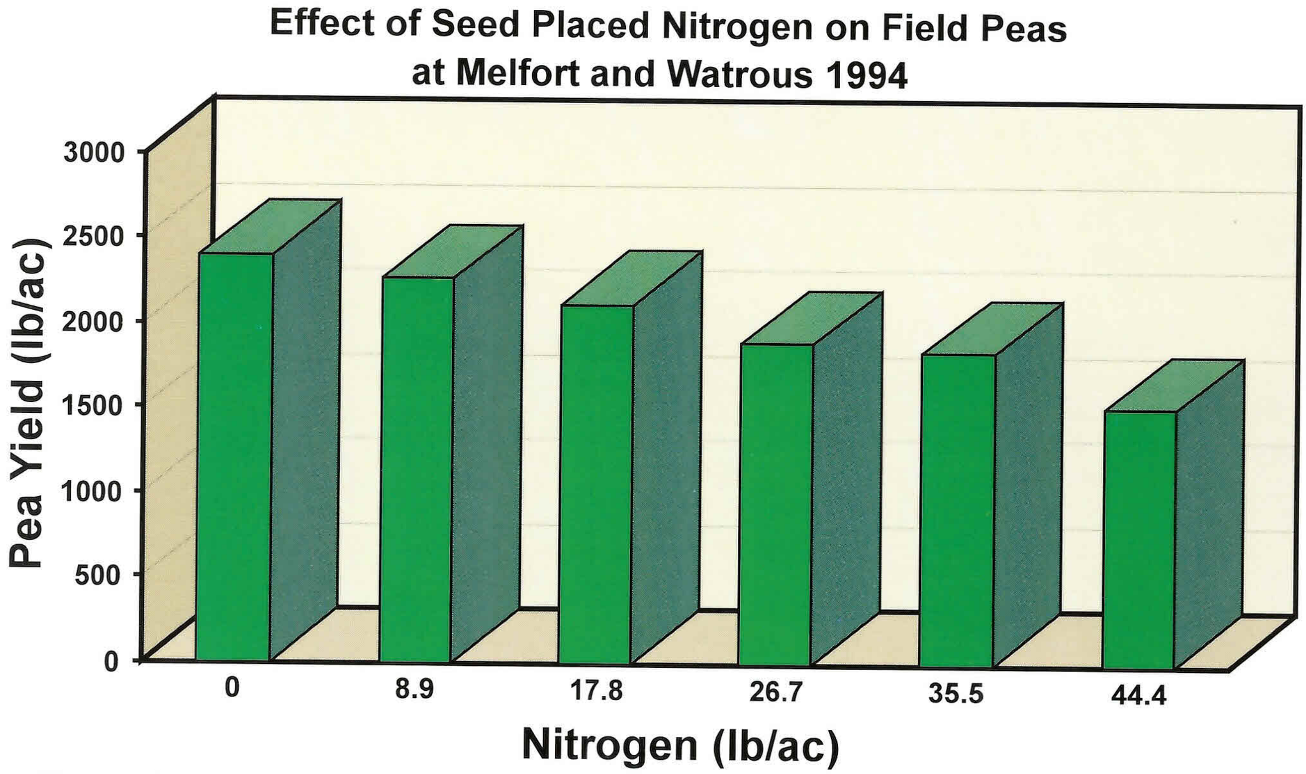

FIGURE 2. Effect of Seed Placed Nitrogen on Field Peas.

Small amounts of phosphate may be applied with the seed if soil tests indicate it is needed. **The maximum safe amount of phosphate to apply with the seed is 40 lb/ac for faba bean, 20 lb/ac for lentil, and 15 lb/ac for pea, chickpea, and dry bean.** This recommendation is based on research using a double disc press drill and six or seven inch row spacings. Maximum safe rates will be lower when using wider row spaces (10 to 12 inch) with narrow spread patterns. Higher rates may be used if the seed-placed phosphate fertilizer and seed is spread laterally in a two inch or wider strip to reduce direct seed/fertilizer contact. Larger amounts can damage the seed and *Rhizobium*, and should be side banded during seeding, or applied before seeding. The use of Provide in conjunction with the safe amount of phosphate is one alternative method available to obtain the correct levels of phosphorus.

Potassium may be deficient in Black and Grey soils. Soil tests should indicate if a problem exists. Soil tests can show adequate potassium reserves, but the crop may not access it due to other factors. Over 130 lb/ac of potassium is needed to grow a 50 bu/ac pea crop. (The potassium requirement of peas is high, especially during flowering and early pod filling.) Generally, potassium fertilizer should be used any time soil tests show levels are too low. When soil test levels are very low, at least some should be seed placed; however, seed placing potassium may cause seedling damage. As with phosphate, a wider seed row may allow for slightly higher than recommended seed-placed rates as direct seed to fertilizer contact is reduced. More information on potassium fertilization is available in "Farm Facts, Potassium and Chloride Fertilization in Crop Production" available from Saskatchewan Agriculture and Food.

Sulphur deficiencies tend to be in small areas within a field so pulse crops should be visually checked for sulphur deficiency symptoms and if a deficiency is suspected, they should be tissue tested. Even flat fields with no apparent soil change can have extensive fluctuations in sulphur content. The pea sulphur requirement which is in the 10 lb/ac range is similar to that of wheat. The symptoms of sulphur deficiency are a yellowing of the plant from the top downward. The plant will have the general appearance of a plant with nitrogen deficiency except that the top leaves yellow first. Peas grown in most soils which test low in available sulphur will not respond to traditional sulphur fertilization with elemental sulphur in that crop year. Some newer products may convert quickly enough to be usable in the crop year, or sulphur applied at higher rates or fall applied may be effective.

Sulphur generally should be applied up to one year or even more before it is required as it takes some time to convert to the sulphate form which the plants use. As such, it is often applied with the fertilizer for the previous year's crop and in excess amounts to provide for sulphur needs for a number of years. **Sulphur can be blended with some fertilizers, but not with ammonium nitrate.** In cases where poor sulphur availability occurs along with low levels of nitrogen, sulphur requirements can be provided in the crop year by using ammonium sulphate (20 or 21-0-0) at the rate needed to provide the sulphur requirements. Sulphur can also be applied in the crop year as a liquid fertilizer by using liquid ammonium thio sulphate. It can be blended with most non-acid liquid fertilizers.

Several other micronutrients are also required by pulses, but they do not normally limit yield. If a deficiency is suspected, soil tests are recommended.

Time of Seeding

Lentils, peas, faba beans, and desi chickpeas are cool season crops that can be seeded early. All four are tolerant of light frosts (-4 to -6°C). Best yields and quality usually result from early seeding as soon as the top inch of the soil reaches 5°C, providing the soil is not excessively wet. This soil condition generally occurs in late April to early May. Kabuli chickpeas should usually be seeded about May 10. Dry beans are a warm season crop and have no frost tolerance. Best yields of dry beans usually arise from seeding later than for the other pulse crops, usually the fourth week of May, when frost risk is low and the soil temperature has reached a minimum of 10°C.

Seeding Rate

Determining the best seeding rate involves careful consideration and calculation. Seed size varies widely among varieties, but within a single variety, the size can easily vary 10 to 20%. A 20% difference in seed cost can be important.

Seeds can be sized during cleaning to produce a more uniform lot. If the desired plant population (plants per square foot), the likely seed survival (in percentage from the seedling vigour and germination tests), and the 1000 seed weight (weight of 1000 seeds) are known, the calculation of seeding rate is straightforward:

Seeding Rate (lb/ac) = (Population/sq ft x 1000 Seed Wt in Grams ÷ % Survival) x 10

For example, for Laird lentil, with a population of 12 plants per sq ft, a 1000 seed wt of 70 g, and 80% of seed producing vigorous seedlings, seeding rate = (12 x 70 ÷ 80) x 10 = 105 lb/ac.

The seeder calibration (done after inoculation) involves some of the same information, plus the row spacing:

Number of Seeds/Foot of Row = (Population/sq ft x Row Spacing (inches) ÷ 12 ÷ % Survival) x 100

For the above example, with 6 inch row spacing, number of seeds/foot of row = (12 x 6 ÷ 12 ÷ 80) x 100 = 7.5 seeds/foot of row.

The adjustment for seed survival should include an adjustment for the rate of germination and the rate of production of healthy vigorous plants.

There is some room for flexibility in determining the best plant populations for a crop. **Recommended numbers for plants per square foot are 12 plants for lentils, 8 plants for peas, 2 to 3 plants for irrigated faba beans or 4 plants for dryland faba beans, 3 plants for irrigated or 4 plants for dryland dry beans, and 4 plants for chickpeas.** The grower may use higher or lower rates, based on the moisture conditions in the field, date of seeding, weed pressure, and experience in the management of the crop. However, stand density does not increase in direct proportion to the increase in seeding rate because of reduced percent emergence resulting from increased competition among adjacent seedlings in a denser stand.

The best seeding rate is a compromise. Seeding rates above those recommended are used to compensate for expected losses. For instance, if harrowing losses of 10% are probable, a 10% boost in seeding rate could offset losses, and result in achieving the recommended plant number after harrowing. Higher seeding rates often result in higher yields because higher than recommended rates reduce competition from weeds by allowing the crop to close off the canopy earlier. Higher plant numbers also stress lentil plants earlier, causing earlier maturity which plays a role in higher yield. However, higher plant numbers also increase the rate of spread of disease, particularly under cool moist conditions. The selected benefits from weed suppression and beneficial stress on the one hand and the increased risk of disease and higher seed costs on the other, have to be weighed for each field each year.

Seeding

Pulse crops can be planted under conventional, minimum till or zero till production systems with a wide range of seeding equipment including: double disc press drills, hoe drills, discers, air drills and air seeders.

Pea, lentil, desi chickpea, and faba bean crops can be seeded into cool soils (5°C). Dry bean and kabuli chickpea crops require warmer soil (10°C) for good germination.

Direct seeding techniques are very effective for pulse production. At Indian Head (Black soil zone), net returns for field peas or lentils grown on stubble using zero-till or minimum till were higher than those from conventional tillage systems. Grain yields were higher in most years, possibly because of improved soil-moisture conservation, and a good, firm seedbed. Work in Alberta suggests that nodulation may be more effective in direct seeded fields, again as a result of improved moisture conditions. **Extended rotations are especially important in direct seeding to reduce the spread of disease from intact residues on the soil surface and to allow for a slower breakdown of residual herbicides.** With any seeding equipment, the seed metering system and the metering device must be able to handle large seed flow rates.

The seed cups or meter clearance must be large enough to allow accurate metering of large seeded pulses without damage to the seed. A trial run with a sample of the pulse will show if the system is capable of handling large seeded pulses without damaging the seed. If there is any doubt, a germination test should be conducted as only slight visible damage may indicate severe reductions in germination.

Air seeders can be successfully used to seed pulse crops, provided the pneumatic system is adjusted to handle the easily damaged seed. **Excessive fan speed and a high airstream velocity may result in substantial physical damage and a major reduction in germination,** especially with dry bean seed below 15% moisture. Studies with Laird lentil showed that up to 30% damage (cracking plus germination reduction) occurred with excessive airflow settings. By reducing the fan speed to the minimum required to convey the seed without plugging, damage can be reduced to low levels. Since ground speed is a factor in airflow requirements for a given seeding rate, reduced ground speed allows for slower fan speeds and results in reduced damage. Refer to the manufacturers recommendations for optimum fan speeds for each crop and machine configuration.

Inoculation can affect the flow and metering of seed, so equipment should be calibrated with inoculated seed. As the cost per acre of pulse seed is often quite high, accurate calibration of seeding equipment can result in minimizing seed costs.

Pulse seeds are sensitive to handling and seeding damage when seeds have a low moisture content. If the moisture content of the seed is below the maximum level required for safe storage (see *Chapter 2 - Table 17*), consideration should be given to moisturizing the seed prior to handling and seeding. Refer to PAMI report #704 Research Update: Moisturizing Pulses to Reduce Damage for information on raising the moisture content of pulses.

Most pulse seeds can emerge from deep seeding depths due to their large size. However, deep seeding is not required, provided the seed is accurately placed in firm, moist soil. In direct seeding systems, the seed can be placed at a shallow depth compared to pre-tilled soils as soil moisture is usually much higher in untilled soils. Large seeds require large amounts of water to germinate and, therefore, the moisture available at seeding depth must be higher than required for a small seeded cereal or oilseed crop. **Lentils should be seeded more than 2 inches deep to minimize herbicide leaching damage to seedlings from Sencor or Lexone DF application.** Seeding into soil conditions that promote rapid emergence is important for crops that are sensitive to soil applied herbicides such as Edge and the trifluralins as longer exposure prior to germination and emergence increases the risk of seedling damage or death.

Rolling

The rolling of pulses after planting is a field operation used to smooth the soil surface. This smoothing of the soil is carried out to improve the harvesting of low hanging pulse pods. Rolling will reduce harvest losses, improve harvest rate, reduce breakage of sickle sections and guards, and may improve seed quality.

Rolling can be done anytime from immediately after seeding up to the 5 to 7 node stage in lentils and up to the 5 leaf stage in peas. Rolling prior to plant emergence will not affect yield, except with very wet clay soil where the soil should be allowed to dry before rolling. The pulverizing effect of rolling can result in soil erosion and plant injury, especially under low residue conditions such as summerfallow. Therefore, when soil erosion is a potential problem, rolling should be delayed until canopy protection is established.

Rolling should take place on hot days as the plants are more flexible when partially wilted and will incur less stem breakage compared to when they are rolled on a cooler day. However, some growers caution that rolling in temperatures exceeding 30°C may result in setting back lentils due to extreme stress. Rolling should be delayed when plants are wet from dew or rain as the roller may transmit diseases to other parts of the field or to other fields. The application of post-emergent metribuzin herbicide Lexone DF or Sencor and rolling are both stressful to pulses so the two operations should be separated by a minimum of two days.

Weeds

Weeds can be a challenging problem to pulse crop producers. Simple, inexpensive herbicide solutions used in cereal production are not as available in pulse crops. Pulse crops are weak competitors with weeds because of their slow seedling growth, low stature, and their failure to effectively close the crop canopy. Limited herbicide choices and increased annual and perennial weed densities, resulting from extended rotations, volunteer crops as weeds, and the increased importance of winter annuals and secondary weed competitors, present special weed control challenges to the pulse grower.

Effective, **integrated weed management** begins long before seeding. Integrating weed management means considering how all aspects of the farm operation work together, and how they influence the weeds in a given field. **To be truly effective, the farmer needs to: know the weeds, prevent problems, practise sound agronomy in growing the crop, have practical herbicide or cultivation techniques available, and know when to use them.**

A producer must always determine if a weed problem is of economic concern or only an appearance problem before selecting a weed control method.

Good, integrated weed management reduces the need to use herbicides in crop and should keep weeds in check so pulses can be seeded. Herbicides are normally needed to maximize pulse production and even to make it profitable.

Weed Identification

Good weed management begins with knowing what weeds are present. **Fields should be inspected repeatedly during the growing season.** Which weed species are present? How many are there? Are they widespread, or in localized pockets? How big are they compared to the crop? Is the crop reduced around them? When did they emerge? How quickly are they growing? Are they annual, biennial or perennial? How are they spreading? What changes have occurred since last year?

Several good guides to weed identification are available through Saskatchewan Agriculture and Food, Alberta Agriculture, Agriculture and Agri-Food Canada, University of Saskatchewan, and extension agrologists. Some of these include detailed information about and pictures of each weed. TABLE 8 includes some information on the most common weeds.

The weeds in a pulse crop are generally similar to those experienced in previous years in the same field in cereal crops. The weeds most commonly found in lentil and pea crops are common in cereals and oilseeds as well (TABLES 9 and 10). If a record has been kept of the weeds in a field over the past 3 to 5 years, it should indicate which weeds to expect in the coming year.

All farm management practices affect weeds and weed communities. Within weed communities, the species often change. For instance, the use of phenoxy herbicides, such as 2,4-D, has significantly reduced the populations of wild mustard in cereal crops. Other weeds, such as wild buckwheat, are not controlled by this herbicide. Herbicides may actually benefit weeds that are not killed because the surviving weeds no longer have to compete with the other weeds.

Even within a weed species, there is a great deal of variability. Because of genetic variability, some individuals survive when most others are killed. If a particular weed management practice is continued, it results in an increase in the proportion of the survivors, making that weed management practice continually less effective. Herbicide resistant weeds are a good example of this. Repeated use of a given product, or products with similar chemistry (and similar ways of killing weeds), has resulted in weeds that are not controlled by that group of chemicals. Such weed resistance to herbicides has been identified in Saskatchewan (TABLE 11). **Avoiding repeated use of the same chemical, or chemicals in the same group, will reduce the likelihood of developing herbicide resistance within a weed population.**

Other management factors also influence weeds. Repeated use of delayed seeding following tillage favours late germinating weeds, such as redroot pigweed and green foxtail, over early germinating weeds such as wild oat and wild buckwheat. Repeated fall tillage favours weeds that germinate in the spring over those that germinate in the fall, and so on. In this way, each practice becomes less effective as it is used repeatedly. Varying management practices can prevent the buildup of a given weed type by not allowing it a consistent advantage. A diverse crop rotation can include both summer and winter crops, annual and perennial crops, grassy and broadleaved crops, and crops with different heights, leafiness, and competitive ability. In addition, the crops can be sown early some years and late in others. The herbicides can be rotated. The timing and method of application of fertilizer, timing of tillage, timing of harvest, and the post-harvest treatments can also be varied. Growing different crops in different years allows for varied management in many areas.

Factors, such as heat, drought, flooding, hail and frost, also have an effect on weeds, but are beyond the growers control. Their impact on crops and weed control practices should be noted in determining what weed pressures to expect in following years.

Weeds respond to competition around them. In traditional cereal crops and in weedy fields, competition from the crop and other weeds has a major impact on the shorter and less competitive weeds. If competitive weeds are significantly reduced in a pulse field, which offers little crop competition, the field is wide open for less competitive weeds. This has happened in some lentil growing areas, where weeds such as cow cockle, roundleaf mallow, blue burr, and wild tomato have became a serious problem. These weeds are not new, but they do not compete well with taller wheat, wild oat, and wild mustard plants. Once these competitive species are removed from the field, wild tomato can become a problem.

Weeds can have a major impact on yield and must to be taken seriously. Lentil, dry bean, and chickpea plants are short and do not form a thick, closed crop canopy. As a result, these crops are weak competitors. Peas and faba beans have slow early development, and are also weak competitors. Yield losses due to weed competition depend on the type and number of weeds, the growing conditions, and the time of emergence of the crop and weeds. Losses can be severe (TABLE 12) and may make production unprofitable.

TABLE 8. Characteristics of Some Common Weeds in Pulse Crops.

Weed	Germination	Maturity	Dormancy
Wild Oat	Early	Medium	Long
Green Foxtail	With Soil Warmth	Mid to Late Season	Short to Medium
Wild Buckwheat	Early	Medium	Medium
Russian Thistle	Early	Mid to Late Season	Medium
Stinkweed	Early Spring and Fall	Early	Medium to Long
Shepherd's-Purse	Early Spring and Fall	Early	Medium to Long
Flixweed	Early Spring and Fall	Early	Medium
Lamb's-Quarters	Early	Late	Long
Canada Thistle	Medium	Late	Medium
Redroot Pigweed	Late in Warm Soil	Late	Long
Wild Mustard	Early and Throughout	Early to Late Season	Very Long

TABLE 9. Abundance in Lentils and Other Crops in the Dark Brown Soil Zone of the 10 Most Common Weeds in Lentil Fields in Saskatchewan.

	Lentils		Cereals, Oilseeds	
	Frequency (%) of Fields	**Number/sq yd**	**Frequency (%) of Fields**	**Number/sq yd**
Wild Oat	75	3	67	10
Wild Buckwheat	69	5	61	5
Green Foxtail	50	28	60	24
Canada Thistle	44	3	32	2
Redroot Pigweed	31	2	27	2
Russian Thistle	31	4	27	4
Thyme-leaved Spurge	31	9	12	6
Vol. Spring Wheat	31	2	19	1
Wild Mustard	31	4	18	5
Stinkweed	25	3	48	7

Source: 1995 Saskatchewan Weed Survey, Thomas, Wise, Frick and Juras, with some recalculation.

TABLE 10. Abundance in Peas and Other Crops in the Black Soil Zone of the 10 Most Common Weeds in Pea Fields in Saskatchewan.

	Peas		Cereals, Oilseeds	
	Frequency (%) of Fields	**Number/sq yd**	**Frequency (%) of Fields**	**Number/sq yd**
Canada Thistle	77	2	66	3
Perennial Sowthistle	73	2	50	3
Wild Oat	73	8	64	9
Wild Buckwheat	64	2	72	4
Green Foxtail	46	5	64	14
Shepherd's-purse	46	7	25	4
Wild Mustard	46	2	30	3
Lamb's-quarters	41	2	39	3
Stinkweed	41	7	45	7
Quackgrass	32	8	16	9

Source: 1995 Saskatchewan Weed Survey, Thomas, Wise, Frick and Juras, with some recalculation.

TABLE 11. Herbicide Resistant Weeds in Saskatchewan.

Weed	Herbicide Group	Description
Wild Oat, Green Foxtail	1	Resistant to a group of herbicides which include Achieve, Affirm, Assure, Champion Plus, Fusion, Hoe-Grass, Hoe-Grass II, Horizon, Poast, Poast FlaxMax, Puma, Select, Triumph Plus, Prevail, Venture.
Kochia, Russian Thistle, Chickweed	2	Resistant to Ally, Amber, Champion Plus, Express, Glean, Laser DF, Refine Extra, Triumph Plus, Pursuit (Chickweed).
Wild Mustard	2	Resistant to Ally, Amber, Assert, Express, Glean, Muster, Pursuit, Refine Extra.
Green Foxtail	3	Resistant to Edge and to trifluralin products Bonanza, Edge, Fortress, Rival, Treflan.
Wild Mustard	4	Resistant to 2,4-D, MCPA, Attain, Banvel, Caliber, Cobutox, Compitox, Curtail, Dichlorprop-D, Dyvel DS, DyVel, Embutox, Estaprop,Mecoprop, Poast FlaxMax, Prevail, Target, Tordon 202C, Triumph Plus, Tropotox Plus, Turboprop.
Note: As well, multiple group weed resistance has been confirmed. Group 1 and Group 3 resistant green foxtail and Group 1, Group 2, and Mataven resistant wild oat have been found.		

TABLE 12. Pulse Yield Loss Caused by Weeds.

Weed	Weed Number	Crop Loss (%)	Crop	Location
Wild Mustard	17/sq yd	45 - 55	Navy Beans	Morden
Wild Mustard	17/sq yd	2 - 35	Peas	Morden
Hairy Nightshade	17/sq yd	45 - 80	Pinto Beans	Lethbridge (irrigated)
Redroot Pigweed	13 - 17/sq yd	70 - 85	Pinto Beans	Lethbridge (irrigated)
Lamb's-Quarters	17 - 38/sq yd	70 - 85	Pinto Beans	Lethbridge (irrigated)
Wild Oat	125/sq yd	74	Lentils	Saskatoon
Green Foxtail	250/sq yd	24 - 34	Lentils	Indian Head
Wild Tomato	400/sq yd	62	Lentils	Vonda

Short pulse crops are susceptible to weed problems that may not be important in other crops. Weeds that remain green late in the season can add to the difficulty of harvest. Wild tomato (FIGURE 3) and round-leaf mallow (FIGURE 4) are low-growing weeds that might not be of concern in a wheat or barley crop, but can cause both a yield loss and a significant increase in harvest difficulty in crops, such as lentils, that are harvested very close to the ground.

Weeds with juicy fruits, like wild tomato, can stain pulse seeds and increase earth tag. Pulses are very susceptible to handling damage so the cleaning out of weed seeds may cause further quality losses.

FIGURE 3. Wild Tomato.

FIGURE 4. Round Leaf Mallow.

New weed problems do arise. Hairy nightshade is a newly introduced and serious weed problem where dry beans are grown under irrigation. In Alberta, up to 30% of the dry bean fields are "infested" and yield losses range up to 75%. It is not common yet in Saskatchewan, but it may spread as bean acreage under irrigation increases.

Weed Prevention

The old saying that "an ounce of prevention is worth a pound of cure" is certainly true in weed management. In growing pulse crops, the two main preventative techniques are to not allow new problems in, and to produce pulses where old problems are under control.

The use of clean seed is an effective means of avoiding the introduction of new weed species into fields. This is especially important when introducing a crop from regions that may have weeds that are not present in your area. Special care should be taken to avoid the introduction of wild tomato and other members of the nightshade family. The seeds of this weed can stick to pulse seeds and since the fruits can be similar in size to pulses, they may not be removed by standard cleaning procedures. This weed can make short crops nearly unharvestable. The use of Certified seed of recommended varieties ensures that the seed will be of known quality and relatively free from weed seed contamination and seed-borne diseases. These factors are important in the establishment of a vigorous crop.

Combines and other equipment can easily introduce weeds into a field, if they are not thoroughly cleaned between fields. Custom combine operators can easily introduce weeds into a field as they travel over large distances and may not clean equipment between fields. Road maintenance also has the potential to bring in weed seeds with the gravel used in resurfacing. New weeds are often introduced in small numbers. If the grower is inspecting the field regularly, the weeds can be more quickly noticed and removed. Hand weeding or spot spraying may be the most cost-effective technique for rare, but potentially problematic weeds such as hairy nightshade.

It is also important to avoid introducing weed problems into a given field from other areas of the farm. Growers can reduce the movement of weeds within the farm, if they control weeds before they set seed, and avoid weedy patches with equipment. Wild tomato and round-leaved mallow are common around abandoned barns and farm yards. Scentless chamomile is often found around sloughs and in less disturbed sites before it is found in crop fields. Shelterbelts often harbour plants with wind-dispersed seeds, such as sow-thistles, groundsels, and various types of tumbleweeds, including kochia and Russian thistle. Feeding cattle with straw or hay from other areas and spreading the manure can introduce weeds.

When a weed problem exists in a small area of a field, it can be readily spread by farm equipment. Harvesting through a wild tomato patch, for instance, will throw the seeds and fruits of wild tomato through the combine. Some seeds adhere to the combine and are spread from the combine to other parts of the field (or even the next fields). Cultivating through a quackgrass patch picks up rhizomes and transplants them throughout the field. Weeds can be contained within a small manageable area if the areas are worked separately and the equipment is thoroughly cleaned afterward.

Chaff management can also have an impact on the weediness of fields in succeeding years. Weed seeds can be very effectively spread through the combine with the chaff, particularly when using a chaff spreader to help improve residue management. Cereal and oilseeds that pass through the combine can also be a source of difficulty as they produce volunteers in following crops. Collection of chaff can reduce weed seed numbers and eliminate chaff rows that can interfere with seed placement and germination. The chaff can often be used as a valuable livestock feed.

Field selection is an important consideration. **It is wise to avoid sowing pulses in very weedy fields, fields with nightshades such as wild tomato, and perennial broadleaf weeds such as Canada thistle and sow thistle.** These weeds are easier to manage in other years of the crop rotation. Growing strongly competitive crops such as barley and using grazing, mowing, and tillage appropriately can reduce these problems before a pulse is grown on a given field. If a pulse is grown in a planned rotation, herbicides not available in the pulse year may be used in the preceding year(s). Effective weed management requires the consideration of several years at once. For instance, a pre-harvest desiccant or pre-harvest herbicide may be more economical in the long run if the following crop is weakly competitive lentils than if the following crop is strongly competitive barley. Weed control measures should attempt to maximize the advantages presented by each cropping situation. An example would be the use of Poast for suppression of quackgrass in peas as this chemical cannot be used in cereal crops.

Sound Agronomy for Weed Management

In weed management, the best defence is a strong offence. **A vigorous and healthy crop has the best advantage in competition with weeds.** Stressed, unthrifty, and sparse crops leave gaps in a field where weeds flourish. Even within a farm, field selection can be important. Low-lying areas may be frost pockets, or frequently waterlogged. Eroded knolls have little waterholding capacity. Problem areas can be reduced by carefully matching the field and the crop.

It is also important to select a field that does not have chemical or biological residues that can harm the pulse crop. If a field has a history which suggests there may be residual herbicides [such as Ally, Amber, Assert, Attain, Banvel (spring or fall application), Curtail, Glean, Lontrel, Muster, Poast FlaxMax, Prevail, Rustler (pre-seed application), Tordon 202C, or Unity], or if high rates or spring applications of 2,4-D, MCPA, Banvel, or trifluralins have been used, then caution is advised. The herbicide label information and the marketing companies provide information on cropping restrictions.

The dissipation of herbicides depends not only on the weather, but often on soil organic matter, texture, and pH. In some cases, a test plot may be needed. A small plot of the pulse crop to be grown should be planted in the field a year in advance and should be grown to maturity to determine if there is any effect from herbicide residues. Chemical assays of the soil are also available from laboratories. To prevent problems, avoid overlap and doubling of herbicide applications on headlands and around obstructions. Field histories should be obtained when purchasing or renting farm land.

The location of the pulse field relative to other fields may also be important. Pulses can be injured from the herbicide drift of most broadleaf weed control herbicides. Pulses can also be infected by diseases from wind-borne pulse residues. Where practical, do not locate pulse crops downwind from last year's pulse field.

Within a crop type, variety selection can be important. Studies in Manitoba have shown that shorter stature pea plants are less competitive with weeds than those of taller stature. (Surprisingly, perhaps, semi-leafless pea varieties seem to be no less competitive than normal-leafed varieties).

The timing of seeding can also effect weed competition. Weeds that emerge with or before the crop have much more effect on the crop than those emerging later. For instance, in Alberta, hairy nightshade that emerged with the crop caused an 80% loss in bean yield, whereas those that emerged 3 weeks after the crop caused only a 35% loss in yield. Early seeding may allow the crop to "get a jump" on the weeds. This may be especially true for weeds such as green foxtail that require warm soil for germination, and in no-till systems where there is no general soil surface disturbance to encourage early weed germination. Delayed seeding can be useful if combined with pre-seeding or pre-emergent tillage to eliminate early and more competitive weeds before the crop emerges, and to activate soil incorporated herbicides. Pre-emergent herbicides create the same advantage by clearing the field as the small crop seedlings emerge.

If sufficient moisture is present, shallow seeding provides for quicker emergence of the seedlings and allows the pulse crop to get ahead of the weeds. Large seeded crops, such as most pulses, require good soil moisture for germination, and shallow seeding reduces the availability of moisture. **The best depth for seeding is generally the shallowest that will provide adequate moisture for rapid germination and emergence.**

Seeding depth must also be considered in relation to the herbicides that are used. Shallow seeding reduces the risk of crop damage from the pre-plant soil incorporated trifluralins (Treflan, Rival, Advance, and Edge), but shallow seeding increases the risk of crop damage from Sencor (metribuzin).

Higher seeding rates (up to nearly double recommended rates) can improve the competitive ability of lentils, peas, and dry beans. This may be true for other pulses as well. Recommendations of the best seeding rates are based on weed-free, small-plot test results. The best seeding rate under weedier conditions may be higher. Seeding rate must be a compromise. Higher rates are more costly, and can increase the probability and spread of disease. Reduced seeding rates may help reduce disease and reduce seeding costs, but only when weed control is effective.

Seed quality is especially important for pulse crops. Rough handling, long storage, disease, early frost, and improper desiccation can reduce germination of the seed and vigour of the seedling. Germination and vigour tests can identify possible problems.

Tillage

Many growers are reducing tillage in order to conserve fuel, reduce erosion, and preserve soil quality. Some growers and researchers have been using direct seeding (seeding with minimum soil disturbance and maximum retention of crop residues) as part of their weed management strategy. In addition to increasing exposure to soil erosion, tillage stimulates weed seed germination by preparing the weed seedbed, warms the soil to speed up weed emergence, hides weed seeds from their predators, and puts weed seeds in contact with soil moisture. In the absence of tillage, weed seeds are not as easily "deposited" in the "weed seed bank" in the soil. This is particularly true of weeds with dormancy such as wild oats. When the old "seed bank" is exhausted, some people are finding that their annual weed problems are dramatically reduced. However, perennial weeds can increase dramatically, and they can be much more expensive and difficult to control.

Some tillage techniques can be used effectively to manage weeds. The benefit of tillage must be considered in relationship to its cost and risks. For instance, fall tillage has traditionally been necessary for effective use of trifluralin for weed management, and also to control winter annual and biennial weeds. Fall tillage does expose the soil to the risk of wind and water erosion in the winter and spring, and reduces stubble that might trap snow and increase soil moisture. The relative costs and benefits depend on the nature of the land, the weather, the amount of surface residue, and the weed problems being addressed.

Fall or spring pre-seeding tillage can be used to control winter annual and biennial weeds, and is required to aerate and warm the soil to activate some soil incorporated herbicides. Spring tillage should control early emerging, summer annual weeds that are present. Shallow tillage avoids bringing more weed seeds up to near the soil surface where they are more likely to germinate. Excessive tillage dries the seedbed making shallow seeding less effective.

Post-emergent harrowing with a tine harrow can be used as a weed control technique in some pulse crops, but it is not a preferred weed control measure. Results are highly variable and depend heavily on weather conditions and both weed and crop stage. Only very small weed seedlings that have emerged from a shallow depth can be killed and this is usually not effective unless the operation is carried out on a hot day and the surface soil is dry. The recommended stages of the crop for harrowing are at seedling stage (no more than 4 inches tall) for lentils and peas, and from 2 to 6 inches in height for faba beans. Harrowing is more effective, and the risk of crop injury is reduced if the plants and soil surface are dry and the day is warm. Some crop stand thinning is inevitable. An increase of about 15% in the seeding rate may compensate for harrowing losses. Harrowing should only be considered when the seed has been placed below the depth of the harrows to avoid disturbing the crop seed and primary root system. Harrowing plants that are damp increases plant damage and will also increase the spread of diseases such as ascochyta. Precautions to reduce the risk of crop injury include the use of tine harrows only and reduced ground speed. Cross harrowing and a reduced angle of harrow tines will also be helpful. Fields with heavy surface residue should not be harrowed if bunching of the residue occurs.

Herbicide Use

Only a limited number of herbicides are registered for use in Saskatchewan pulse crops, especially for lentils and dry beans, and none are currently registered for use in chickpeas. As new crops are developed, herbicide registration often lags behind. A grower cannot simply assume that a product which is safe for one pulse is safe for another.

Herbicide options are not available to control all weeds in all pulse crops. Some weeds must be controlled in other crops in the rotation. Even in crops such as peas, where a greater range of herbicide choices exist, herbicide use should not be considered as a cure-all. They can be used to salvage a crop and to reduce annual weed seed set, but a long term approach to employ weed management options to their fullest potential in all crop years is required. Total weed control is not likely to occur and may not be economical or practical or be needed. A more realistic goal is to reduce weed density to permit commercial cropping and to continually monitor practices to ensure new weed problems do not emerge.

TABLE 13 summarizes the herbicides that are currently registered for use in pulses. Comments on each product are given here, but the user should always read and follow label instructions.

Detailed information on the use of specific herbicides and the recommended rates are contained in the "Crop Protection Guide" updated annually by Saskatchewan Agriculture and Food.

Edge (ethalfluralin) and the trifluralin formulations (Advance, Bonanza 400, QR5, Rival, Treflan) kill seedlings as they germinate. Lentils are very susceptible to crop injury if conditions are cold and dry.

Edge and trifluralin formulations are not recommended for fields prone to erosion because they require intensive incorporation. Fall incorporation is especially damaging to erosion-prone soils. Although not registered for this use, studies at Scott and Indian Head using surface applied Edge and trifuralin under no-till conditions have shown weed control and crop safety comparable with incorporated Edge and trifuralin. The recommended practice includes 2 incorporations, performed at right angles to each other. The first incorporation is done within 24 hours of application to prevent herbicide loss; the second incorporation is carried out at least 5 days after the first to ensure thorough mixing in the soil. For fall applied chemicals, the second incorporation can be done in the fall, or for crops other than lentils, in the spring. Shallow tillage is recommended before seeding to activate the herbicide and warm the seedbed.

Deep seeding or environmental factors which delay seedling emergence increase the risk of crop injury, and may result in stand thinning and/or delayed maturity and reduced yield, particularly for lentils.

Weed resistance to herbicides (Advance, Edge, Fortress, Rival, Treflan, Trifluralin) has been identified for green foxtail in Saskatchewan. As a precaution, do not use herbicides in Group 3 year after year. Use of non-Group 3 herbicides effectively prevents this buildup of weed resistance by killing all green foxtail plants including those with group 3 resistance.

Basagran is a contact herbicide which requires good leaf contact for best results. Environmental stresses like drought, flooding, hail, or changing temperature, reduce control and may cause some yellowing of crop leaves. Basagran can be used when pea plants have 3 pairs of leaves, when faba bean plants are 4 inches tall, or when dry bean plants have from 1 to 3 sets of leaves. The adjuvant Assist Oil Concentrate is recommended for improved control, particularly at an advanced growth stage. Basagran should not be tank mixed with other chemicals. Best results are obtained by using increased water volumes and applying it during active weed growth.

Fusion and Venture are systemic translocated herbicides which rapidly cause yellowing of the leaves, and death of grassy weeds in 2 to 3 weeks. They work best when the plants are not under stress. Treated plants should not be grazed. Early application to pulses is required as peas should not be harvested within 75 days of treatment and lentils should not be harvested within 82 days of treatment. **Because Venture may cause birth defects in rats, women should avoid all contact with both of these products during their reproductive years as they contain the same active ingredient.** These products should also not be used in areas where they may drift into wildlife habitat or wetlands.

Weed control is best if the weeds are not tillered and are small and actively growing. Control will be reduced if the weeds are under stress from high temperatures or drought. Symptoms appear in 10 days as a yellowing of treated plants, and this chlorosis rapidly progresses with death of the weeds in about 14 days. Lentils are tolerant to Hoe-Grass 284 at all stages of growth, but in hot, humid weather, leaf cupping and a transient leaf burn may occur. No tank-mixes of Hoe-Grass with other pesticides are registered for use in lentil crops. Other pesticides should not be applied within 4 days of application of Hoe-Grass, and treated fields should not be grazed prior to harvest.

Lexone DF and Sencor are systemic post emergent herbicides that kill susceptible plants by inhibiting photosynthesis. Control symptoms may not be noticeable for 3 to 7 days after treatment. Continuous agitation is required to keep the metribuzin in solution. Although these herbicides act primarily through the foliage, rain may move them down to the root system where they may cause injury to lentil plants that are sown less than 2 inches deep or on soil that has less than 4% organic matter for Sencor, and less than 3% organic matter for Lexone DF. These herbicides can cause significant crop injury (lentils are more sensitive than peas) under certain conditions. Damage with metribuzin is most likely and most severe if heavy rain falls shortly after application, or when the crop has been seeded shallow (less than 2 inches deep) into coarse textured soils with low organic matter (less than 4%). Damage is also more likely when the crop is stressed by high or low temperatures or frost, or the crop is not in the early growth stage, or when less than 68 L/ac of water is applied with the herbicide.

Under some field and weather conditions, weed control is improved with a split application with the first application (2/3 rate) at the cotyledon to 2 leaf stage of the mustard-type weeds and the second application (1/2 rate) if a second flush of weeds emerges 7 to 10 days later. Split application usually reduces damage to the lentil crop. Sencor is registered as a tank-mix with Treflan (spring or fall for peas and faba beans, fall only for lentils). Lexone is a registered tank-mix with Treflan only on faba beans. Label instructions must be followed carefully to avoid crop injury. Other tank-mixes are not registered for use on lentils. Wild oat herbicides should not be applied within 3 days of application of metribuzin. Treated crops should not be fed to livestock within 70 days of application for Lexone DF and 30 days for Sencor.

TABLE 13. Herbicides Registered for Use in Pulses as of January, 1997.

			CROP				GRASSES				
Herbicide	Manufacturer/Distributor	Herbicide Group	Peas	Lentils	Faba Beans	Beans, Dry	Barnyard Grass	Green Foxtail (Wild Millet)	Persian Darnel	Yellow Foxtail	Wild Oats
Advance 10G (fall)	DowElanco	3	•	•	•	•	X	X	X	X	X
Assure	DuPont	1	•	•			X	X			X
Avadex BW (spring)	Monsanto	8	•								X
Basagran	BASF	6	•		•	•					
Bonanza 400 (spring/fall)	United Agri	3	•	F	•	•	X	X	X	X	X
Edge	DowElanco	3	•		•	•	X	X		X	X
Fusion	AgrEvo	1	•	•			X	X	X		X
Hoe-Grass	AgrEvo	1	•	•	•	•	X	X	X	X	X
Lexone	DuPont	5	•	•	•h						
MCPA[1]	Various	4	•d								
NaTA (TCA)	AgrEvo	26	•					X		X	
Poast	BASF	1	•	•	•	•	X	X	X	X	X
Pursuit	Cyanamid	3	•					X			X
Rival (spring/summer/fall)	AgrEvo	2	•	F	•	SP	X	X	X	X	X
Select	RhonePoulenc	1	•	•			X	X	X	X	X
Sencor	Bayer	5	•	•	•h						
Treflan (spring/fall)	DowElanco	3	•	F	•	•	X	X	X	X	X
Tropotox Plus	RhonePoulenc	4	•								
Venture	Zeneca	1	•	•			X	X	X	X	X

	WEEDS ANNUAL															
Herbicide	Bluebur	Buckwheat, Wild	Chickweed	Cleavers	Cocklebur	Cow Cockle	Dragonhead, American	Flixweed	Groundsel, Common	Hemp-nettle	Knotweed, Prostrate	Kochia	Lamb's-quarters	Lettuce, Prickly	Mustards	Mustard, Dog
Advance 10G (fall)		X	X			X					X		X			
Assure																
Avadex BW (spring)																
Basagran			X	X	X				X				X		X	
Bonanza 400 (spring/fall)		X	X			X					X		X			
Edge		X	X	S		X				S		X	X			
Fusion																
Hoe-Grass																
Lexone			X							X			X		X	
MCPA[1]	1.7L				X		1.7L	X		S_a		X	X	X	X	1.7L
NaTA (TCA)																
Poast																
Pursuit		X	X	X						X			S		X_b	
Rival (spring/summer/fall)		X	X			X					X		X			
Select																
Sencor			X							X			X		X	
Treflan (spring/fall)		X	X			X					X		X			
Tropotox Plus							X			S			X		X	
Venture																

	WEEDS ANNUAL															
Herbicide	Peppergrass, Field	Pigweed, Prostrate	Pigweed, Redroot	Pigweed, Russian	Pigweed, Tumble	Purslane	Radish, Wild	Ragweed, Common, Giant	Russian Thistle	Shepherd's-purse	Smartweed, Lady's-thumb	Sow-thistle, Annual	Spurry, Corn	Stinkweed	Stork's Bill	Sunflower Prairie
Advance 10G (fall)			X			X										
Assure																
Avadex BW (spring)																
Basagran			S			X		X			X		X	X	X	
Bonanza 400 (spring/fall)			X			X			X							
Edge		X	X			X			S		S		X			
Fusion																
Hoe-Grass																
Lexone											X		X	X		
MCPA[1]	1.7L		1.7L	X	1.7L	1.7L	X	X		X		1.7L		X_c		X
NaTA (TCA)																
Poast																
Pursuit			X							X	X			X		
Rival (spring/summer/fall)			X			X			X							
Select																
Sencor										X_p	X		X	X		
Treflan (spring/fall)			X			X										
Tropotox Plus			X				S	X		X		S		X		
Venture																

[1]These rates are for the amine formulations MCPA (500 g active ingredient/litre).

NOTE: Where a rate higher or lower than the maximum rate given for the crop is required for control, the actual rate required is shown in L/ha in the weed section of the chart.

X - Controlled by rate given for crop
T - Top growth control only - new growth will come back from the root
S - Suppression only
F - Fall application only
SP - Spring only
• - Registered for use in this crop

a - MCPA K b - Wild Mustard only c - Spring seedlings only d - Sodium or amine salt (up to 0.56 L/ha MCPA Amine or up to 0.93 L/ha MCPA Sodium Salt) h - Treflan tank-mix only
p - Pre-plant incorporated

continued....

	Manufacturer/Distributor	BIENNIAL			PERENNIALS							VOLUNTEER CROPS								
		Burdock, Common	Goat's Beard	Wormwood, Biennial	Bindweed, Field	Dandelion	Dock	Field Horsetail	Sow-thistle, Perennial	Thistle, Canada	Quackgrass	Wheat	Barley	Oats	Canola	Mustard	Corn	Roundup Ready Canola	Liberty Link Canola	Pursuit Smart Canola
Advance 10G (fall)	DowElanco																			
Assure	DuPont										S	X	X							
Avadex BW (spring)	Monsanto																			
Basagran	BASF									T										
Bonanza 400 (spring/fall)	United Agri																			
Edge	DowElanco											X	S							
Fusion	AgrEvo											X	X							
Hoe-Grass	AgrEvo																X			
Lexone	DuPont														X			X	X	X
MCPA[1]	Various	X	1.7L	1.7L		1.7L T	1.7L T	S	1.7L T	1.7L T					1.2L	1.2L		1.2L	1.2L	1.2L
NaTA (TCA)	AgrEvo																			
Poast	BASF										T	X	X	X			X			
Pursuit	Cyanamid											Xr	Xr		X			X	X	
Rival (spring/summer/fall)	AgrEvo																			
Select	RhonePoulenc											X	X	X			X			
Sencor	Bayer														X			X	X	X
Treflan (spring/fall)	DowElanco																			
Tropotox Plus	RhonePoulenc				T		T	T	T	T					X			X	X	X
Venture	Zeneca										T	X	X	X			X			

[1]These rates are for the amine formulations MCPA (500 g active ingredient/litre).

NOTE: Where a rate higher or lower than the maximum rate given for the crop is required for control, the actual rate required is shown in L/ha in the weed section of the chart.

X - Controlled by rate given for crop
T - Top growth control only - new growth will come back from the root
S - Suppression only
F - Fall application only
SP - Spring only
• - Registered for use in this crop

a - MCPA K b - Wild Mustard only c - Spring seedlings only d - Sodium or amine salt (up to 0.56 L/ha MCPA Amine or up to 0.93 L/ha MCPA Sodium Salt) h - Treflan tank-mix only
p - Pre-plant incorporated

Poast (sethoxydim) is a very effective translocated grass herbicide that can be safely applied at all stages of pulse crop growth. Control is best when the annual grassy weeds are small and actively growing. Annual grassy weeds stop growing within hours after treatment and the vegetation slowly turns brown. Death of the grassy weeds takes 7 to 21 days, depending on growing conditions and stage of application. Top-growth control of quackgrass can be expected for 6 to 8 weeks, but in a weakly competitive crop like lentil some re-growth generally occurs prior to harvest. Drought, flooding, and prolonged periods of heat or cold can reduce grass control. There are no registered tank-mixes of Poast with other pesticides for use in lentils. Other pesticides should not be used within 4 days of Poast application. Poast requires the addition of Merge surfactant. Poast must not be applied to lentils within 65 days of harvest. Avoid drift of Poast onto cereal crops.

The liquid formulation of Avadex BW is a spring soil applied herbicide that kills young wild oat seedlings as they germinate and emerge. Wild oat kill is usually rapid. Pea seedlings have good tolerance to the chemical. Application of Avadex BW is recommended before seeding the pea crop. Two shallow incorporations at right angles with harrows are recommended. Avadex BW is not recommended for soils with residue cover greater than 30%, or where harrowing is likely to increase the risk of soil erosion. Avadex BW requires moisture for activation. On hot, windy days, large losses of Avadex BW can result from delayed incorporation. Early germinating wild oat plants present prior to application will not be controlled so they must be removed by tillage.

MCPA is a translocated phenoxy herbicide that causes rapid undifferentiated growth, and death in susceptible plants. It may delay maturity in peas, and the pea crop under stress may be slow to recover. The recommended stage for treatment is when pea plants are less than 6 inches in height, with 2 to 5 leaf pairs. Only the amine or sodium salt formulations are recommended in peas. Recommended water volumes are higher (65 to 80 L/ac) than in cereals. **MCPA is not recommended for other pulse crops.**

Pursuit is a herbicide with residual soil activity. It is absorbed by roots and leaves of plants, stops growth, and leads to the death of susceptible plants. A surfactant, such as AgSurf or Agral 90, must be added to the spray solution. It is only recommended for peas in the Black and Grey Wooded soils because of the risk of prolonged soil activity in drier areas. Even in the recommended areas, recropping potential is reduced by the use of this chemical as only barley, wheat, lentils, or alfalfa can be grown. Over-application may result in crop injury, and may limit even further the recropping possibilities. A field test plot should be grown the year before growing any other crop. Crop can be treated with Pursuit up to the 6 leaf stage. Treatment or drift into wildlife habitats should be avoided. A pre-harvest interval of 60 days is recommended. Crops should not be grazed or cut for hay. Do not apply Pursuit to the same field two years in a row. In the case of crop failure or hail, only peas can be replanted in the year of application.

NATA (TCA) is a soil-active herbicide registered for green and yellow foxtail control in peas. It can be tank mixed with MCPA amine or sodium salt formulations. It is recommended for use when pea vines are 4 to 6 inches tall and in the 1 to 3 leaf stage. It is most active on sandy soils with good moisture. Application should be made in 40 to 65 L/ac of water.

Tropotox Plus (MCPB + MCPA) is a phenoxy herbicide combination recommended for pea in the 3 to 6 expanded leaf stage. It should not be mixed with other pesticides. Pea crops treated with Tropotox Plus should not be grazed or cut for hay. The primary use of Tropotox Plus is for top growth control of perennial Canada and sow thistle.

Other Herbicide Practices

Some winter annual weeds in the mustard family (flixweed and shepherd's purse) are not controlled by herbicides registered for lentils. Pre-seeding tillage can be effective. Some growers have experimented with late fall or very early spring applications of 2,4-D or MCPA to control these weeds prior to seeding lentils. As a control measure, these treatments are very effective and economical. **However, they are NOT recommended for lentils because of the high risk of crop injury from carry over on the soil or near the surface.** Direct seeding or use of discers often results in the seeds being directly covered with high residue content soil. Tillage to incorporate pre-plant herbicides effectively dilutes these residues.

Glyphosate (Roundup, Laredo, Wrangler, Victor) is a systemic herbicide that can be used as pre-harvest weed control in the week or two prior to harvest. Earlier application can result in reduced crop yield, reduced quality, and residue in the seed. **As germination of the seed and vigour of the seedling can be reduced, pre-harvest Roundup is not recommended for crops grown for planting seed production.** Glyphosate is not a recommended crop desiccant. In addition, glyphosate can also be used as a pre-seeding or pre-emergent burnoff treatment and it leaves no harmful residue.

Know When to Treat

All weed control methods have economic and environmental costs. Several factors are involved in determining whether these costs are justified.

Weeds should not be automatically considered a problem that requires drastic action. The competitive effect of weeds is determined by the type of weeds, the number of them, the time that they emerged relative to the crop, and the weather. In low stature and slow emerging pulses, the competitive effect of weeds is generally much greater than it is in other crops. Weeds are only worth controlling if the damage caused by the weed (yield loss, harvest difficulty, quality loss, weed seed set) outweighs the cost of control. **Generally, it is advisable to spend more herbicide dollars on the less competitive and more valuable pulse crops than on the more competitive cereal crops.**

The weed "problem" should be considered in the context of the entire farm operation. The grower has to decide if the weed problem in a field is cosmetic or economic prior to determining the control method. For instance, consider wild oat in peas grown as green feed for livestock. Would the value of the wild oats as livestock feed offset the reduction in pea yield from competition, or would the loss in value be greater than the cost of a wild oat herbicide? Some weeds such as a volunteer crop can be economically separated and sold. **A grower must be aware that weed competition can cause a disastrous reduction in pulse crop yield. Effective weed control is the key to profitable pulse production.**

Control measures have different levels of effect on different weeds. When a herbicide control exists for only some of the types of weeds in a field, the surviving weeds may still be able to outcompete the crop. For example, treating a field with Sencor to control wild mustard and stinkweed may be of no benefit if the field also has a heavy stand of wild buckwheat which has not been controlled. Some fields may be unsuitable for pulse crops if they contain dense stands of weeds for which no control exists.

In the final analysis, all weed management is a compromise. The best solutions are field-specific and depend on land use, rotations, available equipment, and the cost.

It is important to take advantage of different crops grown in the rotation to attack the weed problems in a field. This will include the use of summerfallow tillage, chemfallow, spot treatments, alternate and inexpensive cereal crop chemicals, field mapping, soil bioassays, herbicide use records, and a clear plan to ensure that weeds not controlled in pulse crops are attacked in other portions of the rotation.

Biological Control

Biological weed control is the use of living organisms to control weeds, such as the use of livestock to graze weeds. Insects have been imported from European and Asian countries and released on rangeland weeds that were difficult to access for chemical control. Today, bio-control is moving to encompass a broader perspective. This may include the encouragement of helpful local insects, the herbicide-style application of certain weed diseases, and all other forms of biological control.

Biological controls may become available for control of common weed species. A fungus that attacks round leaf mallow was discovered by Agriculture and Agri-Food Canada scientists. A commercial formulation, BioMal, was registered, but has now been withdrawn from the market due to manufacturing difficulties.

Wild tomato can be very effectively controlled by use of Colorado potato beetles, but the beetles are not commercially available.

Biological agents may be more available in the future.

Insects

Crop loss from insects in pulse crops is sporadic, but the potential for yield and quality loss is high for specific insects if their populations are high. Insects are most effectively controlled if the grower maintains an integrated management system that includes a knowledge of the biology of the insects that might cause problems, field scouting, knowledge of insect survey projections, sound agronomy, and the use of insecticides when necessary.

The numbers of insects in any given field is dependent on a multitude of factors, including weather, the farm management system, the number of insects in previous years, and the buildup of various predators, diseases, and parasites.

Grasshoppers

Saskatchewan Agriculture and Food publishes an annual grasshopper forecast each year that indicates the likelihood of a grasshopper outbreak. It is based on surveys of egg numbers in each crop district. Regular field inspections should be used to verify that insects are at damaging levels.

Grasshoppers usually lay their eggs in areas with green growth in the fall. Good fall weed management discourages egg laying. When grasshoppers hatch in the spring, they are only 1/10 inch long. They can be spotted in uncultivated areas such as ditches, stubble, pasture, and field edges, by looking carefully, or by using a cloth net swept near the soil surface. Grasshopper survival and crop damage will be the greatest in hot, dry springs, and in field areas that accentuate those conditions such as south slopes and sandy soils. These conditions speed up the grasshopper hatch, bringing more hungry insects to the crop at one time. A heat stressed crop is less tolerant of insect damage than one with adequate moisture because when stressed, growth is slowed and the damaged area is not quickly replaced.

Grasshoppers chew through young shoots, even if they do not eat the plant. Pulse crops are not strongly preferred by grasshoppers, but damage to seedlings bordering ditches and roads can occur. During the early flowering stage, grasshoppers can eat the first buds and flowers of lentils, delaying seed set and reducing yields. **As few as two grasshoppers per square yard can cause serious yield losses in lentils.**

Grasshopper problems are more likely in the warmer, drier southwest region of Saskatchewan. In these areas, summerfallowing is more common, and these tilled areas can be incorporated into the grasshopper management system. Clean summerfallow will starve newly emerged grasshoppers. If grasshoppers have already begun to feed when summerfallow is started, they will be more likely to move to neighbouring fields. In this case, trap strips of green growth can be left to concentrate the grasshoppers before applying a registered insecticide. The effectiveness of the trap strip will be increased, if it is planted early in the year.

Stubble cropping increases the risk of grasshopper problems because the previous crop provides a habitat that encourages egg-laying. This risk is greatest in years when a warm spring occurs and severe or very severe grasshopper outbreaks are forecast.

If insecticidal sprays are used in areas where bees are kept, they should be applied in the evening or early morning, when bees are not foraging. Bee keepers in the area should be notified at least 48 hours in advance of any insecticide treatment.

Cutworms

Cutworms occasionally cause problems. The risk is low, unless more than 2 to 3 cutworms per square yard occur in the top 3 inches of soil. Cutworms overwinter as eggs or young larvae that feed on newly emerged shoots in spring. The shoots may be cut off below the soil surface. Pulse crops such as dry beans, where the cotyledons (seeds) emerge from the soil, are generally killed if attacked by cutworms. Crops such as lentils, faba beans, peas, and chickpeas, where the cotyledons (seeds) remain below the soil surface, can often recover from cutworm damage if cool, moist growing conditions occur. However, recovered plants are generally set back 4 to 7 days by the damage.

Red-backed cutworm moths (more common in the Black and Dark Grey soil zones) lay their eggs in weedy areas. Good weed management in late summer can discourage them. Pale western cutworm moths (more common in Brown and Dark Brown soil zones) lay their eggs in loose soil. Fall tillage encourages them to lay eggs in an area.

Aphids

Aphids rarely overwinter in Saskatchewan. If the wind direction is right, aphids can blow in from the south or the east. If this occurs early in the season, damage can result. Aphids are the mosquitoes of the plant world; they suck the sap from plants, and they can be a method of transmission for viral diseases. Under warm moist conditions, aphids reproduce at astonishing rates. Early seeding, or later arrival of the aphids reduces damage as aphids are less attracted to older plants.

Insecticides

Insecticides registered for use in Saskatchewan pulse crops are indicated in TABLE 14. Decis is more effective at lower temperatures. Knowledge about application of each insecticide will enhance activity and optimize use. Insecticides should be used with caution.

Diseases

Diseases, like weeds, present a challenge to the pulse grower. They can result in substantial yield losses and reduction in seed quality. **Control of diseases is most effective if the grower uses an integrated disease management system that includes a good knowledge base of the diseases and the life cycles of the organisms that cause them, use of disease free seed, sound agronomy in growing the crop, and the use of fungicides when necessary.**

Knowledge of the Diseases

Good disease management begins with knowing which diseases have spread into an area and how serious each is in a given year. TABLE 15 lists pulse diseases that occur in Saskatchewan. Details of each disease are found in the chapter relating to the specific crop.

Fungi are the most common cause of plant disease. Fungal diseases are spread by microscopic spores (the fungal equivalent of seeds) or mycelia (thread-like structures). Spores may be dispersed by wind, in water, by insects or by direct contact. Spores usually require moisture to germinate. Upon germination, spores produce infection tubes that enter the plant through small openings on the surface, or by directly penetrating through the plant tissue. Inside the plant, the fungus forms threadlike structures that extend throughout the tissue. The structures absorb nutrients from the plant, and cause blockage or tissue breakdown. When the food supply is nearly used up, the fungus often produces more spores and reproductive or survival structures that allow identification of the disease. If conditions are right, the release of spores is again followed by germination and infection, and the disease can spread rapidly. Some fungi also produce larger structures as resting stages, such as hard sclerotia bodies formed in the disease sclerotinia that can remain dormant for a time and then resume growth and infect plants.

Some fungi, such as those which cause powdery mildew in peas, can use only a particular living plant as a source of food and for reproduction. These fungi can be controlled by removing the host crop. Other fungi, such as *Botrytis*, can cause considerable crop damage, but they are not limited to the crop. These fungi survive and grow on the remains of a variety of plants, and for this reason they cannot be easily eliminated.

Bacteria are one-celled organisms that may cause plant diseases. They can be spread by infected seed, rain splash, by plant to plant contact and by insects. They enter the plant through stomata (pores in the plant surface), or though wounds caused by hail, insects, sand blasting, machinery, etc. **Phytoplasmas** are a special class of bacteria that cause many yellows-type diseases. They are spread from plant to plant by insects, especially leafhoppers. The leafhopper sucks in the phytoplasmas with the sap as it feeds. The phytoplasmas multiply within the leafhopper, and then infect healthy plants when the insect feeds on them.

TABLE 14. Insecticides Registered for Use in Saskatchewan Pulse Crops.

Insecticide	Registered Crop	Pre-Harvest Interval	Insect	Threshold Populations that Justify Spraying
Ambush	lentils, peas	---	cutworm	2 - 3/sq yd
Cygon (Dimethoate)	dry beans	7 days	aphids, bean beetles, leafhoppers, leafminers, lygus bugs	----
	peas	3 days	aphids	----
Decis	lentils	40 days	cutworm	2 - 3/sq yd
			grasshopper at seedling stage	10/sq yd
			grasshopper at flowering	2/sq yd
Diazinon/Basudin	beans peas	7 days 14 days	root maggots root maggots	---- ----
Guthion (Azinphos-methyl)	dry beans	3 days	leafrollers, aphids, leafhoppers, bean beetle, leafminers	----
Lannate	peas	1 day	alfalfa looper, aphids	----
Lorsban	lentils peas	21 days 60 days	cutworm, grasshopper seed corn maggots	2 - 3/sq yd 2 - 3/sq yd at flowering
Malathion	peas, dry beans	3 days, 1 day	aphid	as per Dibrom
	lentils	7 days	grasshopper at seedling stage	10/sq yd
			grasshopper at flowering	2/sq yd
Ortho, Dibrom (Naled)	dry beans	4 days	alfalfa looper aphid	----
Parathion	dry beans	12 days	aphids, bean beetle, leafhoppers, leafminers, armyworms, leafrollers	----
	peas	15 days	alfalfa looper, aphids, pea weevil	----
Pirimor	peas	6 days	aphids	----
Thimet	beans	60 days	Mexican bean beetle, leafhoppers, aphids, lygus bugs, thrips, mites	
Thiodan (endosulfan)	beans	2 days	potatoe leafhopper, bean aphids, Mexican bean beetle, green cloverworm	----
	peas	7 days	aphid, weevil	----

SAF Crop Protection Guide and O. Olfert, Personal Communication.

TABLE 15. Diseases that Threaten Pulse Crops in Saskatchewan*.

Disease	Crop				
	Lentils	Field Peas	Faba Beans	Dry Beans	Chickpeas
Fungal					
Ascochyta/Mycosphaerella Blights	++++	+++	+		++++
Ascochyta Foot Rot		+++			
Anthracnose	++++			+	
Seedling Blight	++	++	+	+	++
Botrytis Stem and Pod Rot	++++	+	++++		+++
Sclerotinia Stem Rot	++	++	+	++++	
Powdery Mildew		++	+		
Septoria Leaf Blotch		+			
Bacterial Blights		+		++	
Phytoplasms					
Aster Yellows			++		
Virus	+	+	++	+	

++++ often causes major economic losses
+++ widespread and causes significant economic losses when present
++ widespread but usually not of economic importance
+ infrequent and usually not of economic performance

*from Martens et al 1984 and R.A.A. Morrall and A.E. Slinkard, Personal Communication.

Viruses also cause plant diseases. Although some viral diseases spread by plant-to-plant contact, many are spread by insects, especially aphids, or through infected seed.

Many **environmental factors** cause unhealthy plant growth. Among these are mineral deficiencies or excesses (including problems from salinity or extreme pH), seed damage, herbicide injuries, ozone damage (from air pollutants), heat canker, sun scald, wind damage, sand blasting, waterlogging, and frost damage.

Crop monitoring for early symptoms of disease can be crucial. Disease management may be impossible, if the disease is already widespread in the crop. As with weed management, nothing replaces inspecting the fields. Avoid spreading diseases from field to field. Diseases are much more likely to develop where moisture is available. Places to check are where crop canopies are thick or in low lying areas of the field where water accumulates. Of course, any dead or weakened patches should also be examined. Environmental factors determine the likelihood and the rate of spread of most diseases. In general, all factors which increase humidity increase the risk of disease. Monitoring is especially important during periods of cool moist weather, if crop residues are retained, or when crop growth is thick.

Diseases evolve in response to **farming practices**. For instance, when Laird lentil was introduced, it was rated as moderately resistant to ascochyta blight, but it is now rated as susceptible because a more aggressive form of ascochyta has developed. The expansion of Laird lentil acreage over the province has provided a large host crop area for successful multiplication of fungi which can successfully infect it.

Disease Prevention

The most effective way to manage diseases is to prevent or avoid them. A method of choice is the use of resistant varieties. Disease resistance is often a major goal of plant breeding. Ascochyta resistant lentils and chickpeas are excellent examples. Resistance is not available for all diseases in all crops, and each type of resistance can eventually be overcome by evolution of the organisms that cause the diseases. Diseases evolve greater aggressiveness if the disease and crop occur together over a long time. Continued breeding is always required to develop improved varieties.

The use of clean seed avoids the introduction of seed-borne diseases into fields. Seed testing laboratories can determine the level of infection in a seed lot. The test is usually run on a sample of 400 seeds. If none of those 400 seeds carries the disease, the result is reported as "none detected". This is not an absolute guarantee of disease-free seed. If only 1 in 1000 seeds were infected at recommended seeding rates for Laird lentils, there would still be more than 500 infected seeds per acre. This is still less of a risk than sowing 50,000 infected seeds per acre.

Many diseases overwinter and survive on crop residues. The sooner the residues are removed, or broken down, the sooner the disease source is eliminated. Ploughing residues under, or burning them speeds their breakdown. However, both methods substantially increase the risk of soil erosion. With no-till farming methods, there may be a higher and more prolonged risk of disease spread unless attention is paid to crop rotation.

For diseases that persist either in crop residue or in soil, crop rotations are a key to reducing risk. Each year between susceptible crops in the rotation reduces the likelihood of diseases being carried over from one crop to the next. For diseases that require the living crop for growth and reproduction, extended rotations can eliminate the source of disease. For diseases able to grow on either living or dead plant parts, rotations can reduce the level of disease. The length of rotation needed to break the disease cycle depends on both the disease organism and the management system. If the disease is dependent on crop residues, the tillage system, moisture and temperature determine the rate of residue decay, and thus the infective period. If the disease can live in the soil, longer rotations reduce the level of inoculum in the soil.

Some diseases are unique to a given crop, for instance, ascochyta blight of lentils. Each pulse crop has a unique ascochyta fungus disease. Other diseases such as sclerotinia stem rot infect a range of broad-leaved crops.

Expansion of pulse crop acreage increases the likelihood of disease development by increasing the number of fields where diseases can become established. For instance, spores of the fungus that cause anthracnose can travel in the wind on lentil chaff for roughly half a mile. Because of this, producers in a lentil-rich area are more at risk of disease than those who are relatively isolated from other lentil fields.

Sound Agronomy

Crops may be more susceptible to disease when they are weakened by poor weather, physical injury, pesticide treatment, or nutrient deficiency. A vigorous crop is a good defence against disease. All management decisions that influence crop vigour have an effect on the likelihood that the crop will withstand disease.

Whether a disease is severe or insignificant is often determined by the weather. It is possible to change the microclimate within the crop. Some practices reduce the persistence of moisture available within the crop canopy and, thus, reduce spread of the disease. Spring tillage reduces surface residues, and dries out the tilled layer of soil. It also dries and warms the soil and makes it more prone to erosion. Crops seeded at lower rates develop lighter canopies, or develop thick canopies later than those seeded at higher rates. The timing of seeding can be important in the spread of disease. For instance, if the only lentil seed available has a high level of ascochyta, some reduction of seed-to-seedling transmission may be obtained by seeding late as the seeds germinate and emerge quicker in warmer soils. This may create additional problems if late rains promote diseases at a later stage in the life cycle of the crop.

Weeds in a field can harbour diseases and create a thick canopy that favours disease spread. Insects in fields can cause damage that promotes invasion by disease organisms. Good weed and insect management reduce the risk of disease.

Some management practices can increase disease spread. All creatures and vehicles moving through the field, or from field to field, have the potential to spread disease. Activities, such as post-emergent harrowing, rolling, herbicide application, and field scouting increase the risk of disease spread if they are carried out when leaves are damp. If disease is suspected, vehicles and clothing should be washed before moving from an infected field to a healthy field. Overhead irrigation, or rain, at vulnerable stages can also increase the risk of disease.

Disease Control

Good disease prevention practices should reduce the need for treating disease. Suppression techniques are needed when other methods have not provided adequate control. Allowing diseases to proceed unchecked is risky. If weather cooperates, most diseases may be substantially reduced. However, with weather favourable to the disease, the disease can reduce yield, produce infected seeds and plant residues, and build up sources of infection which may cause problems for years. In extreme cases, aggressive disease control is necessary to reduce the spread of disease (e.g. seed growers with a newly introduced crop).

Biological Control

No biological controls are registered for the pulse diseases in western Canada. Viral diseases that are dependent on aphids for spread can be countered by attacks on the aphids. Ladybird beetles (ladybugs) are voracious aphid-eaters. Often, ladybug populations do not build up in time to provide adequate control of aphids.

Chemical Disease Control

Only six fungicides are registered for use in Saskatchewan pulse crops: three seed treatments and three foliar fungicides. Comments on each product are given here, but the user should always read and follow label instructions whenever fungicides are applied. Current information on the use of fungicides and the recommended rates is contained in the "Crop Protection Guides" published annually by Saskatchewan Agriculture and Food. Similar guides are available in Alberta and Manitoba.

Captan,Thiram, and Apron FL are registered seed treatments for peas and dry beans to control seed rots, seedling blights, or damping-off. Apron FL is also registered for use in chickpeas. Studies in Alberta and Saskatchewan have failed to show consistent advantages to treating pea seed with these products. There may be an advantage when the seed is planted into cool, wet soil. Crown is a registered lentil seed treatment for control of seed-borne ascochyta, as well as seedling blight and seed rot. It is also effective on seed-borne Botrytis.

Bravo is a foliar fungicide registered for control of anthracnose in lentils and ascochyta blight in lentils and chickpeas. Bravo does not cure infected plants, but protects plants from infection. It is effective only if used as the crop comes into flower, when symptoms are few and scattered or even before the detection of symptoms. Many producers apply Bravo too late to get maximum benefit. Once the diseases are widespread, fungicide application provides little benefit. A producer can determine the relative risk of disease by considering previous crops, the results obtained from seed test labs, and the relative risk in the geographic area. Cost/benefit ratio is greatest for pedigreed seed fields in years with a rainy period during the start of flowering. For instance, in southern Manitoba, anthracnose of lentils is very likely to develop, whereas in Saskatchewan, at present, it is not. However, nothing can replace careful inspection of a young crop on a frequent and regular basis.

Kumulus is registered for powdery mildew control in pea. Like Bravo, it is a protectant chemical rather than a cure for the disease. Benlate is registered for sclerotinia control in dry beans. Application at an early stage of the disease and good foliage coverage are necessary for disease control.

Irrigation

Not all pulse crops are suited to irrigated production. Faba beans, peas, and dry beans can be successfully produced under irrigation. Some lentil varieties can be produced with extreme care. Chickpeas are unsuitable for irrigation. In general, pulse crops are not tolerant of flooding. Most pulse crops have an indeterminate growth habit, and with sufficient moisture, plant growth will continue rather than seed production starting. Continuing vegetative growth assures that the crops will not mature within the limited Saskatchewan growing season. Lush vegetative growth provides an environment that fosters the development and spread of disease. Growers with experience in irrigation and in pulse production can succeed if care is taken to select appropriate varieties and to avoid overwatering.

Refer to *Chapter 4 - Table 4* for pea varieties recommended for irrigation.

In general, production recommendations follow those for dryland production, except that fertilizer requirements may be higher, crop maturity may be delayed, and disease management, especially for sclerotinia, is much more important. TABLE 16 gives a summary of irrigation recommendations. Risk is reduced by the use of disease-free seed and longer rotations to avoid disease carry-over. Seeding rates are generally lower, again, to reduce the spread of disease.

Irrigation before seeding is recommended if the seedbed is dry. Large seeded pulses require adequate moisture for germination, but are sensitive to waterlogging, cold soils, and seed rot. Irrigation between seeding and seedling emergence is not recommended. Over-irrigation during the vegetative stages can delay or prevent flowering in pulses with strongly indeterminate growth. The additional vegetative growth increases disease potential and lodging, and results in decreased yield. Irrigation to reduce moisture stress during flowering and early pod fill is necessary for maximum yield. In faba beans, irrigation can continue until the lower pods mature. In other pulses, extended irrigation will delay maturity. In general, irrigation should be discontinued at mid to late pod fill, often in late July or early August.

Harvest

Many pulse crops have an indeterminate growth habit, which means that they will continue to flower and produce pods until they are stopped by some stress. Plants may still be actively growing and flowering when the first pods are ripe, and ready to shatter. Harvest timing is a compromise between increased yield from the younger pods and increased losses from shattering of the older pods. The optimal time for harvest is usually before shattering losses occur, because young pods are at greater risk than the mature pods for weather, disease, and insect damage. If the weather is warm, windy or dry, the crop can mature very rapidly. Walking the field daily will improve the chances of the grower selecting the right time to harvest.

Complete crop dry-down is unlikely before the optimal harvest time for most pulse crops in most years. Crops often do not dry down uniformly in the field. Uniform, quick dry-down is generally accomplished by either swathing or the use of a desiccant.

Desiccation

Desiccation reduces the risks associated with swathing, such as wind movement of the swath and disease and sprouting of the crop in the swath. Standing, desiccated crops dry more

TABLE 16. Recommendations for Irrigated Pulse Production.

	Faba Beans	Peas	Lentils	Pinto Beans
Seeding Rate (lb/ac)	110 - 120	Variable	30 - 40 (Eston)	67
Target Plants/sq yd	25	72	80	35
Earliest Seeding Date	April 15	April 20	April 20	May 20
Moisture Use (in)	20	18	15	18
Critical Stage	Flowering	Flowering to mid-pod fill	Flowering to early pod fill	First 2 weeks, flowering to early pod fill
Discontinue Irrigation	August 12	Mid to late pod fill	3rd to 4th week of July	August 10
Rotation to Pulse	Minimum 2 year	Minimum 4 year	Minimum 4 year	Minimum 3 year
Rotation to Broadleaf Crop	Minimum 2 year	Minimum 4 year	Minimum 4 year	Minimum 3 year
Average Yield (lb/ac)	2500	2400	1500	1500

From SWC 1992, A.E. Slinkard, Personal Communication.

quickly after a rain than do swaths and generally retain better seed quality.

Two chemical products are registered for pre-harvest application: Reglone and glyphosate (Laredo, Roundup, Wrangler, Victor). **Glyphosate formulations are recommended for pre-harvest management of perennial weeds (see Weeds section of this chapter). This will reduce the amount of green material going into the combine, but glyphosate is not an effective desiccant.** The drying of the crop following glyphosate application is slow and inconsistent, and may not occur at all. In addition, early application can cause crop loss or residues that interfere with seed germination and seedling vigour.

Desiccants speed the drying of the crop, but do not speed maturation. If the desiccant is applied before the crop is mature, it will dry the foliage, but will not mature the seed. Desiccation is often used in dry green food peas to facilitate harvest at 20% seed moisture with minimal loss of the desired green colour.

Lentil crops are mature when the bottom 10 to 30% of the pods are brown and dry, but not split. Seeds in the bottom pods are hard and rattle in the pods. Pea crops are mature when seeds in the bottom pods are detached and loose in the pods, and when the upper pods are turning yellow. Bean crops are mature when 80 to 90% of the leaves have dropped off. In Saskatchewan, light frost often acts as a natural desiccant.

Reglone is registered for desiccation of lentil, pea, and dry bean crops. The optimal timing for use of Reglone is at 25 to 35% seed moisture. The crop usually can be harvested in 4 to 7 days. Seed and seedling quality are generally not affected. Both ground and aerial application are licensed.

Losses from wheel tracks can look substantial, but studies at Scott have indicated that high clearance, narrow tired, 60 ft sprayers cause on average 1% yield loss per wheel track.

Swathing and Straight Cutting

To avoid excessive shattering losses, pulse crops must be swathed or straight cut at the correct stage and seed moisture content. In general, pulse crops should be cut when the straw is "tough" to reduce crop losses (TABLE 17).

Rolling after seeding makes swathing or straight cutting easier since rolling levels the soil surface and pushes small stones into the ground, reducing damage to the cutterbar. Rolling after emergence is not recommended for chickpeas because of excessive crop damage, and it is unnecessary for faba beans.

Conventional swathers and straight cut headers are not designed to cut low growing pulse crops as the headers are unable to cut closer than about 3 inches from the soil surface and, therefore, miss the pods on the lower parts of the crop. Swather or straight cut header modifications can substantially improve the efficiency of the cutting operation and reduce seed losses. Suggested modifications to the system include header adjustments, use of a pickup reel, addition of vine lifter guards, and the use of a floating cutterbar.

Adjusting existing header flotation springs by adding additional springs to increase flotation, using a floating or flexible cutterbar, and addition of adjustable gauge wheels and poly skid plates will keep cutterbar damage to a minimum. Use a narrow swather or header on uneven terrain. The pickup reel substantially improves harvesting of pulses and should be used in combination with vine lifter guards. Proper adjustment of the pickup reel is important to obtain the maximum possible lifting action. This setting will differ considerably from the setting used for cereal crops. The cam action of the pickup reel should be adjusted so it has a positive lifting action and the reel should be positioned as far ahead of the cutterbar as possible.

Vine lifter guards greatly improve the swathing of lentil and pea by lifting the vines and pods up to the cutterbar (FIGURE 5).

The addition of rigid lifters can reduce lentil swathing loss from 5% to less than 1% compared to a swather without lifters and allows faster travel speeds. Rigid lifters (attached rigidly to the cutterbar) perform better over a wide range of operating conditions as they penetrate the soil to lift completely flattened vines. In contrast, skid lifters are hinged and allowed to float. When needed, growers modify them to ensure they do not float over the lowest vines and cause losses. In taller crops, longer and taller lifters perform better while shorter lifters perform best in short and medium height crops.

TABLE 17. Timing for Swathing and Combining Pulse Crops.

Crop Kind	Moisture Content	Colour of Crop Seed &/or Seed at Cutting Stage	Quick Test for Proper Moisture Content at Combining	Registered Desiccant	Other Important Notes
Dry Beans	16% for safe storage	For straight cutting of pinto beans with flex header and air reel; pods and vines should be dry and yellow. For undercutting, start at 50% buckskin stage.	Difficult to penetrate seed with thumbnail.	Yes	Weed control is critical for straight cutting of dry beans. Shattering losses are within acceptable limits if proper equipment is used.
Faba Beans	16% is dry and safe for storage	Swath when 25% of the plants in the field have the lower-most pods turning from green to black.	Thresh when bean can no longer be dented with thumbnail - 20% moisture content or lower. Overdry seed will shatter.	No	Faba bean pods turn black as they ripen. Because of the high moisture content of the plant, a fairly light swath should be laid to hasten dry-down.
Lentils	14 - 16% for short term storage, 14% is dry for long term	Swath when lower-most pods are tan coloured and rattle when shaken.	Thresh when seeds test 18% moisture content or lower. Overdry lentils (9 - 13%) are hard and difficult to bite.	Yes	Plants may still be green when pods are ripe. Crop typically matures in patches. Some shatter loss usually occurs.
Yellow Field Peas	16% dry and safe for storage	Swath when pods and vines are yellow coloured. Vines are prostrate.	Thresh when seeds are firm and can no longer be penetrated with thumbnail. 20% moisture content or lower.	Yes	Some shatter loss usually occurs. Mixing wet soil with pea seeds can cause earth-tagging - a down-grading factor.
Green Peas	Same as Yellow	Swath when peas are mature and have a good green colour. Pea vines are yellow coloured. If desiccating, apply when vein pattern of upper-most pods is easily recognized and 75 - 90% of the pods have turned to yellow tan.	Seeds are firm, but no longer penetrable with a thumbnail. Pea vines may or may not be prostrated depending on variety and conditions. Combine at 18 - 21% moisture and aerate for food grade, unbleached dry green seed.	Yes	2% bleached pea seeds is maximum. Bleached seeds are caused by high humidity, bright sunshine, and warm temperatures during final maturation stage.
Feed Peas	Same as Yellow. Some companies accept 17% moisture content.	Swath when pea vines are yellow coloured. Vines are often prostrate.	Seeds are firm, but no longer penetrable with a thumbnail. Combine settings and operation are not as critical for feed peas as for human food peas. Admixtures of various pea kinds are allowed.	Yes	Any amount of bleached, cracked, or split pea seeds, and earth-tagged pea seeds are accepted for feed peas.

FIGURE 5. Vine Lifters.

FIGURE 6. Knife Gumming.

Vine lifters should be spaced between 9 and 12 inches apart on the cutterbar. Wider spacing results in missed vines and spacing less than 9 inches causes plugging between the lifters. Lifters must be adjusted (shimmed) to match the angle of the guards so the tip of the lifter just touches the ground with the swather header fully lowered.

Pea and lentil plants often cause gumming due to the juice associated with cutting green plants and weeds and the presence of soil from cutting close to the ground (FIGURE 6). The buildup of gum on the cutterbar results in a decrease in clearance between the cutting surfaces of the knives and may add resistance to knife movement. In most pea and lentil fields, the knife must be removed and cleaned about every 10 hours to maintain cutting effectiveness and to avoid knife damage. A thorough brushing with soapy water every few hours may be adequate.

The direction travelled while cutting the crop can also make a difference to the effectiveness of the pickup reel and lifters, especially if the crop has a prevailing lean. Often it is advisable to cut the fields so that the cutting direction is perpendicular to the direction of crop lean as the lifters will then be more effective.

Threshing

Pulse crops are highly susceptible to mechanical damage from harvesting. This damage can be in the form of cracking, splitting, and germination damage.

Pulse crops should be handled gently to reduce seed damage. Cylinder or rotor speeds should be kept to a minimum with maximum concave clearance, especially with larger seeds.

Chaffer and cleaning sieves should be adjusted to the specifications required for each pulse crop. However, with all pulses the sieves should be adjusted to minimize tailings as re-threshing will increase cracking, splitting and germination damage.

High chaffer air flow can be used with all pulses, except lentils, as heavy seeds will not blow out of the back of the combine and this will result in a cleaner sample. Lentil seeds are flat (oval) and are easily blown out, so wind speed should be adjusted to allow maximum cleaning without seed loss.

Elevators should be properly adjusted as too loose an adjustment increases the chance of cracking seed. Combine unloading augers should be run full at a slow speed to minimize seed damage.

POST HARVEST

Drying and Storing

To reduce harvesting losses and maintain optimum quality, pulse crops are often harvested at moisture contents above the safe level for storage. As a result, pulse crops must be dried to preserve the quality of the product.

Research conducted by Sokhansanj showed that for safe storage pulses must be dried to less than 14% moisture content and cooled to less than 15°C for prolonged storage (TABLE 18).

TABLE 18. Number of Weeks for Safe Storage of Peas at the Specified Grain Moisture Content and Storage Temp.

Storage Temp. (°C)	Moisture Content (%) 12	14	16	18	21
25	31	16	7	4	2
20	55	28	13	7	4
15	100	50	20	12	6
10	200	95	38	20	21
5	370	175	70	39	20
Sokhansanj, 1995.					

Pea seeds at 18% moisture content can be stored for 20 weeks at 10°C, but only for 4 weeks at 25°C. Warm grain must be cooled immediately following binning, even when the moisture content is low. Cooling with an aeration system usually takes less than one day. However, in-bin drying with unheated air may take 3 or 4 weeks. The recommended airflow volume for bins is about 1 to 2 cubic feet of air per bushel per minute, or about 2000 to 4000 cubic feet per minute for a 2000 bushel bin.

The fan must be able to provide the required air flow by overcoming the resistance of the grain to airflow. The resistance of grain to air flow depends on grain size, with lower resistance for large seeds such as peas and beans, and higher resistance for smaller seeds such as lentils. At typical airflow rates, lentils have about 18% less resistance to airflow compared to wheat while peas have about 75% less resistance to airflow than wheat. Though airflow will be higher, the rate of drying depends on other factors including air temperature, humidity, and the rate of movement of moisture out of the seeds. As such, drying must be carefully monitored to prevent overdrying.

The aeration floor or perforated tube layout will affect the distribution of air through the bin. A fully perforated floor will provide more even air distribution compared to systems that only cover part of the floor area. Partial perforation systems may result in drying of the seed in one part of the bin and damp seed in other parts which can lead to storage problems. In addition, when pulses with high dockage are binned, the dockage concentrates in the centre of the bin and air flow is reduced in that area. This leads to a high localized concentration of moisture and problems with storage. Cleaning the seed prior to storage or using a distributor in the bin will help to reduce high local moisture concentrations.

Storing pulses in high moisture conditions can result in the crop absorbing moisture. Conversely, under dry conditions pulse crops lose moisture more readily than wheat or canola. As the climate in western Canada is primarily dry, stored pulses may dry to a percentage moisture that is likely to result in cracking or splitting in any subsequent handling process. The seed moisture should be checked prior to handling stored pulses and if too low, moisture can be added to the seed to reduce handling damage. Refer to PAMI report #704 Research Update: Moisturizing Pulses to Reduce Damage for information on raising the moisture content of pulses.

Mould growth can be a problem in the storage of pulses. Some micro-organisms will grow at relative humidities as low as 70% and at temperatures as low as -2°C. Using aeration in the winter should allow pulses to be cooled and reduce the relative humidity in the bin to safe levels.

Drying pulses with grain drying systems using heated air must be done with caution. Hot pulses are extremely susceptible to breakage in recirculating drying systems and while augering out of the dryer. The damage can be reduced by using low drying temperatures and cooling the seed prior to augering from the dryer. **Drying temperature should be limited to a maximum of 45°C and at moisture contents above 24% the maximum drying temperature should be 38 to 40°C.** Due to the slow drying process in pulses, drying from high moisture contents may require two or more separate drying operations to prevent cracking of the seed. If the pulse requires a reduction in moisture of 10%, the drying should take place in two or three passes through the dryer with a minimum of 8 hours between passes to allow the moisture in the seed to equalize. Larger seeds such as chickpeas and beans require 24 hours between drying operations.

If pulses are stored for extended periods, the seed should be cooled in the fall in stages until the entire bin is cooled to 0°C. In spring the pulse should be aerated in stages until the temperature is raised to about 10°C. In summer, the seed carried over should be periodically aerated during fair weather when the outside temperature is lower than the grain temperature. These measures prevent air currents and wet spots caused by the natural circulation of air and condensation within the bin.

Grain storage structures are designed for center loading and unloading. Off center loading and eccentric unloading cause large non symmetric pressures on the bin wall. These pressures induce bending forces on the bin wall that often lead to bin wall denting and collapse. FIGURE 7 shows two cases of unloading. In Case A, grain is unloaded uniformly from the center and the pressures are distributed evenly around the circumference of the bin. In Case B, the bin is being unloaded off-center. The result is a non uniform circumference load on the bin wall.

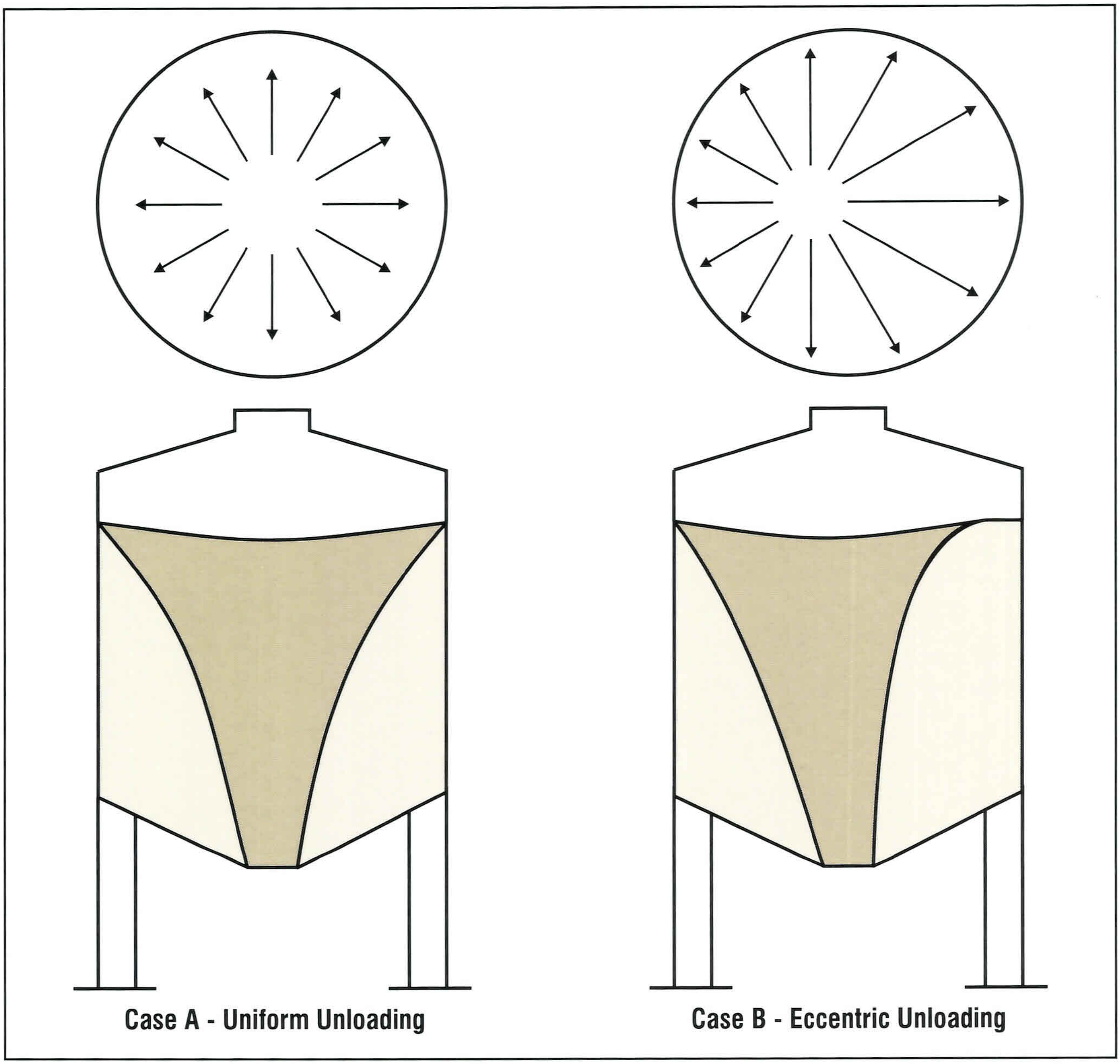

FIGURE 7. Bin Unloading and Loads on the Bin Wall.

Eccentric unloading can be caused by improper design of the unloading gate, caking and crusting of stored grain, or non-uniform flow within the bin caused by bean ladders or other obstructions. The use of bean ladders must be done in close consultation with the bin manufacturer. The following are a few points that must be considered to prevent bin failure due to eccentric unloading: (a) the bean ladder should not impede the free flow of grain; (b) provide stiffeners for the bin wall especially at the cone-cylinder junction and where the ladder is connected to the floor; (c) provide air vents to prevent moisture accumulation and possible crust development; (d) provide adequate support for the bean ladder; (e) minimize grain impurities; (f) check the bin periodically for moisture, temperature, and any grain shrinkage and possible consolidation; (g) seek professional engineering services for planning and installation of grain handling systems.

Handling

Damage to pulses during handling and processing can significantly reduce the grade and value of the crop. In addition, non-visible damage can occur with pulses that can significantly affect germination of the seed.

Pulse crops are very fragile and are extremely susceptible to injury at low moisture levels. However, mechanical injury can also occur at moisture levels normally considered safe.

As a general principle, pulse crops should be handled as little as possible and with great care to reduce damage. Mechanical damage is much higher with dry seed. Raising the moisture content of the seed combined with the proper operation of equipment and/or using specialized conveying equipment can be used to minimize damage.

The type of conveyor can substantially reduce seed damage. With both lentil and pea crops, damage was at least double with a typical steel flighting auger compared to paddle, bristle flighting and belt conveyors (FIGURES 8 and 9).

Dropping of the seed from conveyors is another source of pulse damage. Augers should be adjusted to minimize drop height of the seed. When the pulse seed must drop long distances, such as in processing plants, bean ladders should be used to slow down and soften the impact of the seed. Bean ladders are devices attached to the end of conveying systems which direct the seed in a zig zag direction to reduce velocity and reduce impact damage to the seed. The bottom of the bean ladder must be far enough above the bin clean-out that the bin contents empty in a symmetrical and unimpeded manner. Any asymmetrical flow of seed during bin emptying may result in warping and bursting of the bin.

Seed Cleaning and Grading

Seed cleaning involves removal of undesirable particles from a grain lot. Grading, on the other hand, involves classifying the grain into its different grades usually based on kernel quality. Pulse grading follows the cleaning operation usually in one cycle.

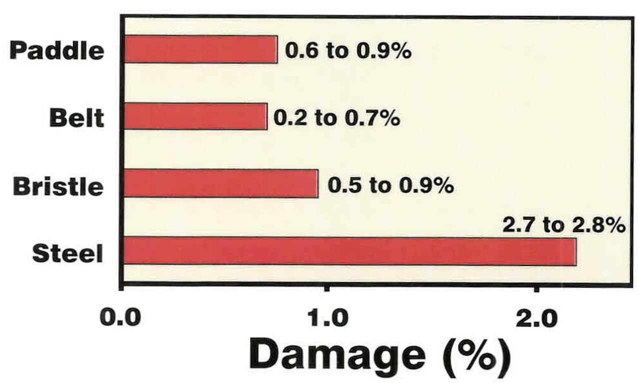

FIGURE 8. Lentil Damage.

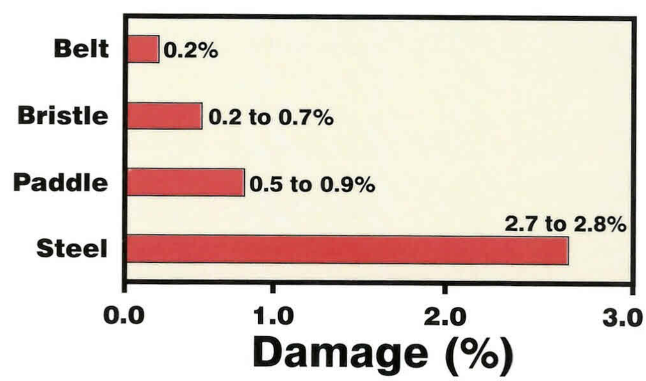

FIGURE 9. Pea Damage.

Conventional cleaning equipment operates based on physical characteristics of the seed. Air classification is used to separate the components of a mixture of seed and its undesirable contents based on density (or specific gravity). When we compare the density of a particle to that of water, we call it the specific gravity of the particle and it means how much the seed is heavier or lighter than water.

Seed cleaning is also done based on the kernel's length, width, or thickness. Length is the longest dimension, width is the intermediate dimension, and thickness is the smallest thickness. Wheat has a clear dimension to it whereas peas are recognized by one dimension (diameter) or lentils can be recognized by two dimensions (diameter and thickness). In practice sieves with round holes are used to separate seeds for their width, slotted holes are used to separate seeds based on their thickness and indents are used to separate seeds based upon their length.

Other devices are used to separate seeds based on a combination of properties or more unconventional properties. For example gravity tables are used to clean and grade seeds based on their shape, density, size, and surface characteristics. Color sorters are used to separate the seeds based on their color reflecting property. Velvet rolls or belts are used to sort seeds based on surface texture of the particles and spirals sort seeds based on their friction and rolling characteristics. TABLE 19 lists some physical properties that are important in the selection of equipment for seed cleaning and grading.

FIGURES 10 and 11 show two sequences which are used to clean peas and lentils. Both sequences start with a scalper aspirator to remove large unwanted trash and fines. The scalpers work based on the overall size of the seed and airflow. This pre cleaning makes the workings of the subsequent machines easier.

Air screen machines also work based upon seed size and airflow, but the motion of the mix through the machine is more precisely controlled. There may be several sieves required for a complete clean out of the seed. Peas might be completely cleaned on these machines. Disc separators and indent cylinders are more precise machines than the previous one. They separate and grade seeds based on their lengths. Disk separators and indent cylinders can be adjusted in many ways and with a proper adjustment, a high degree of cleaning can be expected.

Contaminants in a lot that have a size similar to the seed but are of different specific gravity can be separated on a gravity table. the seed mixture is fed onto a perforated table. The air blowing through perforations keeps the mixture fluidized while an oscillating/vibrating motion stratifies the material and separates the heavy seeds from light ones. The material is divided into several fractions and, each individually collected at the other end or at the side of table. Gravity tables are quite versatile machines but require experienced operators to run at their peak efficiency. At least nine variables can be adjusted in a well designed gravity table. The most important variables are degree of oscillations; rate of vibration; air flow; slope and direction of the deck; decking configuration and decking material; number of output spouts, loading rate on the deck, and the location of the unloading dividers.

Color sorters are used as final equipment to separate seeds based on their reflective (color) characteristics. In these devices the seed is fed into the machine in single file (or channel). One or a series of light diodes emit a filtered light onto the seed as the seed passes through the detector ring. The reflected light from the seed is compared electronically to the reflected light from a reference plate. The seed is ejected from the stream by a mechanical means if its reflected light is different from the reference. The mechanical ejector is usually a pressurized air nozzle and may pulsate at a maximum rate of 70 ejections per second. The amount of air per ejector may be as much as 0.75 cubic feet per minute.

Factors that affect the operation of a color sorter are: loading rate; i.e. the rate seed flows against the sensor light; electronic settings; ambient light (or background light); dust accumulation on lights and reflector plates; vibrations, type and degree of discoloration on the seed. The capacity of color sorters can be increased by adding channels and the size of a channel controls the grain size. For larger seeds such as Laird lentil rollers are used to guide the seed through the detector ring. Slider channels are used for small seeds.

TABLE 19. Physical Characteristics of Commonly Grown Pulses on Prairies.

Pulse	1000-Seed Mass (g)	Specific Gravity	Bulk Density lb/bu	Porosity Fraction (mm)	Length (mm)	Thickness (mm)	Spherical Equivalent Diameter (mm)	Sphericity Fraction
Desi Chickpea	248	1.25	61.9	0.38	8.7	7.0	6.3-9.7	0.88
Field Pea	219	1.27	65.6	0.37	7.6	6.8	6.5-7.9	0.99
Laird Lentil	70	1.43	60.7	0.47	7.0	2.8	6.3-7.4	0.73
Eston Lentil	33	1.40	61.0	0.45	4.8	2.5	4.1-4.9	0.78

Source: Agricultural and Bioresource Engineering, University of Saskatchewan

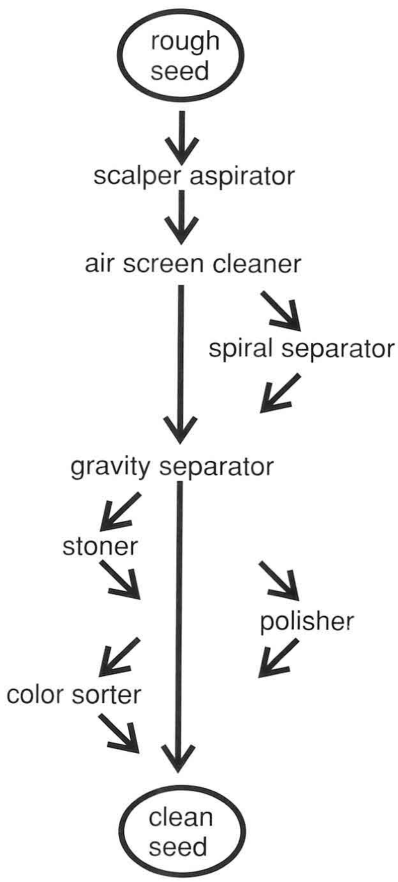

FIGURE 10. Sequence for Cleaning and Sorting Peas and Beans.

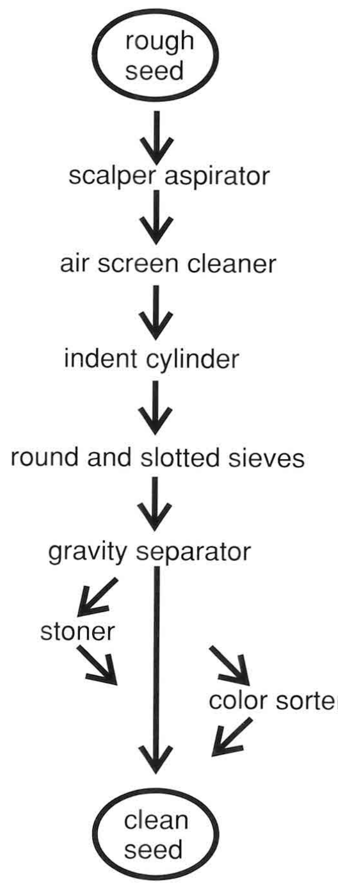

FIGURE 11. Sequence for Cleaning and Sorting for Cleaning Lentils.

Land Management

Peas, dry beans, lentils, and chickpeas leave very little plant residue. After harvest, fields without plant cover are at higher risk from erosion. Responsible soil management includes some provision for reducing the erosion risk on susceptible land. If moisture is adequate and the season sufficiently long, fall-seeded cover crops may be beneficial. Cover crops of wheat, barley, or oat are usually seeded at reduced rates (e.g. 1 bu/ac) and achieve sufficient growth to provide cover before being killed by fall frosts.

Wind barriers can reduce wind erosion. Field shelterbelts effectively reduce wind speeds for approximately 700 ft. Annual strips (taller crops, seeded in rows 50 to 60 ft apart) can be used to reduce wind speeds in the crop, and to trap snow over winter (FIGURE 12). Strip cropping can be effective in reducing field size and, therefore, the exposed land area.

FIGURE 12. Use of Annual Barriers to Reduce Erosion and Trap Snow.

Quick Tips - Lentils

Seeding Rate:	Variable, depending on seed size. Target 12 plants per square foot (40 lb/ac Eston; 80 lb/ac Laird).
Seeding Depth:	1.5 to 3 inches.
Seeding Date:	Mid-April to early May.
Recommended Varieties:	Laird is standard. CDC Richlea and Eston are highest yielding. Eston for irrigation. Indianhead for green manure. CDC Redwing is ascochyta resistant.
Best Performance:	Cereal stubble on Dark Brown soils.
Rolling:	Up to 5 node stage.
Registered Herbicides & Registered Fungicides:	Refer to Table 13, pages 2-23 and 2-24 or the Saskatchewan Agriculture and Food Crop Protection Guide.
Rotational Frequency of Lentil Production for Disease Control:	4 to 5 years for anthracnose; 3 to 4 years for ascochyta.
Swathing or Desiccation:	1/3 of bottom pods turn yellow to brown and seeds rattle when pods are shaken.
Direct Harvesting:	16 to 22% seed moisture.
Storage Moisture:	14%.

Chapter 3

Lentil Production

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Chapter 3

Lentil Production

INTRODUCTION

Lentils were one of the earliest cultivated crops in the world. Archeological investigation has shown that they have been grown since the early stone age. India leads the world in lentil production, and most of the lentils are consumed by India and its neighbours. The Palouse area of Washington and Idaho was the main area of lentil production in North America, but since Canada began production in 1969, Canada and Turkey are the largest lentil exporters in the world. Saskatchewan produces about 90% of the Canadian lentil crop and the rest is produced in Alberta and Manitoba.

Historically, lentils were widely used in India, Southwest Asia, and the Mediterranean areas in the form of split lentil (dhal) and it is still used as an important source of dietary protein in these areas. Lentil contains approximately 25% protein, and is high in fibre, Vitamin A, calcium, starch, iron, phosphorus, copper and manganese. While the lentil seed is used mainly as food, the straw can also be used as a high quality animal feed or as a source of organic material for soil improvement.

Lentil production provides a number of advantages to producers. It can be used to diversify and lengthen crop rotations which reduces disease pressure in other crops and has weed control advantages. Lentils also improve soil tilth and reduce the requirement for nitrogen fertilizer.

Lentil prices vary, but net returns are often higher than those obtained from wheat. On the prairies, lentil yields range between 450 and 2500 lb/ac, with an average yield of about 1000 lb/ac.

THE LENTIL PLANT

Lentils are classified into two groups by seed size. The large seeded Chilean type has a seed size which averages 50 grams or more per 1000 seeds. The small seeded Persian type has a seed size which average 40 grams or less per 1000 seeds. For both types of lentils, the seeds are lens-shaped which is the source of the name lentil. Seed coat colours range from clear to green, brown, grey, blotched purple or black. The cotyledons can be yellow, red, or green (FIGURE 1).

The lentil seeds remain under the ground after germination. This offers some protection to the young seedling. If the main shoot is damaged above ground by a late spring frost, heat canker, or Sencor (metribuzin) burnoff, the plant can regrow from buds (at the second scale node) below ground. Under good growing conditions, the lentil seedling produces a new node every 4 days. The first two very small nodes are known as scale nodes (FIGURE 2).

Lentil plants are typically short, but with variations in crop conditions and variety, heights range from 8 to 30 inches.

Early maturing varieties like Eston flower at about the 11th or 12th node stage. Later maturing types like Laird flower at the 13th or 14th node stage. Flowers are self-pollinated so they do not require insects for pollination or seed formation. The flowers are borne on short flower stalks at the base of the upper leaves in clusters of 2 to 3 flowers per flower stalk. The first few flower clusters on the main stem often shrivel without seed formation (flower abortion). This is especially likely to occur if conditions favour vegetative growth over seed production such as occurs with good moisture and high nitrogen fertility. **Lentil plants have an indeterminate growth habit. Plants continue to flower until they encounter some form of stress, such as drought, heat, frost, nitrogen deficiency, mechanical damage, or chemical desiccation.** Seed pods are small, usually less than 1 inch long, and generally contain 1 or 2 seeds. Vigorously growing lentil plants with adequate space will produce two or more primary shoots from the base of the stem. However, the main contribution to seed yield is made by secondary (aerial) branches that arise from the uppermost nodes of the main stem just below the first flowering

Lentil

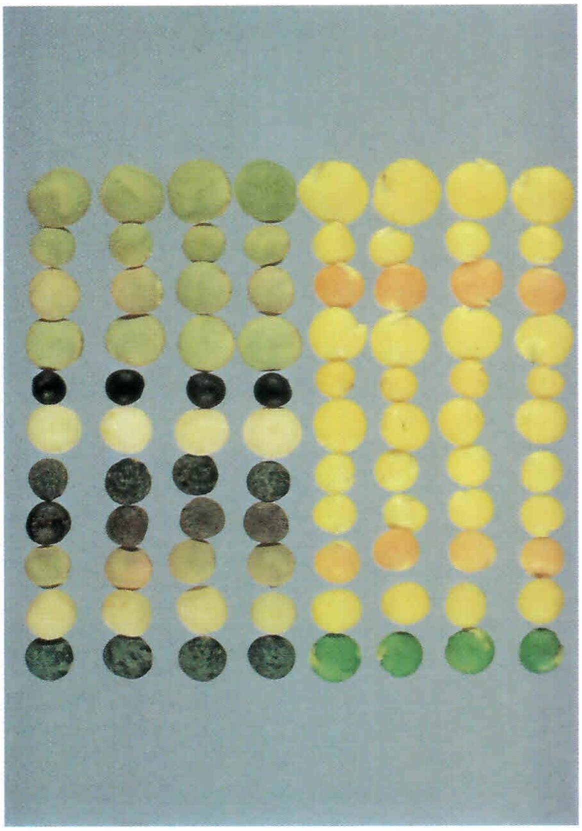

FIGURE 1. Lentil Seed With and Without Seed Coat.

node. There may be up to five aerial branches per main stem. When growing conditions are suitable for an extremely high yield, the secondary branches also produce additional seed bearing branches.

ADAPTATION

Lentils perform best on level or slightly rolling land at a soil pH of 6.0 to 8.0. **Lentil plants do not do well on waterlogged soils and will not tolerate flooding or salinity. Although lentils are somewhat drought tolerant, they do require at least moderate moisture (6 to 10 inches) during the growing season to produce a full seed set.** Excess moisture before the plant is in full bloom can delay and reduce seed set, and excess moisture near the time of harvest encourages the spread of fungal diseases. Lentil plants are short and must be cut near the soil surface, so fields should be free of surface stones and dirt lumps. To obtain the best surface possible, a land roller is used to smooth the soil surface. **Lentil seedlings are tolerant of light frost (-4°C), and can regrow from below the soil surface if early frost damage is severe.** Frost in late summer or early fall will damage young pods and immature seeds.

In the Brown soil zone, lentil performance is best on fallow on medium to fine textured soils, or when grown under irrigation. If lentils are grown on cereal stubble in the Brown soil zone, yields will average slightly less than 600 lb/ac. However, stubble yields of lentils at Agriculture

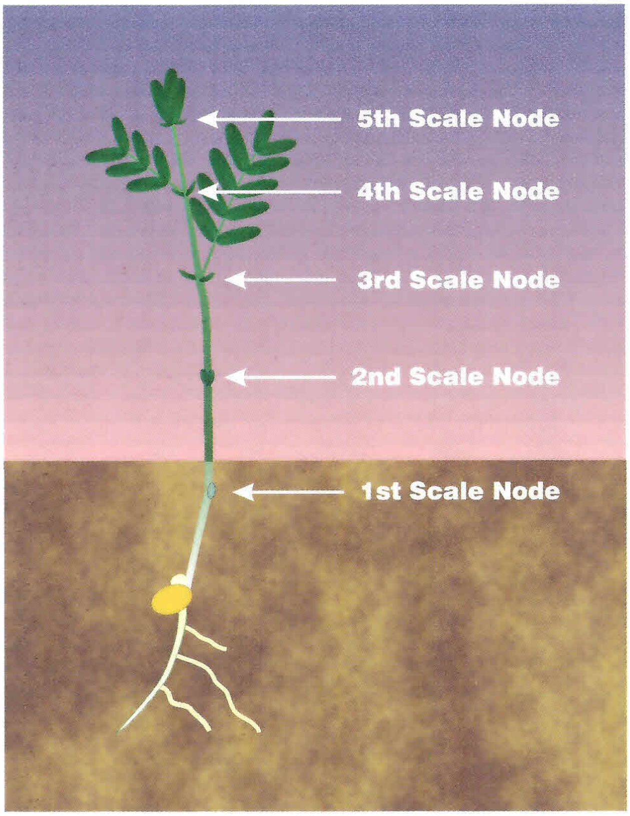

FIGURE 2. Lentil Growth Stages.

Canada Swift Current from 1979 to 1994 averaged 971 lb/ac, ranging from a low of 0 in 1980 to a high of 1898 lb/ac in 1991.

In Dark Brown, moist Dark Brown, and Thin Black soils, lentils generally can be grown successfully on stubble with good soil moisture reserves. Lentil yield on stubble in the Dark Brown and moist Dark Brown soil zone averages about 90% of the yield of lentils grown on fallow. In contrast, stubble-seeded wheat may yield only about 75% of fallow-seeded wheat. This efficient use of available moisture and nutrients make lentils very suitable as a stubble crop in the Dark Brown and moist Dark Brown soil zone.

Moist Black and Grey soils are often too wet for consistent production of high quality lentils as excess moisture aggravates disease problems and delays maturity. The growing season is often not long enough for production of later maturing varieties such as Laird in these areas.

FIELD HISTORY

Field history is an important consideration in field selection for lentils (see *Chapter 2 - Field History*). If there is reason to believe there may be active residual herbicide which could be harmful, a test plot should be sown the year before lentils are planted. The plot should be grown to maturity to ensure there are no late season herbicide effects on yield or crop quality. **In rotation, lentils should not follow lentils as this frequently results in a severe infection of ascochyta blight.** Sclerotinia and volunteer crops may be a problem if lentils follow peas, faba beans, sunflowers, canola, or mustard. Fields free of Canada thistle or perennial sow-thistle offer the best probability of success as lentils compete poorly with these weeds and effective herbicide control methods are not available.

Lentils fit well into a direct seeding crop production system. Lentil seedlings can emerge through cereal crop residue because of the large seed size and high seedling vigour. **If lentils are direct seeded into stubble, the match of lentils to the previous crop is important.** Volunteer canola or mustard may be difficult to control in some years. Volunteer cereals such as barley or durum are difficult to separate from large-seeded lentils during the cleaning process and must be controlled in the field. Likewise, small-seeded lentils are difficult to separate from red spring wheat. If the two crops cannot be separated, lentil grade can be severely reduced. In areas where Anthracnose is widespread, avoid seeding lentils next to other lentil fields or lentil stubble to avoid the possibility of disease transfer in wind-blown dust. In areas where ascochyta is the main risk, avoid lentil fields and lentil stubble. A buffer strip of cereal at least 50 feet wide between a lentil stubble field and a new lentil planting will delay the rate and onset of ascochyta spread from the lentil stubble.

VARIETIES

The first lentils grown commercially in Canada were common Chilean, an unregistered type from the United States. Small quantities of other unregistered types are still grown in Canada, primarily common Chilean, Spanish brown and French green or dark speckled.

All registered varieties in Canada were introduced or developed by Dr. Al Slinkard of the Crop Development Centre in Saskatoon (TABLES 1 and 2). **More than 80% of the lentils grown in Canada today are the variety "Laird" which has extra large seeds that suit the quality preferences of many international markets.** Laird has a strongly indeterminate growth habit and in cool moist areas, it may continue to grow late into the season. This thick vegetative growth and late maturity provides an excellent environment for the development of disease, particularly in moist weather. **As a result, Laird is better suited to drier production areas which have longer growing seasons.**

Eston makes up a further 10 to 15% of the Canadian production of lentil. Eston is a small-seeded lentil. It is less indeterminate and earlier maturing than Laird, and performs better in moist conditions. When affected by drought conditions, however, the plants may be too short to harvest. Eston lentils are especially suited to markets where a firm cooked seed is important as they remain intact after cooking.

CDC Redwing has red seeds and pale green seed coats and is intended for the red, split lentil, markets. CDC Redwing is ascochyta resistant. CDC Richlea has a seed size between Laird and Eston, and generally outyields Eston. CDC Gold

TABLE 1. Market Characteristics of Varieties.

Variety	Year of Introduction	Type	g/1000 Seed	Cotyledon Colour	Seed Coat Colour	Market Niche
Laird	1978	food	60 - 70	yellow	pale green to beige	industry standard
Eston	1980	food	35 - 40	yellow	pale green with some flecks	small, retains shape
Indianhead	1986	green manure	25 - 30	yellow	black	N-fixation
CDC Richlea	1992	food	50 - 55	yellow	pale green	yield
CDC Gold	1993	food	45 - 50	yellow	white to clear	seed coat does not darken
CDC Matador	1995	food	30 - 35	yellow	brown, flecked	spanish type
CDC Redwing	1995	food	35 - 40	red	pale green	red split
CDC Royale	1996	food	35 - 40	green	blue-green, flecked	green split

TABLE 2. Agronomic Characteristics of Varieties.

Cultivar	Yield (% of Laird)	Seeding Rate (lb/ac)	Height (in)	Days to First Flower	Maturity Rating	Ascochyta Resistance
Laird	100	80 - 90	16	53	late	no
Eston	117	40 - 45	12	48	early	no
Indianhead	98	30 - 40	16	57	late	yes
CDC Richlea	117	55 - 60	14	50	medium	no
CDC Gold	70	55 - 60	15	52	medium	no
CDC Matador	118	35 - 40	14	50	medium	yes
CDC Redwing	98	40 - 45	14	49	medium	yes
CDC Royale	117*	40 - 45	13	49	medium	no

*Limited data. Tested in 1993 and 1994.

is a premium quality, zero tannin lentil, with yellow seeds and a thin white to translucent seed coat. The tannin-free seed coat makes the seed especially suitable for cooking as the cooked lentils and broth will retain their light colour. The lack of tannins, however, makes the seed more susceptible to fungal seed diseases since tannins inhibit these diseases. As a result, zero tannin varieties usually can not be successfully grown without fungicide treatment of the seed. CDC Royale is a niche market type with green cotyledons.

Indianhead is a black-seeded lentil used as a green manure or plowdown crop. It is seeded at 30 to 35 lb/ac and will produce seed, if seeded early and if drought stress occurs in July and August. To use it as a green manure, it is generally seeded in mid to late May to avoid seed production, and the plants are killed with 2,4-D herbicide or by cultivation when flowering begins. Either herbicides or a high residue retention method of cultivation helps to protect the soil from erosion and provides for greater snow-trap capability. Indianhead lentil does not add as much nitrogen to the soil as a plowdown of peas or faba beans, but it can be a cost effective alternative as the small seed size makes it relatively inexpensive to grow.

CROP MANAGEMENT

Seeding Considerations

Lentil production success is highly dependent on the quality of the seed used (see *Chapter 2 - Seed Quality*). **Lentil seeds are susceptible to mechanical damage during harvesting, handling, storage, and seeding.** Mechanical damage and herbicide misuse in the parent crop can reduce both germination and seedling vigour. Lentil diseases can also be spread by infected seed. To avoid potential problems, it is best to have seed tested for germination, seedling vigour, weed seed contamination and seed-borne ascochyta blight infection.

Dry lentil seed (14% or less seed moisture) is very brittle and difficult to handle without cracking and splitting the seed so **all handling should be done as gently as possible** (see *Chapter 2 - Handling*). Even nearly invisible seed cracks can result in a reduction in germination.

Seed treatment of lentils for fungal diseases is generally not recommended, except for the zero tannin lentil varieties. Crown (carbathiin and thiabendazole) is registered for control of seedling blight, seed rot, and seed-borne ascochyta infection in lentil. Crown is safe to use with inoculants.

Inoculation

Successfully inoculated lentil plants can fix up to 79% of the nitrogen required by the crop. Inoculation of lentils with the lentil strain of *Rhizobium* is necessary to ensure nodulation (see *Chapter 2 - Inoculation*). Since the *Rhizobium* is a living bacteria, it must be handled carefully to ensure it stays alive. Single strain inoculant products contain *Rhizobium* ideally suited to one crop (e.g. lentils), whereas mixed strain products contain *Rhizobium* suitable for a number of crops (e.g. lentils and peas). In general, single strain products are more efficient and more cost effective than mixed strains. Inoculants cannot be relied on after the expiry date and should be refrigerated if not used immediately. Four basic types of inoculant are available: peat based, liquid, self-sticking, and granular. Generally, liquid-based products are more convenient to apply and more costly than peat-based products. The liquid products are also more susceptible to damage from environmental extremes prior to seeding than peat-based inoculants. **An application rate of 1 lb of peat-based inoculant to 300 lb of lentil seed is adequate under good growing conditions.** Milk powder sticker is often applied at a rate of 1 lb of sticker to 0.4 gal of water for treatment of 600 lb of lentil seed. Commercial stickers are also available.

Fertilization

Fertilizer requirements are best determined by soil testing (see *Chapter 2 - Fertilization*). Nitrogen supplied by the *Rhizobium* can meet up to 75% of the nitrogen required by the lentil plant. Additional fertilizer nitrogen may be required if the level of available soil nitrogen is less than 15 lb N per acre in the top foot. **If nitrogen is applied, it should not be placed with the seed as crop injury may occur.** It may be applied prior to seeding or side banded with openers which provide adequate separation between the seed and fertilizer during seeding. **Excess**

nitrogen encourages excess plant growth and reduces seed production.

Recommended levels of phosphorus based on soil tests should be applied as phosphate. Lentil seedlings are moderately tolerant of seed placed phosphate. If 20 lb (30 lb 12-51-0) per acre or less is required, it may be applied with the seed. Larger amounts should be side banded during seeding as other methods of applying phosphate are inefficient at supplying that year's crop. Phosphorus fertilizer close to the seed often results in a pop-up effect where the seedlings emerge more quickly and are more vigorous. Provide, a microbial inoculant, can also be used as a means of increasing phosphorus availability. It is applied as a seed treatment and should be used in conjunction with phosphate fertilizer. It may supply some of the phosphate requirements for lentil and may be particularly useful if more than 30 lb/ac of phosphate is required, as it can be seed placed and boost phosphate availability without crop damage.

Several other nutrients, including potassium, sulphur and micronutrients, are required by lentils, but their availability is usually adequate so they do not normally limit yield. Soil tests are recommended if a problem is anticipated.

Time of Seeding

Lentil seedlings tolerate light frosts and can even regrow after severe frost. This allows for early seeding which usually results in the best yields and quality. **Seeding can begin when the top inch of the soil reaches 5°C, providing it is not excessively wet.** This generally occurs in mid April to early May. Early seeding increases plant height and the height of the lowest pods. Higher pods are desirable as they are easier to swath and they stay cleaner which helps to maintain a higher grade. In most years seeding may be delayed in southern areas to as late as May 25 for Laird or June 10 for Eston, though late seedings rarely yield as well as early seedings.

Plant development may be more rapid for plants that are seeded later because of warmer growing conditions and longer days during early growth. Early maturing varieties may be able to nearly "catch up" with plants seeded at an earlier date, but late maturing varieties generally will not. The rate of plant growth and development generally increases with daily maximum temperatures up to about 27°C after which heat stress starts reducing growth rate.

Seeding Rate

Recommended seeding rates are based on a seed spacing of 18 seeds per yard of row, with rows 6 inches apart, or 108 seeds per square yard. **This seeding rate requires an average of 40 lb/ac of seed for Eston and 80 lb/ac of seed for Laird. Seeding equipment should be calibrated using inoculated seed as the inoculant may reduce the flow rate through the metering system.** Seeding rates should be adjusted for germination (see *Chapter 2 - Seeding Rate*), as lower than recommended plant numbers will severely reduce the already weak competitive ability of the lentil seedlings. Lentil yields are often lower at lower seeding rates.

Higher than recommended seeding rates are often used as a hedge against expected losses. For instance, if harrowing is planned as an early season weed control measure and plant losses of 15% are anticipated, then a 15% boost in seeding rate will help offset these losses.

Seeding

Seeding can be done with any type of seeder, including hoe drills, disc drills, discers and air seeders. **When using air seeders, caution is advised as seed damage may occur if the seed is too dry (below 14%) or if the air velocity in the distribution system is too great.** The lowest possible air speed that avoids line plugging should be used (see *Chapter 2 - Seeding*). Laird is more prone to seed damage than Eston. Lentil seed damage during handling and seeding due to dry seed can be reduced by adding water to the seed in an auger. Refer to PAMI Research Update #704 for more information on lentil moisturizing.

Lentil seedlings can emerge from relatively deep seeding because the seeds are large, but large seeds are also prone to drying out. A seeding depth of 1.5 to 3.5 inches is advised. If Sencor (metribuzin) is to be used, the crop should be seeded more than 2 inches deep to minimize possible herbicide injury to the seedlings. If the soil is not waterlogged, it should be firmly packed to ensure good soil contact with the seed. Avoid overpacking in wet soils. If the seedbed is very wet, delaying packing and rolling for a day allows the seed to absorb the oxygen it requires. Letting a wet clay soil dry slightly will also help prevent surface crusting. Harrowing or further packing after seeding is not needed if seeders with on-row packing are used, but rolling will be required to smooth the surface. Seeding with discers or air seeders without packer wheels should be followed by harrowing and packing to level and firm the soil, and this should then be followed by rolling. Lentil seeds germinate quickly so harrow packing and rolling should be completed very soon after seeding.

Intercropping

Researchers in North Dakota have found that intercropping flax and lentils (growing both together in the same field) can increase the harvestability of lentils. It increases the height of the pods above the ground and reduces lodging. Lentil yield will be reduced by the flax, but the yield of lentils plus flax is usually about the same as for either crop grown alone. **However, the results of intercropping flax and lentils are too variable for the practise to be recommended to Saskatchewan growers.**

In-Crop Considerations

Rolling

Lentil plants are harvested close to the ground, so a smooth and level ground surface is desirable (see *Chapter 2 - Rolling*). **A light to medium land roller can be used successfully between seeding and up to the 5th node stage of the lentil.** Rolling a wet clay soil before plant emergence can cause crusting and may delay or reduce emergence. Later rolling can damage stems, crimp aerial branches, and may result in yield reductions from 5% at the 5 to 7 node stage to 15% at the 11 to 13 node stage.

The following study conducted in Saskatchewan by Whatley with Laird lentils showed yield reductions from rolling after the 5 to 7 node stage (TABLE 3). Late rolling resulted in yield losses of 15% due to breakage of main stems and crimping of aerial branches.

TABLE 3. Effect of Post Emergent Land Rolling on Laird Lentil Seed Yield.

Node Stage	Percent of Check
5 to 7	100
8 to 10	95
11 to 13	85

Rolling when the crop is damp from rain or heavy dew can speed up the spread of ascochyta blight. Rolling may damage and weaken the lentil seedlings, so rolling and herbicide application should not follow each other too closely. A minimum of 2 days between operations will allow the crop to recover. Likewise, rolling should not follow immediately after a frost. The major benefit to rolling is to allow for easier swathing or direct combining with reduced damage to the guards, sickle sections and combine from stones and dirt.

Weeds

Lentils are a short crop with a sparse crop canopy which makes them a poor competitor with most weeds. Yield losses due to weeds can be severe, and lentils are susceptible to weed problems that may not be important in other crops (TABLE 4). For instance, a low growing weed, such as wild tomato or round-leaf mallow, in a wheat or barley crop may not be cause for concern. **In a lentil crop, the competitive effect of these types of weeds can be severe, and no herbicides are available to control them.** These low growing weeds can dramatically interfere with harvest. Wild tomato produces an abundance of juicy fruit that can be crushed during threshing and may stick dirt to the combine and to the lentil seed.

TABLE 4. The Effect of Weeds on Lentil Yield.

Weed	Weed Free Lentil Yield	Lentil Yield with Weed Competition	Yield Loss
Wild Oat (125/yd^2)[a]	2000 lb/ac	520 lb/ac	74%
Green Foxtail (250/yd^2)[b]	2640 lb/ac	1850 lb/ac	30%
Wild Tomato (418/yd^2)[c]	1280 lb/ac	490 lb/ac	62%

Source: [a]Slinkard et al. 1988; [b]Douglas 1994; [c]Pastl 1994

Good weed management depends on a strategy that considers all of the interrelated conditions of the crop production system and the entire crop rotation in the field rather than simply the lentil crop. Techniques for effective weed control (*Chapter 2 - Weeds*) are applicable to lentils.

Post-emergent harrowing with a tine harrow can be used for weed control in lentil crops when the crop is in the seedling stage (no more than 4 inches tall), providing the foliage is dry and the work is done on a hot sunny day. There will be some plant losses, but these can be offset by using higher seeding rates.

The number of herbicides available for use in lentils is quite limited, compared to those available for many other field crops. Although herbicides registered for use in lentils control a number of common weeds, not all broadleaf weeds can be controlled. Controlling only some of the weeds in a field may not be economical. In all cases, a producer must decide if a weed problem is of economic concern or only a cosmetic problem before choosing a control method.

Chapter 2 - Weeds **includes a listing of the herbicides registered for use in lentils.** Some specific cautions with respect to herbicide use in lentils follow. The general cautions provided in *Chapter 2* and all label instructions, cautions, and recommendations should also be followed.

Lentil plants are tolerant of Hoe-Grass (diclofop methyl) at all stages of growth except during hot, humid weather when leaf cupping and some leaf burn may occur after application.

Poast (sethoxydim) can be expected to suppress quackgrass for 6 to 8 weeks, but in a weakly competitive crop like lentil, some re-growth may occur prior to harvest.

Caution must be used in applying Sencor (metribuzin) to lentils. It should not be used if the lentils are seeded less than 2 inches deep or on soil that has less than 4% organic matter. Sencor can cause significant crop injury if the lentil seedlings have fewer than 2 nodes or more than 5 nodes at the time of application, but a split application of Sencor (1/2 to 2/3 rate at the cotyledon to 2-leaf stage of the weed and 1/2 rate about 10 to 14 days later if needed) reduces the risk of crop damage and increases the effectiveness of Sencor. **A full rate of Sencor applied on a hot day to lentil plants at the 6-node stage will burn the leaves off.** Label instructions must also be followed carefully to avoid crop injury when Sencor is used in a tank-mix with fall applied liquid Treflan. A second metribuzin formulation, Lexone, is not licensed as a tank mix with Treflan and it has a number of different use restrictions which differ from the Sencor label restrictions.

Only fall applications of trifluralin products (Advance, Rival, Bonanza 10G, Treflan) are recommended for lentils as spring application can result in crop injury, delayed seeding, and because of incorporation tillage, a dried out seed bed. These herbicides should not be used on land where there is a severe risk of soil erosion as the extra tillage for incorporation and low levels of residue from lentil production can aggravate the problem. Deep seeding or environmental factors which delay seedling emergence increase the risk of crop injury from these products and may result in stand thinning, delayed maturity, and reduced yield. **Although not registered for this use, studies at Scott and Indian Head using surface applied granular herbicides under no-till conditions have shown weed control and crop safety comparable with incorporated Edge and Trifuralin.** This method of application would provide important advantages for control of erosion.

Some winter annual weeds in the mustard family such as flixweed and shepherd's purse are not controlled by the herbicides registered for lentils. Pre-seeding Roundup application or pre-seeding tillage can be effective. Some growers have experimented with late fall or very early spring applications of 2,4-D or MCPA to control weeds prior to seeding lentils. These treatments are very effective as a control measure and have the added benefit of low cost. **However, they are <u>not</u> recommended because there is a high risk of crop injury from soil residues, particularly under dry, cool conditions. Early fall treatment of winter annuals with 2,4-D is much safer in terms of crop injury compared to spring treatment.** Use of salt or amine formulations reduces the risk of chemical residual relative to the ester formulations. MCPA is also less likely to cause injury than 2,4-D. Either fall or spring application of Banvel (dicamba) will cause lentil injury. If glyphosate is used as a pre-seeding spring burnoff, care should be taken in selecting the formulation. Roundup is safe for use, but Rustler, which contains dicamba, can cause crop injury.

Insects

Several insects can cause damage to lentils, including lygus bug, aphids, cutworms, and grasshoppers. However, the only insect likely to cause economic levels of crop injury in lentils in Saskatchewan is the grasshopper. Damage can occur at both the seedling and flowering stages. Lentil seedlings on the edge of the field can be attacked by grasshopper nymphs as they emerge in spring, but lentils will generally regrow from buds below or near the soil surface. If the damage is not repeated, maturity will be delayed, but the plant will not be permanently harmed. If lentils are seeded early, they may outgrow the susceptible stage before the grasshoppers emerge. **Early seeding is recommended if the Saskatchewan Grasshopper Forecast predicts a severe to very severe grasshopper risk.**

Grasshoppers cause greater damage if they attack flower buds, flowers or young pods. This damage does not hurt the lentil plant, but the yield can be reduced up to 90% and maturity can be delayed due to delayed pod set. Contamination of the lentil seed lot with grasshopper parts can also reduce lentil quality. During combining, grasshoppers enter the combine, the heads are broken off, and due to size similarity, are generally not easily separated from the lentil seeds. Additional cleaning may be required to remove them.

Decis (deltamethrin), Lorsban 4E (chlorpyrifos), and malathion (50%) are registered for grasshopper control in lentils. Decis has greater activity in cool temperatures, whereas malathion has greater activity in warm temperatures. Pre-harvest intervals of 40 days for Decis, 7 days for malathion, and 21 days for Lorsban 4E must be observed.

Diseases

Disease management is important in reducing the likelihood and severity of lentil diseases (see the suggestions given in *Chapter 2 - Disease*). Crop breeding supported by funding from grower check off will soon result in the release of varieties resistant to some of the major lentil diseases in Saskatchewan.

Ascochyta blight and anthracnose are two diseases which are of significant concern. A third disease, botrytis stem and pod blight (sometimes called grey mould), can be a significant problem under wet conditions.

Ascochyta blight is a fungal disease caused by a specific strain of the fungus which only infects lentils. The disease is widespread in Western Canada, and common in other lentil growing areas of the world. Yield loss in Eston and Common Chilean may be as high as 30 to 50%; loss in Laird may be 15 to 30%. **Recent evidence indicates that new aggressive strains of ascochyta have developed, and Laird, which had partial resistance to ascochyta, now has no better resistance than other varieties to the new strain.** The yield loss due to ascochyta is caused by flower and pod abortion, but heavy infection may delay maturity as well. The reductions in lentil quality and grade may cause larger economic losses than the reduction in yield. Symptoms of the disease include the occurrence of grey to tan spots or lesions on the leaflets, stems and pods, with dark margins and often with tiny black fruiting bodies (pycnidia) in the centres (FIGURE 3). Under severe conditions, leaves may be lost and the seeds discoloured. Seeds may become partly or wholly brownish purple, and may be shrivelled (FIGURE 4). In extreme cases, they may have fluffy white patches or bumps. Disease symptoms are most severe under wet conditions. A late seed-borne infection may occur which causes little or no seed discoloration in the harvested lentils.

The fungal spores can overwinter in the field on lentil stubble. Movement of spores from field to field is limited. Ascochyta can also be seed-borne, even if the seed does not show symptoms. The likelihood of disease can be reduced by allowing several years (at least 3) between lentil crops, and by planting only seed that is ascochyta-free. Agar plate tests of seed that indicate "none detected" are recommended for pedigreed seed growers or for growers in Black or Grey soil zones where cool moist conditions are most likely. Even 1% seed-borne ascochyta can result in epidemics in cool moist seasons, but up to 4% seed infection will not normally cause a problem in dry areas. If infected seed is planted, seed treatment with Crown fungicide or delayed seeding is recommended to reduce transmission from infected seed to seedlings.

FIGURE 3. Leaf Symptoms of Ascochyta in Lentils.

FIGURE 4. Ascochyta Infected Lentil Seed (Left).

FIGURE 5. Anthracnose in Lentils (Susceptible and Resistant Varieties).

Anthracnose is a fungal disease which is severe in southern Manitoba and is widespread in Saskatchewan and other parts of Manitoba. Disease symptoms include grey to cream spots on leaves, and spreading tan to golden brown lesions on stems (FIGURE 5). Leaves, and entire plants may die back and the stems of mature and dead plants often blacken. This is especially evident after swathing. The disease is favoured by warm moist weather, frequent showers and a dense lentil canopy. Severe stem infection will kill the stem before any seed becomes infected.

Anthracnose can be carried by stubble, wind-blown dust, and probably by seed. The fungus spreads readily, and low levels are able to initiate epidemics, especially in southern Manitoba. The incidence and severity of anthracnose in Saskatchewan is generally less than in Manitoba, probably because of the cooler, drier summers. The fungal spores can readily move from field to field, and can remain viable in the soil on buried plant material for more than 2 years. Risk factors for anthracnose include the previous presence of the disease in the field, or even the district, and frequent rainfall. **It is recommended that growers avoid infected seed and use crop rotations that include at least 4 or 5 years between susceptible crops such as lentils, peas, or faba beans.** Several lines of lentils with an intermediate level of resistance are being evaluated by the Crop Development Centre.

Bravo (chlorothalonil) is registered for ascochyta and anthracnose control in lentils. It is a fungicide that protects the sprayed plant from infection until new non-sprayed growth develops. Bravo must be handled carefully as it can cause severe eye damage and label recommendations should be followed.

Crown (carbathiin and thiabendazole) is registered as a seed treatment for control of seedling blight, seed rot and seed-borne ascochyta. It also controls seed-borne infection by *Botrytis*, but has not been registered for this use. The chemical is sold as a liquid (water base) that can be used as a sticker for inoculant. Treated seed is toxic.

Botrytis stem and pod rot can cause severe crop losses (FIGURE 6). It is most destructive under irrigation, or in cool wet years (such as 1992, 1993, and 1994). Symptoms of the disease include wilting, premature ripening, failure of pods to fill, and dead infected crop areas. Grey mouldy growth on the surface of the plant can be found throughout the canopy, on stems and pods. No control is available for this form of Botrytis. The fungi causing these rots can overwinter at the soil surface or in debris, and can occasionally be seed-borne. Inoculum is widespread and needs only prolonged cool wet periods and a dense canopy to become serious. No resistant varieties are available. Botrytis infected seeds usually produce infected seedlings which die soon after emergence.

FIGURE 6. Botrytis in Lentils.

Sclerotinia can cause rotting of stems and pods (FIGURE 7). Although Sclerotinia is widespread in lentils, it is not often of economic concern. There is an increase in risk to other susceptible crops, especially canola, if it follows lentils in the rotation because of the multiplication of the fungus in the lentil crop.

FIGURE 7. Sclerotinia Symptoms on Lentil Stems.

Seedling blights and root rots can be widespread, but usually they only occur on scattered plants and they are rarely of economic importance (FIGURE 8). Individual diseased plants turn yellow, die and dry up. The root system and the base of the stem are brown and rotten, and may have white or pink mold growing on them. The disease affects only scattered plants and does not spread far. Crop rotations that include cereals can delay the build up of these soil-borne diseases. Zero tannin lentils are very susceptible to seed rot which can be controlled by Apron FL (metalaxyl). (Apron FL is not registered for lentils.)

FIGURE 8. Lentil Plants Infected with Root Rots.

Viral diseases are not severe in lentils in Saskatchewan, but several viruses attack lentils in other areas of the world. Pea seed-borne mosaic virus is a potential threat to lentils as it may be introduced with infected pea seed. The virus usually is spread by pea aphids, which occur commonly in Manitoba. Symptoms of the disease include light green mosaic patches (mottled) on the leaves, stunting, abnormally small leaves and flowers, and reduced seed set. The risk of this disease is reduced if lentils are planted away from other legumes.

Heat canker can easily be confused with seedling blight (FIGURE 9). The base of the stem looks pinched, leaves wilt and turn yellow, and the stem dies. With heat canker, the stem remains plump below the canker. Heat canker occurs when the young seedlings are exposed to high soil surface temperatures before they have enough leaves to shade their own stems. Heat canker was a major problem in 1987 and 1988. Seedlings can regrow from buds below the soil surface if the soil surface cools down and the soil moisture supply is adequate for good growth. Heat canker is less likely to be serious if the crop is seeded in a north-south direction, or if the soil surface is well covered with crop residue.

Herbicide injury sometimes can be mistaken for diseases (FIGURE 10). Herbicide injury can be avoided or at least reduced by applying herbicides according to label instructions, carefully cleaning sprayers, and avoiding spray drift.

FIGURE 9. Heat Canker on Lentil Seedlings.

FIGURE 10. Phenoxy Damage to Lentil Plants.

Irrigation

Irrigated lentil production requires a thorough knowledge of dryland lentil production as well as specific knowledge of irrigation requirements. Laird and common Chilean lentil both have a strongly indeterminate growth habit which often results in excess vegetative growth and low seed yields. Lentil plants do not tolerate water logged soils and will die if flooded. Dense lentil canopies favour the spread of disease and increase the severity of disease.

Eston lentil is not as sensitive to high soil moisture conditions as Laird and is more suited to being grown under irrigation. Highest yields are obtained with an application of 6 to 10 inches of total water, with the exact amount depending on the rate of evaporation. It is important to avoid water accumulation on the surface and water logging of the soil, especially at seeding time. Irrigation of 0.8 to 1.2 inches in early June may be used to prevent the stunting (short plants) and lowered yield from drought stress. Irrigation is usually avoided in mid to late June as a slight moisture stress for a brief period after the onset of flowering encourages seed set. **Irrigation should be avoided for at least 2 weeks after spraying with Lexone or Sencor (metribuzin) to avoid leaching it into the lentil rooting zone where it can cause damage.** Supplemental moisture may be beneficial during flowering and early pod filling stages. Approximately 4 inches of total water are recommended during the first 3 to 4 weeks of pod set. After this critical period, irrigation should be shut down to allow enough moisture stress to ensure that the crop matures.

When grown under irrigation, lentils should be seeded early, at a depth of 1 to 2 inches. The seeding rates of Eston should not exceed 30 to 35 lb/ac as higher rates increase the risk of disease. To reduce the risk of sclerotinia, lentils should not be seeded on land that has produced mustard, canola, lentils, peas, sunflower, or faba beans in the previous 4 years.

Harvest

Lentil plants have an indeterminate growth habit and will continue to flower until stopped by some stress, such as heat, frost or drought. Laird lentils are more indeterminate than Eston and in many years, crop maturity will not occur in a timely manner. Because of this, many farmers hasten the drying of their crop by either chemical desiccants or by swathing. Lentil pods shatter easily when dry and thus, early swathing or desiccation is used to hasten dry down and to make it more uniform which reduces shattering losses. Straight combining without desiccation can be done with Eston in a hot dry harvest season. This may increase shattering losses due to dry pods and will increase crop losses due to unthreshed green pods.

The best time to swath or desiccate can not be determined by the colour of the crop as seen from the road. The fields should be walked and the plants should be examined. Swathing and desiccation provide the best results when the bottom pods of the lentil plants turn yellow to brown, and the seeds rattle within them when shaken. At this time, the upper pods will still be green, but further delay will increase the risk of harvest loss due to shattering of the bottom pods.

Desiccation

Reglone (diquat) and Roundup (glyphosate) are registered for use in lentils. Additional information on these products is found in *Chapter 2 - Desiccation.* **Roundup is not an effective desiccant and is not registered as a desiccant, but is used to control perennial weed growth before harvest. Seed germination and seedling vigour can be reduced if Roundup is applied earlier than is recommended on the label. Do not use Roundup on crops which are to be used for seed.**

Reglone application is recommended when one-third of the pods have turned colour. If the crop is chemically desiccated, it can still be either swathed and combined or straight-cut. With Reglone, about 7 to 10 days are required between application and threshing. Straw from lentils desiccated with Reglone or sprayed with Roundup for perennial weed control can be used as livestock feed.

Swathing

If the crop has not been desiccated, it can be swathed when about 1/3 of the lower pods turn yellow and the seeds in them rattle. Cutting under conditions of high humidity can reduce shattering losses.

Swathing the crop may be the most difficult part of lentil production. The bottom pods are close to the soil surface, so the cutterbar must travel very close to the ground. The cutterbar should preferably be about 2 inches from the ground, at an angle of 20 to 30° to the ground. Cutting will be easier if the surface is level, firm and dry. Fields that were rolled after seeding are easier to swath since rolling helps to level the soil surface.

A properly equipped forage or grain swather can be used to cut lentils. However, pull-type swathers are a poor choice because of the severe side draught and frequent dragging that occurs when cutting lentil plants near the soil surface. **Ideally, a swather should be equipped with a pickup reel and vine lifter guards for a good job of cutting, especially if the crop is lodged.** A good quality pickup reel without lifter guards may do an adequate job and is preferred over a swather having only lifter guards and a standard bat reel. Proper adjustment of the pickup reel is important to obtain the maximum possible lifting action. The reel should be positioned as far ahead of the cutterbar as possible.

The direction travelled while cutting the crop can also make a difference in the effectiveness of the pickup reel and lifters, especially if the crop has a prevailing lean to it. The cutterbar lifter guards will have a greater effect if the cutting direction is perpendicular to the direction of crop lean.

Since the cutterbar will be operating close to the ground, an alteration to the header flotation system may be required. Adjusting existing header flotation springs or adding additional springs to increase flotation will help keep cutterbar damage to a minimum. On uneven terrain, use a narrow swather or swather equipped with a floating or flexible cutterbar and/or adjustable gauge wheels. Lentil and weed residues can be gummy and may stick to the cutterbar. An excessive buildup will cause poor cutting and increase wear on the cutterbar. **The cutterbar may need to be cleaned periodically with soapy water and a scraper to maintain cutting efficiency.**

Lentil swaths can be light and fluffy, especially if cut a bit on the dry side. Because the crop is cut very close to the ground, very little stubble remains after harvest. This makes the swath very prone to wind damage. Using a swath roller will reduce the risk of wind damage, but can greatly increase shattering losses. Swaths will settle after a day or two and are then less likely to be moved by the wind. Swaths are also less prone to damage if they are laid in the same direction as the prevailing wind. Swathed lentil plants may dry more rapidly than standing lentil plants, but rain on the swath is a serious concern as it can result in sprouting, wrinkling of seeds, disease spread to pods and seeds, and reduced quality. Wet swaths flatten out and are harder to pick up. To speed the drying process, they can be turned with a swath turner or a side-delivery rake, but shattering losses may be high.

Straight Cutting

Straight cutting, like swathing, is best done with a properly equipped header. **In desiccated lentils, flex headers, automatic header height control, and air reels work well, provided the crop is relatively weed-free. In non-desiccated lentils, a pickup reel and vine lifters provide good cutting, especially if the crop is lodged.** The improvement in lentil grade obtained by reducing the amount of debris harvested with the seed may pay for the additional cost of a header if harvesting conditions are difficult. As a guideline, operators who produce 300 acres or more of lentils and/or peas each year can usually justify the expense of a direct cut attachment for their combine.

Threshing

If the weather is warm and windy, the lentil crop can dry very rapidly. The crop should be monitored to determine when it should be threshed. Correct timing can make a large difference in the ease and success of the combining operation.

Lentil seed can be safely stored at 14% moisture. If no drying equipment is available, it may be necessary to wait until the seed reaches this moisture content before threshing. This is not the best solution because shattering losses and seed damage are likely to result.

Experiments conducted to investigate the effect of moisture content on breakage showed that the percentage breakage increases with decrease in moisture content when it is less than 14% (w.b.). It has also been observed from field experiments that when moisture content of seeds were greater than 20% (w.b.), the crop was extremely hard to combine without smashing the seeds. Therefore, 20% (w.b.) and 14% (w.b.) are the recommended upper and low boundaries for the grain moisture content in a harvest operation.

Ideally, the seed should be threshed at about 16% moisture. This will result in a cleaner crop sample and a reduction in shattering losses and seed damage.

Lentil plants thresh easily, and the seed is easily damaged. Rotor and cylinder speeds between 250 and 500 RPM are often used. However, determining the proper cylinder speed involves a compromise between a slow enough speed to avoid damage and a fast enough speed to avoid cylinder plugging. Cylinder speeds can be increased if the lentil plants are moist, but samples should be monitored for cracking and splitting, and the cylinder speed should be reduced if a problem develops. Concaves should be set to allow good threshing and separation. If the lentil plants and seeds are very dry, settings must be adjusted accordingly. Chaffers should be initially set at 3/4 inch and cleaning sieves at 3/8 inch and adjusted as necessary. Tailings should be kept to a minimum to reduce cracking and splitting. Clean grain and return elevator chains should be kept properly adjusted as too loose an adjustment increases the chance of cracking seed. Fan speeds should be high enough to ensure a clean sample, but no higher.

POST HARVEST

Drying

Lentil seeds can be safely stored at up to 14% moisture content and at temperatures below 15°C. Higher temperatures and moisture contents result in a more rapid degradation due to discoloration. Higher moisture contents will also cause the air in the bin to be more humid which can lead to mold growth. Lentil seeds should also be cleaned before drying to reduce the content of green weedy material that holds moisture and to eliminate finer dockage that interferes with airflow. Lower moisture content does increase the risk of damage during handling. If high moisture lentil seeds are dried too rapidly, tiny cracks may develop on the seed. **Lentil seeds should not be**

dried by more than 4 or 5 percentage points per pass through the dryer, and they should be tempered up to 8 hours between passes to allow adequate time for moisture migration and cooling. All drying should be done at temperatures below 45°C if germination needs to be preserved. If lentils are to be sold for commercial purposes, higher drying temperatures may be possible. Recent research suggests drying air temperatures as high as 70°C may be possible. This will speed up drying. However, operators are cautioned to have their buyers test samples of grain dried at different temperatures as safe drying temperature can vary between dryers and with grain condition.

The seed is easily damaged in conveyors or in the dryer, especially when hot. One way to minimize passes through conveyors is to use a natural air drying system. Aeration bins should be able to provide at least 2 cfm/bu or more air flow with partial or fully perforated floors. TABLE 5 presents computer simulation results of aeration drying of lentils.

TABLE 5. Days Required for Natural Drying of Lentils with Unheated Ambient Air.

Start Date	Moisture Content (%)	Airflow Rate (cfm/bu) 1.0	2.0	3.0
August 15	20	36	21	6
August 15	17	26	20	17
September 15	20	38	12	10
September 15	17	35	10	9

Source: Agricultural and Bioresource Engineering, University of Saskatchewan.

Drying time is calculated from the initial moisture contents given in TABLE 5 to a safe storage moisture content of 14%. The simulation results indicated that 1 cfm/bu would dry lentils in about a month. Airflow rates above 1 cfm/bu are beneficial if drying has to be completed in a shorter period. The starting date (harvest date) used in the simulation had some effect on drying time. Generally, earlier harvest resulted in shorter drying time, but this was dependent on the airflow rate and specific dates of drying. The amount of energy used to achieve drying increased with the airflow rate, ranging from 20 to 80 kWh/t of grain dried. Assuming 5 cents per kWh of electricity, the operating cost of natural drying of lentils amounts to $1 to $4 per ton of dried grain.

Generally, aeration bins which have good performance when drying cereal grains will have adequate airflow performance with lentils. Laird lentils have 25% less resistance to airflow than wheat has per unit of depth, so aeration bins will generally have an equal or faster drying rate with lentils than when drying an equal amount of wheat. An increase in moisture content of Laird lentils from 10.5 to 20% results in a 22% decrease in resistance to airflow. The resistance of Laird lentils to horizontal airflow is one-half of the resistance to vertical airflow. The resistance to airflow of Eston lentils is up to 27% higher than that of Laird. The drying rate or drying performance is influenced by the type of seed and bin parameters, fan performance curve, and the weather, so drying conditions must always be carefully monitored.

Storing and Handling

Lentil seed coats brown with age, resulting in a reduction in grade. The browning is a result of the oxidation of tannin precursors in the seed coat, and occurs faster at high temperature, high humidity and in sunlight. For this reason, it is advisable to store lentil seeds in light tight bins, and to aerate them to cool them to below 15°C immediately after binning. The effect of storing undried lentils at 13.4% w.b. for a period of 6 months was investigated. Storage increased breakage by 2 to 5%, decreased germination by 2%, and the shear force of a cooked sample was slightly higher. Each of these effects is a small, but significant quality deterioration. **Lentil seeds from successive years should not be mixed as all the lentil seeds may be downgraded by the colour changes in the oldest seed.** Oxidized lentil seeds may be used for seed if germination and viability are high. All lentils should be sold within two years of harvest.

Lentil seeds are very susceptible to peeling and cracking of the seed coat and to splitting if they are handled while it is colder than -20°C or drier than 14% seed moisture content.

Grading

The Canadian Grain Commission under recommendation of the Producer Trade Advisory Committee sets the standards for the lentil grades. Lentil grading is based on colour; presence of earth tag or dirt and other material attached to the seed; damage, such as cracking, splitting, wrinkling, and smell; and the content of foreign material such as stones, insect parts, other plant material, sclerotinia and ergot (FIGURES 11 to 19 and TABLE 6).

Fall Land Preparation

Lentils leave very little stubble or residue, and can leave land prone to erosion. In erosion prone areas, it is advisable to take steps to reduce the problem. Spring cereals, seeded after September 15 as a cover crop, can be used to help stabilize the soil in a wet year. The cereals are seeded at a rate of about 1 bu/ac.

Lentil stubble is too short to use in snowtrapping. Strip seeding one row of flax or durum per seeder width (30 to 40 feet) when lentil is seeded may help with snow trapping if the row is left standing at harvest time. Seeding perpendicular to the prevailing wind may also help.

Shelterbelts, direct seeding, and strip cropping can also be very effective. Planning the rotation is very important as it can help in eliminating or reducing the need for fall incorporated herbicides on land where there is a severe risk of soil erosion.

FIGURE 11. Good Natural Colour Lentil Sample.

FIGURE 12. Reasonably Good Natural Colour Lentil Sample.

FIGURE 13. Fair Colour Lentil Sample.

FIGURE 14. Not Stained Lentil Sample.

FIGURE 15. Not Considered as Stained Lentils Sample-Evaluated on Colour.

FIGURE 16. Stained Lentil Sample.

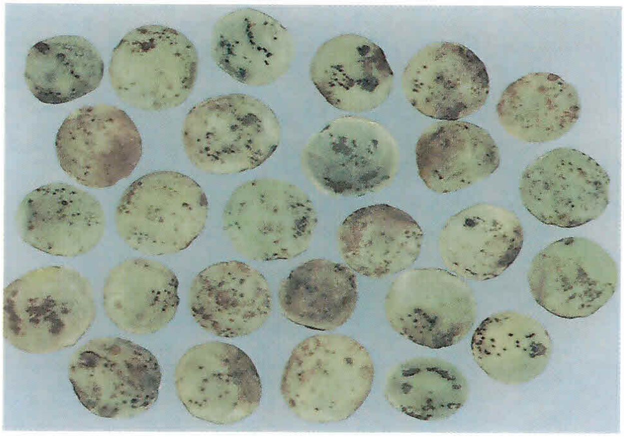

FIGURE 17. Mottled Lentil Sample - Considered as Stained.

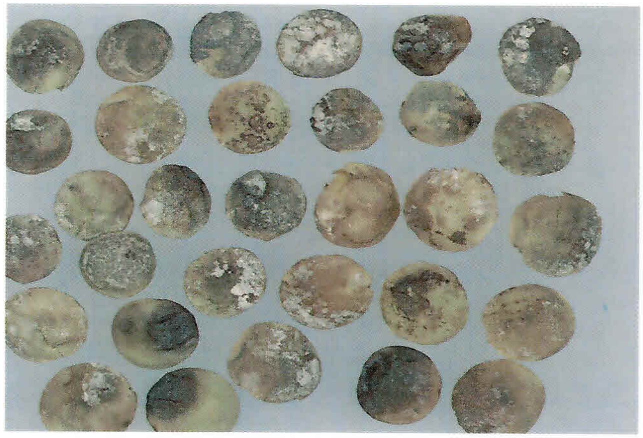

FIGURE 18. Damaged Lentil Sample - Ascochyta Also Considered as Stained.

FIGURE 19. Damaged Lentil Sample - Frost.

TABLE 6. Primary and Export Grade Determinants for Lentils.

Grade Name	Degree of Soundness	Maximum Limits								
			Damage	Foreign Material						
		Stained	Heated	Peeled, Split, & Broken	Other Damage	Total	Stones	Ergot	Sclerotia*	Total Foreign Material
No. 1 Canada	Uniform in size, of good natural colour	1.0%	About 0.2%	2.0%	1.0%	2.0%	About 0.1%	0.05%	0.10%	About 0.2%
No. 2 Canada	Uniform in size, of reasonably good natural colour	4.0%	About 0.5%	3.5%	2.0%	3.5%	About 0.2%	0.05%	0.10%	About 0.5%
Extra No. 3 Canada	Uniform in size, of fair colour	7.0%	About 0.5%	5.0%	5.0%	5.0%	About 0.2%	0.05%	0.10%	About 0.5%
No. 3 Canada	Poor colour	---	1.0%	10.0%	10.0%	10.0%	About 0.2%	0.05%	0.10%	1.0%
If specs for No. 3 Canada are not met, grade:			Lentils, Sample Canada, Account Heated	Lentils, Sample Canada, Account Damaged	Lentils, Sample Canada, Account Damaged	Lentils, Sample Canada, Account Damaged	Up to 2.5%: Lentils, Rejected (grade) Account Stones. Over 2.5%: Lentils, Sample Salvage	Lentils, Sample Canada, Account Ergot	Lentils, Sample Canada, Account Admixture	Lentils, Sample Canada, Account Admixture

*On export shipments of lentils, all grades may contain up to 0.05% by weight of sclerotia. All other established tolerances apply.

Peas

Quick Tips - Peas

Seeding Rate:	Variable, depending on seed size. Target 8 plants per square foot.
Seeding Depth:	2 to 3 inches.
Seeding Date:	15 to 30 April in Moist Dark Brown soil zone. Early May in Black and Grey soil zones.
Recommended Varieties:	Many available.
Best Performance:	On cereal stubble in the Black and Grey soil zones.
Rolling:	After seeding; or if too wet, before the 5 leaf stage.
Registered Herbicides & Registered Fungicides:	Refer to Table 13, pages 2-23 and 2-24 or the Saskatchewan Agriculture and Food Crop Protection Guide.
Rotational Frequency of Pea Production for Disease Control:	4 years for mycosphaerella.
Swathing or Desiccation:	No more than 1/3 green pods.
Direct Harvesting:	20% seed moisture.
Storage Moisture:	16%.

Chapter 4

Pea Production

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Chapter 4

Pea Production

INTRODUCTION

Pea is among the world's oldest crops as it was first cultivated as early as 9000 years ago. It is native to Syria, Iraq, Iran, Turkey, Israel, Jordan, and Lebanon, and has been cultivated in Europe for several thousand years. It is now grown in all climatic zones, including the tropics where it is grown at high elevations.

Early in the century, first Ontario and then Manitoba led Canadian pea production. Since the mid-1980's, Saskatchewan has produced the majority of Canadian pea with significant acreage also being grown in Alberta and Manitoba. Ontario is no longer a large scale producer. In Saskatchewan, pea yields average 1600 lb/ac, but yields as high as 3500 lb/ac have been reported.

About 80% of the Canadian pea crop is exported to Europe, South America, and Asia. Much of the crop is grown for the large European livestock feed market. An increasing amount is being used in Saskatchewan for livestock feed for hogs and a small amount of the pea crop is processed into pea fibre, pea protein and pea starch. Only a small portion of the Canadian pea crop is used domestically as food. A further 10% of the crop is required for seed. This high percentage is due to the large size of the pea seed.

Peas contains 20 to 25% crude protein. There are some components of the pea (trypsin inhibitors) which prevent its complete digestion and utilization. These components are at very low levels in peas compared to the levels in soybean so they are of little concern when peas are used for food or in most livestock rations (TABLE 1).

THE PEA PLANT

The two major types of peas are the round seeded, used primarily for food and feed, and those with wrinkled seed which are usually harvested when immature and used for freezing and canning. The round-seeded pea is the main type grown in Saskatchewan. Pea seeds may have either green or yellow cotyledons under a white or occasionally pale green seed coat (FIGURE 1). A third type of pea has coloured seed coats and coloured flowers. This type includes the Austrian winter pea and maple pea which are feed peas and not normally used for food.

Pea seed weighs from 100 to 350 g/1000 seeds (commonly 190 to 260 g/1000 seeds) when dry and mature. During germination, the seed doubles in volume in the first day and when it germinates, the seeds remain underground. The first two scale leaves are relatively small, and seldom emerge completely from the ground. If the young seedling is damaged, regrowth is possible from buds at the base of these scale leaves (FIGURE 2). The first leaf usually has 1 pair of leaflets and a tendril. As the plant grows, later leaves have increasingly more leaflets and tendrils. A pair of large stipules which are like a leaf are wrapped around the stem at the base of the leaf stem. In semi-leafless types, the stipules are

TABLE 1. Chemical Composition of Feed Peas (90% Dry Matter Basis).

	Average
Moisture (%)	10.00
Crude Protein (N X 6.25%)	22.60[1,5]
Ether Extract	1.38[1]
Linoleic Acid	0.56[2]
Fibre Measurements	
Crude Fibre %	5.50[1]
Acid Detergent Fibre %	8.19[3]
Neutral Detergent Fibre %	16.65[3]
Lignin %	0.85[3]
Starch %	46.80[4]
Total Ash %	3.30[1]
Phytic Acid %	1.20[1]

[1]Marquardt and Bell, 1988. [2]Rhone-Poulenc Animal Nutrition, 1993. [3]Fonnesbeck et al., 1984. [4]McLean et al., 1974. [5]Sask. Feeding Testing Lab 1990.

Pea

FIGURE 1. Assortment of Yellow and Green Pea Seeds.

still there, but all the leaflets are replaced by tendrils. Plants with more tendrils intertwine more which results in a greater standing ability.

Pea plant growth can be either determinate or indeterminate. Determinate varieties reach a certain growth stage and then mature. Plants with an indeterminate growth habit continue to grow and flower over a prolonged period of time until drought, heat, or other factors brings on maturity. Varieties grown in Saskatchewan are moderately to strongly indeterminate. Older varieties, such as Century and Trapper, grow tall and mature late in the season, especially under conditions of adequate moisture and cool weather. These varieties flower for a long time so a short period of poor weather during flowering can often be compensated for by later flowers, but such varieties are at risk of not maturing during a short growing season. Most newer varieties have shorter vines and earlier maturity, but they require some stress to bring on maturity.

Those pea varieties adapted to Saskatchewan produce their first flower at about the 12th to 16th node, and flowering continues at successive nodes as growth continues. Each flowering node produces 2 flowers on a short flower stem which self- pollinate before they open. The plants produce mature seed pods between 1.5 to4 inches long, about 0.5 inches wide, and each pod contains from 6 to 10 seeds.

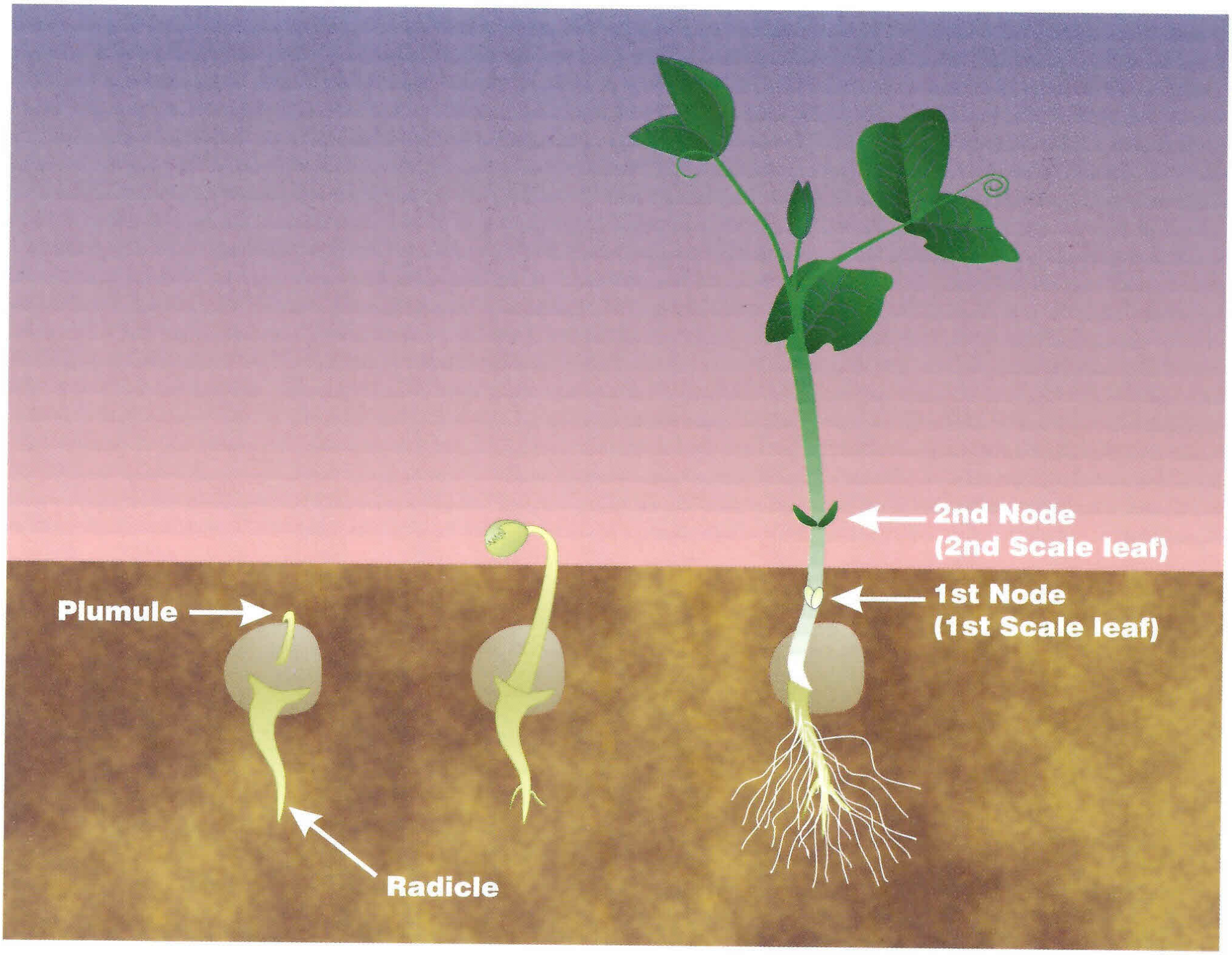

FIGURE 2. Seedling Showing Seed, Radicle, Plumule and First Two Leaves.

ADAPTATION

Pea performs best on well-drained soils with adequate moisture such as are found in the Black and Grey soil zones. Peas do not tolerate salinity or waterlogging. Wet or cold soils favour the development of disease. Stony fields can be used, but they must be rolled to prevent problems at harvest. Pea roots grow 40 to 45 inches deep so they develop best in deep soils and do not do as well in eroded or compacted soils. Peas can be grown on summerfallow, but do not require the extra nitrogen provided by summerfallow. **Peas perform very well on cereal stubble where the soil nitrogen is often depleted.**

Pea seeds germinate at temperatures between 4 and 24°C. The best growing temperature range is when daytime highs are between 13 and 23°C. The plants can not tolerate drought or high temperatures. Flowers often blast (open briefly and fall off without setting seed) in hot weather. The plants flower for a shorter period, and fewer flowers result in pods if daytime high temperatures are over 27°C. Seedlings tolerate frost down to -7°C, but frost at the flowering stage can cause heavy pod losses. Frost during the early pod fill stage causes discoloured and deformed seeds.

Peas are sensitive to drought, especially during flowering and pod set, with shorter, earlier types performing best in moist, short-season areas. In drier areas, taller varieties can be easier to harvest. **The taller, indeterminate types flower over a longer period so they are more likely to be able to compensate for periods of hot, dry weather during flowering.** In the moist Dark Brown soil zone on dryland, pea yields on average are less than yields in the Black or Grey soil zone, or than when grown under irrigation, but maturity is earlier. The risk of encountering adverse heat and drought effects in the moist Dark Brown soil zone can be reduced by early seeding in mid to late April. This allows a potential for seed production before mid-July when hot, dry weather usually occurs. Research from Agriculture and Agri-Food Canada at Scott and Swift Current is showing peas may be more suited to the Brown and Dark Brown soil zones than previously thought. This is consistent with growing producer experience in this region. Pea yields in the Brown soil zone were competitive with CWRS wheat yields in a tillage trial, especially when both crops were grown on wheat stubble (see TABLE 2). In this trial, three of the site-years were wetter than normal, two had near normal climatic values, and one was drier than normal.

When seeded into cereal stubble, pea has shown a strong response to an early spring seeding date at Swift Current (TABLE 3). Pea yields declined sharply as seeding date was delayed. At Scott, indications were that field pea should be seeded earlier than wheat, but, unlike Swift Current, there was no advantage to seeding as early as possible. It is critical that field pea be seeded as early as soil temperatures permit to get the maximum yield potential from a pea crop in the Brown soil zone.

A unique feature to growing field pea in the Brown soil zones is that normal-leafed cultivars yield about 5% higher than semi-leafless cultivars due to higher photosynthetic capacity. It remains to be seen whether or not diseases such as mycosphaerella will plague the Dry Prairie region as is the case for the moister Parkland region.

The Dry Prairie region could potentially supply high quality, economical seed for production in moister regions. Due to the very low disease incidence in the Dry Prairie, pea seed is naturally of very high quality. Also, in disease-free conditions, pea seed size has typically been 10 to 15% smaller in the Dry Prairie than the Parkland due to greater moisture stress during seed filling. If the smaller seed maintains similar vigour and yield potential as larger seed, as anecdotal evidence suggests, then it becomes a more economical seed source of any cultivar, due to a greater number of seeds per unit of volume.

TABLE 2. Average Yield of Field Pea Relative to CWRS Wheat in Tillage Trial at Swift Current (1993-96) and Assiniboia (1995-96) when Sown on Fallow and Wheat Stubble Treatments.

	Fallow	**Stubble**
	--- % wheat yield ---	
Total 6 site-year average	124	134
Driest 3 site-year average	110	126

Source: Agriculture and Agri-Food Canada - SPARC, Swift Current

TABLE 3. Relative Yields of Field Pea Grown in Cereal Stubble at Different Spring Seeding Dates at Scott (1993-96) and Swift Current (1994-96).

Site	**Date 1***	**Date 2**	**Date 3**
	Yield % of Date 2		
Scott	76	100	84
Swift Current	117	100	77

*Seeding dates were early May (4-7), mid-May (16-22) and late May/early June (25-3) at Scott and were on or near April 21, May 5, and May 24 at Swift Current.

Source: Agriculture and Agri-Food Canada - SPARC, Swift Current

FIELD HISTORY

Pea plants cannot tolerate some herbicide residues. The recommended period following herbicide application before peas can be grown safely varies with the herbicide, the rate applied, and soil characteristics such as pH and organic matter. (See *Chapter 2 - Field History* for details.) The Sask Ag and Food publication "Crop Protection Guide" contains up-to-date information on the problems caused by active residues from herbicides. Growers should consult this publication and herbicide product labels to help them avoid residue problems. These problems can vary depending on soil properties and weather conditions, so if there is some doubt, tests for active chemical should be conducted. Canada thistle, quackgrass, or perennial sow-thistle are likely to be problematic weeds. Clean fields offer the best chances of success for pea production. Routinely monitor and survey fields in all years to ensure that the limited herbicide choices registered for use in peas will be able to control the weeds present in the field to be seeded to peas.

Peas perform well in rotation on cereal stubble fields in the Black and Grey Wooded soil zones. Peas sown on pea stubble have a higher risk of ascochyta (mycosphaerella) blight. Peas following alfalfa, beans, flax, or lentils have a medium risk of seedling blights or root rot. There is a risk of sclerotinia when peas are sown following sunflower, canola, rapeseed, mustard, beans, faba beans, or lentils. These disease risks, along with low nitrogen requirements, make peas especially suited to cropping on cereal stubble.

Traditional pea production recommendations include spring tillage, but peas perform very well under minimum or zero tillage (when direct seeded) if the seed is planted at uniform depth. The large seed provides for good emergence through surface residue.

VARIETIES

A large number of pea varieties are registered for Saskatchewan (TABLES 4 and 5). Many of them are recently introduced European varieties. Most are higher yielding, earlier maturing, shorter in vine length, and less prone to lodging than the older varieties. **Selection of a variety to grow depends on the target market and the area in which the peas are to be grown.** A selected market will have colour, size, shape, or cooking characteristic requirements.

A high yield and small seed size (which reduces seed volumes and lowers seed cost) are important in the livestock feed market. Varieties with coloured flowers and brown or maple coloured seeds are slightly less desirable as feed because they have higher tannin levels than the green or yellow pea. Tannins are bitter and reduce protein digestibility. The level is low enough in these varieties that detrimental effects are minimal. Peas intended for sale for food, but of poor quality, can be sold as feed. Disease, poor weather, and damage during threshing and cleaning can downgrade peas to a feed quality level.

Quality is extremely important in the food pea market. A large proportion of production is of yellow peas. These are often about 15% higher yielding than green peas and in addition, green peas are subject to bleaching, especially if rainy and hot sunny days are interspersed just prior to harvest. Bleaching can downgrade the green peas' seed quality, and may make them unsuitable for food. **Good quality green peas usually sell at a slightly higher price than yellow peas; however, the net returns may still be higher for yellow peas because of a higher yield.** Green and yellow food pea markets pay attention to smoothness, roundness, colour uniformity and size. Some varieties are more consistently round than others. Some yellow feed pea varieties may be acceptable for food markets when their quality level is high.

Vine length and leaf type can be important considerations. The strongly indeterminate varieties have a lower risk of major yield loss due to flower blasting on hot days because of the longer flowering period. With their longer vines, there is also less difficulty in harvesting. Under adequate moisture conditions, the early types are more likely to mature in a limited growing season such as may occur in cooler areas. Under all moisture conditions, the semi-leafless varieties are less prone to lodging. Short and medium vine types and semi-leafless types do provide less weed competition so effective weed control is more important.

Most varieties have similar susceptibility to disease. None of the varieties is resistant to ascochyta (mycosphaerella) blight. (See TABLES 4 and 5 for details.)

All varieties of peas except Princess should be seeded early to produce the highest yields. Princess pea is very early in maturity and if seeded early, it matures rapidly during and after the mid-July hot spell which results in low yields. Seeding Princess in the first week of June results in higher yields as it allows it to be at early pod set stage in mid-July. The pods can then fill during cooler weather in August and this results in higher yields.

CROP MANAGEMENT

Seeding Considerations

Crop yield depends to a great extent on seed quality. The risk of crop failure is substantially reduced if seed germination is 90% or better. **Seed germination will be the highest if the pea seeds are allowed to dry slowly on the plant and then are stored at a moisture content below 16%.** Pea seed is very susceptible to physical damage during threshing, cleaning and other handling, especially if the seed moisture content is below 14%. To maintain pea seed quality, gentle handling is essential as damaged seed will not germinate. **Express, an older variety, is much more susceptible to mechanical damage than most other varieties.** Seed damage can be caused by bleaching, poor weather before harvest, weathering, conveying, combining, aging in storage, diseases, insects, or other factors. Poor quality seeds are susceptible to infection by seed rot and seedling diseases.

Captan, DLC, Apron FL, and Thiram are registered seed treatments for peas. Studies in Alberta have shown that the benefit of using seed treatment is inconsistent, but it may reduce disease if seeding into cold, water-logged soil.

Inoculation

The legume-*Rhizobium* combination has the potential to fix up to 70% of the nitrogen needed by the pea crop so it is important to ensure proper inoculation. To carry out successful pea inoculation, a grower should use *Rhizobium* inoculant of the pea strain. The inoculant must be stored in a cool place prior to use and must be used before the expiry date. The sticker (depending on the type of inoculant) and the inoculant (see *Chapter 2 - Inoculants*) should be thoroughly mixed with the seed just prior to seeding (FIGURE 3).

FIGURE 3. Effect of Inoculation on Pea (left).

TABLE 4. Description of Registered Yellow Cotyledon Dry Pea Cultivars (1997).

Cultivar	Year Regist.	Maturity	Vine Length	Leaf Form	Saskatchewan Yield as % Grande South	North	Irrigate	Ascochyta Blight Resist.	Powdery Mildew Resist.	Seed Coat Break.	Lodging Resist.	Seed Weight (g/1000)	Market Class	Comments
AC Tamor	1990	late	short	normal	81	64	75*	poor	very good	good	poor	280	food	Powdery mildew resistance
Alfetta	1996	medium	medium	semi-leaf	106*	108*	105*	poor	poor	poor	fair	290	food	
Anno	1994	early	short	semi-leaf	73	85	115	poor	poor	poor	fair	250	food	
Baroness	1993	early	medium	semi-leaf	89	90	101	poor	poor	fair	fair	290	feed	Angular seed
Bohatyr	1991	medium	medium	normal	85	80	85	fair	poor	fair	fair	270	food	at Fair ascochyta
Carrera	1996	early	short	semi-leaf	103*	107*	114*	poor	very poor	poor	fair	270	food	
Carneval	1993	early	medium	semi-leaf	91	92	119	fair	poor	poor	good	250	food	Good standability
CDC April	1995	late	short	semi-leaf	88*	77*	78*	fair	poor	good	fair	140	feed	Maple/coloured flower
CDC Vienna	1995	late	short	semi-leaf	94*	87*	99*	fair	poor	good	fair	170	feed	Maple/coloured flower
CDC Winfield	1996	medium	medium	normal	99	97	90	poor	poor	poor	fair	260	food	
Celeste	1993	early	medium	normal	80*	71*	103	poor	very poor	poor	poor	270	food	
Choque	1994	medium	short	semi-leaf	79	79	108	poor	poor	fair	fair	260	feed	Blocky seed
CPB CONCORDE	1995	early	short	normal	99*	99*	115*	poor	very poor	poor	poor	280	food	
CPB SPITFIRE	1995	medium	medium	normal	84*	88*	124*	poor	poor	poor	poor	230	food	
DISCOVERY	1995	medium	medium	normal	NR	NR	107	poor	poor	poor	fair	320	food	Recommended for irrigation
EIFFEL	1996	early	medium	semi-leaf	99	112*	106*	poor	very poor	poor	fair	290	food	
ENDEAVOR	1995	medium	medium	normal	NR	NR	109	poor	poor	poor	fair	260	food	Recommended for irrigation
Express	1987	medium	medium	normal	92	90	91	poor	poor	poor	poor	240	food	Yield standard
FLUO	1993	early	medium	semi-leaf	83	87	90*	poor	poor	fair	fair	320	feed	Very early maturing
GRANDE	1994	medium	medium	normal	100	100	100	poor	very poor	good	fair	260	food	
Highlight	1993	early	medium	semi-leaf	90	92	104	poor	very good	poor	fair	210	food	Powdery mildew resistance
Impala	1993	medium	medium	semi-leaf	88	83	101	poor	poor	poor	fair	270	feed	
LG 110	1996	early	short	semi-leaf	100*	108*	102*	poor	very poor	poor	fair	260	food	
Mandy	1995	medium	short	semi-leaf	101*	91*	105*	poor	very poor	poor	fair	270	food	
MARCO	1996	early	medium	semi-leaf	85*	85*	124*	poor	very poor	poor	fair	260	food	
Miko	1991	early	medium	semi-leaf	96	82	110	poor	poor	poor	fair	260	food	
Montana	1993	early	short	semi-leaf	89	95	103	poor	poor	good	fair	300	feed/food	Very early maturing
MUSTANG	1995	early	short	semi-leaf	94	86	105	poor	poor	fair	fair	210	food	
Patriot	1991	early	medium	semi-leaf	86	91	108	fair	very poor	poor	fair	200	food	
PROFI	1995	early	medium	semi-leaf	96	94	102	poor	poor	poor	fair	270	food	
Proton	1995	early	medium	semi-leaf	*	*	*	poor	poor	poor	fair	230	food	
Richmond	1992	medium	medium	normal	91	91	89	fair	very poor	poor	poor	210	food	
Scorpio	1996	early	short	normal	83	75	94	poor	very poor	poor	poor	280	food	
Sirius	1989	medium	tall	normal	76	75	*	poor	poor	good	poor	240	feed	Maple/coloured flower
Spring D	1992	early	medium	normal	86	85	90*	poor	poor	fair	fair	240	feed	
Stehgolt	1989	early	short	normal	61	75	*	poor	poor	poor	poor	290	feed	
Tara	1978	late	tall	normal	82	82	87	fair	very good	fair	fair	210	feed	Powdery mildew resistance
TENOR	1996	early	medium	semi-leaf	100*	107*	100*	poor	very poor	poor	fair	260	food	
Titan	1985	late	tall	normal	76	70	80	poor	poor	poor	poor	250	food	
Topper	1989	medium	tall	normal	82	74	*	poor	poor	fair	poor	290	food	
Trapper	1970	late	tall	normal	79	80	*	poor	poor	poor	poor	140	food	Small seed
Victoria	1984	medium	medium	normal	86	85	*	poor	poor	poor	poor	190	food	
VOYAGEUR	1995	medium	short	semi-leaf	NR	NR	109	poor	poor	poor	fair	190	food	Recommended for irrigation
YORKTON	1995	medium	medium	normal	98	97	97	poor	poor	poor	fair	270	food	
Whero	1989	late	tall	normal	64	63	*	poor	poor	good	poor	210	feed	Maple/coloured flower
Yellowhead	1989	late	tall	normal	*	*	*	poor	poor	fair	poor	252	feed/food	Food fibre extraction

"Yield data: South = Areas 1, 2, & South 3, North = Areas North 3 & 4" * Limited data NR = Not recommended
** Check Saskatchewan Seed Guide for distributors. Source: Saskatchewan Agriculture and Food

TABLE 5. Description of Registered Green Cotyledon Dry Pea Cultivars (1997).

Cultivar	Year Regist.	Maturity	Vine Length	Leaf Form	Saskatchewan Yield as % Grande South	North	Irrigate	Ascochyta Blight Resist.	Powdery Mildew Resist.	Seed Coat Break.	Lodging Resist.	Bleach Resist.	Seed Weight (g/1000)	Market Class	Comments
Ascona	1995	medium	short	semi-leaf	81	71	124	poor	poor	poor	fair	poor	300	food	Oval seed
CPB PHANTOM	1995	medium	short	semi-leaf	94	78	101	poor	poor	poor	fair	poor	310	food	
Clipper	1995	medium	short	normal	96	82	100	poor	poor	poor	fair	fair	300	food	
Danto	1990	medium	short	semi-leaf	73	56	100	poor	poor	fair	fair	fair	290	food	
Emerald	1992	medium	medium	normal	80	84	97	poor	poor	fair	fair	fair	250	food	
Keoma	1996	medium	short	semi-leaf	90	86	100	poor	poor	poor	fair	good	240	food	
MAJORET	1994	medium	short	semi-leaf	84	82	109	poor	poor	fair	good	fair	250	food	
Obelisque	1996	medium	medium	semi-leaf	100	98*	102*	poor	very poor	poor	fair	fair	310	food	Blocky seed shape
Olivin	1995	medium	medium	normal	98*	98*	96*	poor	very poor	fair	poor	fair	270	food	
ORB	1992	medium	short	semi-leaf	72	76	102	poor	poor	poor	fair	poor	240	feed	
Princess	1988	early	short	normal	77	60	91	poor	poor	good	poor	good	200	food	Good bleaching resistance
Promar	1994	medium	medium	normal	*	*	*	poor	poor	good	poor	fair	300	food	Marrowfat specialty market
Radley	1990	medium	short	semi-leaf	77	75	91	fair	poor	fair	fair	good	210	food	
Ricardo	1993	medium	short	normal	81	74	127*	fair	poor	fair	poor	fair	280	food	
TOTEM	1995	medium	short	normal	94	84	93	poor	poor	poor	fair	fair	240	food	
Trump	1990	late	medium	normal	71	64	*	poor	poor	fair	poor	fair	250	food	

"Yield data: South = Areas 1,2 & South 3, North = Areas North 3 & 4" * Limited data NR = Not recommended

** Check Saskatchewan Seed Guide for distributors. Source: Saskatchewan Agriculture and Food

Fertilization

In general, fertilizer requirements are always best determined by soil test (see *Chapter 2 - Fertilizer*). Crop inspection and tissue testing once the crop has emerged can identify localized deficiencies. Most of the pea crop nitrogen requirement can be supplied by the *Rhizobium*. Additional amounts are rarely required; however, if the soil tests less than 15 lb/ac available nitrogen in the top foot, then up to 30 lb/ac of additional nitrogen may be of some benefit, especially when the crop is irrigated or if the soil is low in organic matter.

Nitrogen should not be placed with the seed. (Refer to *Chapter 2 - Figure 2* for details of yield damage from seed placed nitrogen.) In the Black soil zone, or in other soils with higher organic matter (>5%), but low available nitrogen, peas may need an addition of up to 20 lb/ac as the soil should be able to supply additional nitrogen through release of nitrogen from the organic matter. **The application of excess nitrogen is likely to result in less nodulation and less nitrogen fixation. This may result in longer vines, delayed maturity, more lodging, and associated harvest problems.**

If soil tests indicate that phosphorus is required, up to 15 lb/ac of phosphate may be seed placed. This recommendation is based on research using a double disc press drill based on a 6- to 7-inch row spacing. Maximum safe rates will be lower when using wide row spaces (10 to 12 inch) with narrow spread patterns. Higher rates may be used, if the seed-placed phosphate fertilizer is spread laterally in a 2 inch or wider strip to reduce direct contact with the seed. Any additional amount can be side banded with an opener which provides adequate separation, or should be banded before seeding or broadcast and incorporated. Another alternative is to use "Provide", a fungal inoculant that enhances phosphorus uptake by plants. It can be seed placed either alone or in conjunction with the maximum allowable 15 lb/ac of phosphate. It is a self-sticking liquid product that can be used as a sticker for peat-based inoculants.

Potassium may be deficient in Black and Grey soils. Soil tests should indicate if a problem exists. Soil tests can show adequate potassium reserves, but the crop may not access it due to other factors. Over 130 lb/ac of potassium is needed to grow a 50 bu/ac crop. (The potassium requirement of peas is high, especially during flowering and early pod filling.) Generally, potassium fertilizer should be used any time soil tests show levels below 240 lb/ac. When soil test levels are very low, at least some should be seed placed; however, seed placing more than 15 lb/ac of total nitrogen plus potassium may cause crop damage. As with phosphate, a wider seed row may allow for slightly higher seed-placed rates as direct seed to fertilizer contact is reduced. More information on potassium fertilization is available in "Farm Facts, Potassium and Chloride Fertilization in Crop Production" available from Saskatchewan Agriculture and Food.

Sulphur deficiencies usually occur in small areas within a field so pulse crops should be visually checked for sulphur deficiency symptoms and if a deficiency is suspected, they should be tissue tested. Even flat fields with no apparent soil change can have extensive fluctuations in sulphur content. The pea sulphur requirement, which is in the 10 lb/ac range, is similar to that of wheat. The symptoms of sulphur deficiency are a yellowing of the plant from the top downward. The plant will have the general appearance of a plant with nitrogen deficiency except that the top leaves yellow first. Peas grown in most soils which test low in available sulphur will not respond to traditional sulphur fertilization with elemental sulphur in that crop year. Some newer products may convert quickly enough to be usable in the crop year, or sulphur applied at higher rates or fall applied may be effective. Elemental sulphur generally should be applied up to one year or even more before it is required as it takes some time, depending on the product, to convert it to the sulphate form which the plants use. As such, it is often applied with the fertilizer for the previous year's crop and in excess amounts to provide for sulphur needs for a number of years. **Sulphur can be blended with some fertilizers, but not with ammonium nitrate.** In cases where poor sulphur availability occurs along with low levels of nitrogen, sulphur requirements can be provided in the crop year by using ammonium sulphate (20 or 21-0-0) at the rate needed to provide the sulphur requirements. Sulphur can also be applied in the crop year as a liquid fertilizer by using liquid ammonium thio sulphate. It can be blended with most non-acid liquid fertilizers.

Micronutrients are also required for pea production. Soil tests or foliar tests can identify shortages if a problem is suspected.

Time of Seeding

Pea seeds will germinate at temperatures as low as 4°C, and pea seedlings will tolerate light frosts and can even regrow after severe frost. The best yields and quality are usually obtained from early seeding. Seeding can begin when the top inch of soil reaches 5°C, if the soil is not too wet. This condition generally occurs in the Black and Grey soils in early May. **Peas should be seeded between April 15 and 30 in the Dark Brown soil zone in order to increase the chance that flowering will be complete before the hot temperatures of July reduce yield by causing flowers to blast and not set pods.** In cool, wet summers, pod set may continue into August with resulting high yields.

Germination and plant development are more rapid when peas are seeded into warmer soils, but later seeding is less likely to provide the best yields. Later seeding does decrease the chance of seedling diseases.

Seeding Rate

Pea seed varies with size, variety, and even with the seed lot. The correct seeding rate is easy to calculate if the seed weight is known. **Recommended seeding rates are based on a goal of 8 plants/sq ft, or 12 good seeds per yard of row with rows 6 inches apart.** Seeding rates for a range of seed sizes are presented inTABLE 6.

TABLE 6. Seeding Rate vs Seed Size in Pea.

Seed Weight g/1000 Seeds	Seeding Rate
150	120 lb/ac
180	144 lb/ac
210	172 lb/ac
240	192 lb/ac
270	216 lb/ac
300	240 lb/ac

Seed drills should be calibrated after inoculation as inoculant may reduce the flow rate through the equipment. Seeding rates should also be calculated based on the tested germination rate of the seed (see *Chapter 2 - Seeding Rate*).

Lower than recommended seeding rates will reduce the competitive ability of peas and usually will result in reduced yields. Higher than recommended rates may be used as a hedge against anticipated seedling losses from causes such as post-emergent harrowing. However, as higher seeding rates may support an increase in the spread and severity of disease, a balance must be struck.

If peas are intercropped with a cereal for silage, peas are generally seeded at 75 to 100% of the recommended rate whereas the cereal rates are reduced to 25% of the normal cereal seeding rate for silage production. Peas may be intercropped with canola or mustard to reduce lodging and facilitate swathing. To be effective, peas are generally seeded at the recommended rate, while the oil seed is seeded at 50% of the recommended rate. Seeding the cereal or canola 5 to 7 days after seeding peas will help the pea seedlings to compete in the mixture.

Seeding

Traditionally, early spring cultivation to the seeding depth has been the recommended method to warm and mellow the soil for more rapid germination. Spring cultivation should be minimized, particularly in drier areas to avoid drying out the soil and to reduce the risk of soil erosion. Recent advances in direct seeding have provided a solution to this problem. A properly designed direct seeding opener and packer system can create a micro-climate in the seed row which allows for soil warming and produces excellent germination conditions. The elimination of prior cultivation retains soil moisture reserves and eliminates the risk of erosion. The retention of soil moisture allows for shallower seeding and a quick emergence of the crop.

Seed drills or air seeders must have adequate metering devices to handle the large pea seeds. If an air seeder is used, extra caution is necessary to avoid seed damage. The air velocity should be set as low as possible without the hoses plugging. To obtain low enough airflow rates to reduce seed damage in some machines, it may be necessary to reduce the travel speed. Since a lower speed requires lower seed flow rates, a lower air velocity will carry the lesser quantity of seed without plugging occurring.

Pea seeds are very sensitive to seed coat damage, though some varieties are more durable. The older variety Express is extremely susceptible to mechanical damage, especially if the seed moisture level is much below 14%. Some growers use a water hose to wet a truck box full of seed the day before seeding and let the excess moisture drain off over night. This procedure adds about 1% seed moisture and helps to reduce damage.

Pea seedlings are able to emerge from relatively deep seed placement because the seeds are large, but the seeds are quite sensitive to moisture conditions. They require large amounts of moisture for germination, but soils that are too wet foster seed and seedling disease. Also, waterlogged soils do not provide enough oxygen for adequate germination. **The best seeding depth is often 2 to 3 inches when seeding into preworked soil. When direct seeding, it is often possible and advisable to seed much shallower, but the seed must be placed firmly into moist soil.**

After seeding with a drill, discer, or air seeder without packers, the soil should be harrowed or harrow packed to level and firm it around the seed. If soil moisture is high, delay harrowing or harrow packing for 1 or 2 days to allow seed respiration. Overpacking should be avoided, particularly if the soil is a very wet clay or low organic matter grey soil where crusting can occur. Rolling should also be done at this stage, provided that the soils are not too wet. **In heavy clay soils where rolling before emergence can cause crusting problems, rolling should be done between emergence and the 5-leaf stage.**

Intercropping

Two different types of pea intercrops (both crops grown in the same field) are occasionally used. The need for intercropping to improve "standability" of the pea crop has been reduced by the availability of semi-leafless varieties. Even without the new varieties, advances in harvesting equipment such as vine lifters, reels, and flex headers have made it possible to achieve the same advantages by a simpler method. As a result, the use of intercropping for improved standability has declined.

A pea-cereal intercrop can be used to improve silage quality. The cereal increases the carbohydrate content, which facilitates ensiling. The legume increases and balances the protein content. Barley is often the preferred cereal as it is high yielding and early maturing, and barley has a higher feeding value than oats. If the barley and peas are seeded in strips, they do not compete directly. They are then harvested across the strips to provide some mixing of the harvested materials. If the peas and barley are seeded in a mixture, both components yield less than when they are grown alone, but the peas will twine around the barley and stay off of the ground. The mixture is generally harvested when the lower pods reach maturity and show signs of starting to dry down, and the cereal is in the late milk to soft dough stage. Earlier harvesting increases the proportion of cereal in the mix; lateharvesting increases the proportion of pea seeds. After swathing, the pea should be allowed to wilt to 65% moisture before ensiling.

A pea-canola (peaola) or pea-yellow mustard mixture is sometimes used to provide growth support for pea vines. This improved standability reduces the opportunity for disease and lodging. Standard harvest equipment can then be used, and swathing is delayed less after a rain. A crop desiccant usually is not needed. Shattering losses are minimized since the pea plants can mature in the swath which is anchored and dries well if needed after rain. The oil seed provides a buffer for the pea in the combine and in augers, reducing pea seed damage. The crop can be cut higher off the ground so there is less earthtag (dirt stuck to the seed coat), and more standing stubble is left to trap snow over winter.

When intercropping (peaola), fertilizer recommendations for canola should be followed, though the excess nitrogen availability will reduce nodulation of the pea plants. Several herbicide options exist. (Refer to the Saskatchewan Agriculture and Food Crop Protection Guide for detailed options.) Sencor-trifluralin mixture should only be used if a triazine-tolerant canola variety is used. The crop can be combined at 16% moisture for the peas and 9 to 9.5% moisture in the canola. **The two should be separated before they are binned.** If they are dried together, mixing with a bin spreader will help reduce clumping of the oil seed and dockage, which may restrict airflow in the drier.

In-Crop Considerations

Rolling

Stones or soil lumps on the soil surface interfere with pea harvesting. Rolling allows for higher speeds when swathing or direct combining, and reduces guard and sickle section breakage. Peas can be rolled after harrowing or harrow packing if conventional tillage is used or after seeding if direct seeded. **Heavy or excessive rolling with wet, heavy soils causes crusting which will interfere with emergence. In such cases, post emergent rolling prior to the 5-leaf stage should be used.** All rolling should be carried out on dry days to lessen the spread of disease.

Weeds

Pea plants are more competitive with annual weeds, if these emerge rapidly and cover the soil surface before the weeds germinate. If emergence is slow or germination is poor, weeds have an advantage. Factors such as diseases, insects, and low fertility will also reduce the competitive ability of peas.

Research at Morden has determined that different varieties have a different competitive ability against wild mustard. Tall, rapidly developing varieties such as Titan, Topper, Tipu or Victoria were more competitive than the shorter types such as Radley, Danto, Patriot, Trump and AC Tamor. The wild mustard grew above the canopy of the shorter pea varieties. The leaf form (semi-leafless vs normal) did not appear to make a difference in competitive ability. The older varieties, such as Express and Century, had an intermediate ability to compete with wild mustard.

At Melfort, Express, Century, and Titan peas did not have a different competitive ability against a mixed infestation of grassy and broadleaf weeds. The research indicates that the competitive ability in peas depends strongly on the weed types and the environmental conditions. The Melfort study showed that peas were more competitive at higher seeding rates of up to 9 plants per square foot. At lower seeding rates with reduced competition, the use of herbicides to control weeds becomes more important.

Good weed management depends on a strategy that considers the management system of the farm and the entire field rotation, rather than simply the pea crop. Techniques described in *Chapter 2 - Weeds* are applicable to peas.

Harrowing with a tine harrow between seeding and crop emergence will often control weeds that have escaped previous efforts. Harrowing should be avoided immediately after crop emergence to prevent damaging the seedlings. Post-emergent harrowing for weed control is generally less effective. Weed control may be erratic and crop damage may cause variable maturity. The amount of damage is reduced if finger weeders or flexible harrows are used. **If post emergent harrowing is used, it should be done on a dry, warm,**

sunny day for the most effective weed kill and to reduce seedling damage and the spread of disease.

A large number of herbicides are registered for use in peas in Saskatchewan. *Chapter 2 - Weeds* lists these herbicides and briefly discusses their use. Additional information is found in the publication "Crop Protection Guide" from Saskatchewan Agriculture and Food, and of course, on the herbicide labels. Always follow label precautions and directions as they may vary for different crops.

Quackgrass, perennial sow-thistle, and Canada thistle are difficult weeds to manage in a pea crop and are easier to control in other years of the rotation. Pre-harvest application of glyphosate in the previous year's crop is one method that can be used to control these weeds. Spot spraying may be advisable as pea losses are generally severe. Wild buckwheat, cleavers, Russian thistle, and kochia are weeds that can remain green and make harvesting peas difficult, and interfere with drying and storage of the crop. Weed management in peas is easier, if fields with infestations of these weeds are avoided, or if these weeds are controlled in other years in the rotation.

Pea plants are sensitive to residual herbicides. Keep a complete record of herbicide use for each year and refer to recropping restrictions on the label. If herbicide carryover is suspected, a test area can be seeded in the year prior to seeding the pea crop. The test area should be allowed to mature to properly indicate potential problems as pea may initially show normal growth, but may not set seed or may die later in the season. A chemical assay can also detect herbicide residues. Pea plants are also especially sensitive to 2,4-D drift which can cause serious crop injury.

If trifluralin is used, fall incorporation provides the advantages of uniform distribution of active ingredient and conservation of spring soil moisture by reducing the need for spring tillage. With fall incorporation, there is a possibility of increased crop tolerance, and the reduction in spring tillage should allow earlier seeding. However, fall incorporated products are not recommended if the soil is prone to erosion from wind or water in the fall or spring or if fall soil conditions prevent thorough incorporation. A spring tillage operation is still recommended to warm and aerate the soil to activate those herbicides which are fall applied. Although not registered for this use, studies at Scott and Indian Head using surface applied trifluralin under no-till conditions have shown weed control and crop safety comparable with incorporated trifluralin. Pre-seeding burnoff by herbicide applications of glyphosate (Roundup) are usually only effective for later seeding dates as there is often little weed germination prior to early seeding dates for peas.

If post-emergent herbicides are used, they should be applied before the 4- or 5-leaf stage to ensure weeds are at the best stage for optimum coverage and control, and the pea crop will be the most resistant to damage. Application of post-emergent herbicides after pea vines reach the 5-leaf stage causes vine damage from the sprayer, and pea plants often will show increased sensitivity to herbicide injury by this point. Annual weeds (particularly broadleaf species) may already be too large for effective control and the yield may have already been reduced, even if the control measures are effective.

Insects

In Saskatchewan, it is not likely that any insects other than grasshoppers will be a problem. Even the grasshopper risk is not severe. Although grasshoppers can cause severe damage to a pea plant, peas are not a preferred food for them. In addition, the main areas of pea production are not in the main areas which usually have heavy grasshopper infestation. In general, infestation of grasshoppers of 10 per square yard or less does not cause enough damage to be of economic significance, but the stage of crop growth when infested plays an important role in the effect that grasshoppers have on the crop in any given year.

Pea aphids are a problem of economic importance in Manitoba. In Saskatchewan's cooler climate in the areas where peas are grown, aphids develop more slowly and are less likely to cause severe problems. Pea aphids are small (about one-eighth of an inch), light green, long-legged insects. They may overwinter as eggs in alfalfa and clover and then fly into neighbouring pea fields, but more commonly they blow in from the United States in early summer. Populations of 10 aphids per plant can begin to cause an economic effect, especially if the plants are heat stressed. The aphids suck the sap from the plant and weaken it, but even more importantly, they can act as the disease spread mechanism for viral diseases.

Aphids can be controlled chemically or biologically, but heavy rains or strong winds can also virtually eliminate them.

FIGURE 4. Mycosphaerella Blight Showing Lesions on Stems, Leaves and Pods of Pea Plants.

Diseases

Disease management through crop rotation is important in reducing the likelihood and severity of disease (see the suggestions given in *Chapter 2 - Disease*). Several diseases occur in peas in Saskatchewan.

Mycosphaerella blight and ascochyta foot rot are the most common diseases of peas in western Canada and are of the greatest economic concern. It is often difficult to distinguish between them in the field. Losses of up to 80% have been reported when a heavy infection occurs in mid-June. Mycosphaerella causes purple spots on leaves and basal stems. The spots may come together to form into larger lesions (FIGURE 4), and the leaves may dry up. The lesions may also be found on flower petals and when this occurs, the lesions are followed by blossom drop. The lesions form on the pods, and the fungus can infect the seed as well. Infected seed may appear normal, or may be shrunken and discoloured. Similar lesions form during ascochyta foot rot, though they are commonly more concentrated at the base of the stem and near the point where the cotyledons are attached. With ascochyta foot rot, a blackening of the taproot and base of the stem may occur. Early season infection leads to weathering of the stem base and the collapse of the plants as the first pods fill, resulting in premature lodging and further yield and quality reductions.

Mycosphaerella is a seed-borne disease, but infected plant debris is the primary source of infestation in established pea areas. Mycosphaerella also produces persistent, long-lived chlamydospores which serve to maintain the disease in the soil for long periods of time. Sowing disease-free seed decreases the risk of spreading the disease into new pea growing areas. Seed produced in semi-arid areas is less likely to carry the disease. Both crop stubble and soil particles may carry spores for several years and these spores can be blown several miles. With both diseases, healthy plants can contact the infection as they emerge through infected residue, and additional transmission may occur with rain splash of soil onto leaves and stems. Good crop rotations, with a 4 year break between pea crops and the removal or burial of infected plant material, lessens the risk. **As spores also travel in the wind, locating fields as far away as possible from fields seeded to peas in the preceding 4 years may be helpful.**

Seedling blight can be caused by a number of different fungi. The main symptom is the death of the young seedling as it emerges, and before the leaves expand (FIGURE 5). In severe cases of seed rot, the seed and seedling are encased in white cottony mold. The fungi that cause seedling blight are common in the soil. Infection is more likely if the soil around the seed is excessively wet. Seeding peas after alfalfa, beans, flax, or lentils increases the risk. This disease may be more difficult to control in no-till systems due to the maintenance of surface residue which maintains a more favourable environment for the disease. To prevent this being a problem, a rotation which provides an adequate time period between pea crops is extremely important.

FIGURE 5. Seedling Blight of Pea Plants.

FIGURE 6. Sclerotinia Plant Lesion on Pea Stem.

Sclerotinia stem rot is less likely to be of economic concern with the newer short erect pea varieties. The symptoms include a white mat-like growth on older tissue lying on the soil surface. Leaves yellow or wilt, and hard black bodies (sclerotia) develop inside the hollow pea stem or pods (FIGURE 6). Infection occurs when lodged stems come into contact with infected petals previously dropped on the soil surface. Generally, yield losses are minor, although infected plants may wilt or ripen prematurely. Of greater concern is the fact that the black sclerotia that develop inside the stem and pods thresh out, contaminating both the soil and the pea seed. Sclerotia survive in the soil and are carried with the seed. They produce spores the next July that can also be carried for miles on the wind. The risk of sclerotinia is greater if peas follow lentils, beans, faba beans, rapeseed, canola, mustard, sunflower, or safflower. Risk is also increased if the crop is sprinkler irrigated, the crop canopy is dense, or if the crop is subject to cool, moist weather. Varieties which remain standing until late in the season are less prone to sclerotinia infection.

Powdery mildew does not generally cause yield losses unless infection occurs prior to pod set. Infection usually occurs in late summer, and thus it is more apparent on medium and late maturing varieties. The first symptoms of the disease are white spots which occur first on lower leaves and then on stems and pods. The white powdery spots can eventually spread to cover the entire plant (FIGURE 7). Under the white mat, the pea plant appears brown or purple. Heavily infected plants do not mature normally. Frequent rain can control the infection by causing spores to swell and burst rather than germinate. Dew without rain and cool nights favour the disease. The fruiting bodies overwinter on plant debris and are carried in the air. There are three powdery mildew resistant pea varieties currently available: yellow food varieties AC Tamor and Highlight, and the feed variety Tara. The fungicide Kumulus is registered as a control and may be of benefit if powdery mildew is known to be a problem in the area. Sulfur is the active ingredient in Kumulus, but it is in a form that stays in suspension in water.

FIGURE 7. Powdery Mildew on Pea Plants.

Septoria leaf blotch seldom reduces yield as it affects mainly aging leaves. It causes yellow blotches on the leaves which become speckled with tiny brown fruiting bodies. The disease is spread by rain splash, and the fungus overwinters on plant debris.

Bacterial blight is not common, but can be destructive in wet years. Dark green, water-soaked spots form on leaves, stems and pods. Under cool and humid conditions, these spots enlarge and turn brown, and often have a greasy appearance. Severe infections can kill seedlings, or cause pod abortion. The infection spreads by rain or irrigation splash, from stubble or infected plants, or from direct contact of leaf to leaf. Hailed fields tend to have increased levels of bacterial blight. It can also be spread by harvesting equipment. Contaminated straw will be free of the bacteria after a year. The bacteria can overwinter in the pea seed.

A relatively new disease, pink seed, is also caused by bacterial infection. The bacteria enter the pods through wounds and discolour the seeds. Yield is generally not affected, but pink coloured seeds are undesirable and are treated as dockage so the quantity of good peas is reduced. Pink seeds are often confused with treated seed and may be considered as a contaminant.

Pea seed-borne mosaic virus causes mottled yellowing of the upper leaves and decreased vigour. It has rarely been a problem in Saskatchewan, but it can be introduced by aphids that blow in from other infected areas or by the planting of infected seed.

Four products are registered to control pea diseases in Saskatchewan. Captan (including DLC), Apron FL, and Thiram are registered seed treatments for the control of seed rot and seedling blights. Although studies in Alberta have failed to show a consistent benefit from these treatments, in wet, cold soils there may be a benefit. Kumulus is registered for powdery mildew control.

Herbicide injury can cause symptoms similar to disease such as distortion of leaves and stems, yellowing, stunting, and dead areas on the edges of leaves and between the veins. Flowers may abort and in serious cases, seed set may be reduced.

Irrigation

Peas are well suited to the Black soil zone, but can consistently be grown very successfully in wet years or under irrigation in the Brown or Dark Brown soil zones. In general, the agronomy of irrigated peas is similar to that of dryland peas. Early maturing short vine varieties are best suited for irrigated production. Yields average 2700 lb/ac, but can be as high as 3500 lb/ac.

Excess irrigation can result in early lodging and disease development. Rotations that include at least a 2-year break away from legumes, mustards, and sunflowers reduce the risk of soil-borne diseases. Typically, peas are grown on cereal stubble.

Irrigation prolongs the growing season requirement, making it critical to seed as soon as soil temperatures reach 5^0C. Seed should be placed 2 to 3 inches deep or into moisture. Light irrigation (less than 1 inch) before seeding may promote germination. Lack of potassium can limit yield on sandy soils after several years of irrigation. Potassium fertilizer should be used if soils test below 240 lb/ac.

Once established, pea plants can tolerate low moisture, but not drought, until the beginning of flowering. Excess moisture while the plants are growing increases vine growth but does not increase yield. The best yields (more pods per plant and more seeds per pod) are obtained if soils are brought to field water capacity just before flowering and all water use is continually replaced during the flowering period. The field water capacity should be based on 2 ft soil depth, if pivot irrigation is used, and on 3 ft depth, if sideroll or gravity sprinklers are used. **The plants can use 2 inches of water per week, whether from rain or irrigation.** After flowering is complete, continued irrigation is not recommended as it is likely to delay maturity and promote stem diseases. See TABLES 4 and 5 for suitable pea varieties for irrigated production.

Harvest

The decision of when to harvest involves a compromise. Harvesting too early does not allow the seeds of yellow varieties to fully mature as some seed remains green, resulting in a reduced grade.

Harvesting too late increases harvesting losses from shattering and increases the risk of weather damage to seeds. Green varieties may bleach. The crop dries very quickly once mature if the weather is warm and dry. Field scouting helps in determining the best time to harvest. Scouting should be done during warm, dry periods to reduce the transmission of disease. The crop matures from the bottom up and is mature if the bottom pods are dry and tan coloured, and if seeds have detached from the pods and will rattle. At maturity, middle pods are yellow-tan and the pea seeds are dry and firm. Top pods are similar to middle pods, or may have some green seeds that are not yet dry and firm.

If the crop is uniformly mature, it can be straight-cut, or swathed and immediately combined. If some areas of the crop are green or have green weeds, while other areas are dry, spot combining, desiccation, or swathing may be beneficial.

Desiccation

Reglone is a desiccant registered for use in peas in Saskatchewan (see *Chapter 2 - Desiccants*). It can be used when all pods are fully mature. It will not hasten maturity, but will dry vines and kill most weeds that interfere with harvesting. Desiccation is often used on dry green pea varieties in order to reduce the time in combining and to help retain the bright green colour demanded by the food market. After desiccation, dry green peas are combined at 20% seed moisture and aerated down to 16% moisture to help retain the green colour.

Swathing

The crop can be successfully swathed when a majority of vines and pods are yellow to tan. Pods will cure in the swath if no more than 1/3 of them are green. Fully formed seeds generally dry without much shrinkage. Delays to allow low lying areas to mature may jeopardize the quality of the rest of the crop, and are likely to increase shattering losses. If the crop is short, with many pods near the ground, swathing while the crop is still partly green will help reduce shattering losses. Swathing at night or early in the morning may also reduce shattering losses as the pea pods will be damp from dew.

The pea crop is often lodged at harvest. Swathing is easier if done at right angles to the direction of lodging. If the crop is long and heavy, a narrow swather cut may be necessary.

If the crop is swathed when fully mature, the combine should directly follow the swather to prevent windblown swaths. The use of a canola swath roller may help reduce wind damage by flattening the swath, if the swath requires a few days of warm weather to cure. A dry swath is more prone to wind damage, and shattering may occur during rolling.

Straight Cutting

Pea pods are not prone to excess shattering, if they are left standing, so the preferred harvest method is often to straight combine at full maturity. Straight combining results in fewer losses at the cutterbar because any pea seeds released from cut pods are carried onto the header and into the combine. These pea seeds would be lost if the crop was cut with a swather.

Threshing

Ideally, the crop can be threshed at 20% moisture content. The splitting and cracking of seeds increases as the seeds dry. Damaged seed is downgraded for seed or for human consumption. When threshed too green or wet, the vines are more likely to plug and wrap in the combine, slowing harvest operations, and there will be an increase in the amount of earthtag.

Pea seeds require gentle handling for optimal quality. Cylinder speeds of 250 to 600 rpm, depending on cylinder diameter, are often used. Concaves may be initially set to between 1/4 and 5/8 inch clearance in front and to 1/2 inch clearance in the rear. Chaffer sieves are often set at a 5/8 to 3/4 inch opening and cleaning sieves at 3/8 to 1/2 inch. The tailings should be kept to a minimum to reduce seed damage.

A very mature crop can be pulled and combined, using special equipment such as a Rake-up or Sund pick-up. This harvest method requires a weed free crop with dry, brittle stems, which occurs usually as a result of a very mature crop and rain and redrying. This harvest method is not suited to green peas as the crop will generally bleach before it is sufficiently mature to harvest in this manner.

POST HARVEST

Drying

Peas can be stored at 16% moisture or lower. Because harvest is more successful at higher moisture levels, drying is often necessary. The crop should be cleaned as soon as possible after harvest. **If the crop is to be used as seed, it should not be dried at temperatures over 45°C as high temperatures and rapid cooling will cause stress cracking of the seed and reduced germination.** Instead, drying should take place in 2 stages if the moisture content is to be reduced by 5% or more. An aeration bin can be used effectively in conjunction with a hot air dryer. For best efficiency, pea seeds can be dried to within 2% of final moisture content and then tempered in the aeration bin for at least 6 hours after which they can be cooled to outdoor temperature. This slow cooling reduces cracking and removes an additional 2% moisture content during the cooling process. Drying at temperatures above 45°C may cause quality losses due to hardening, if the pea seeds are intended for food use. Temperatures up to 70°C should only be used for drying feed peas. Aeration bins can be used both for drying and also to eliminate condensation problems during fall and spring periods. During these times, the fan can be run sufficiently to cool or warm the grain in parallel with seasonal temperature changes. This practice prevents air circulation patterns establishing and condensation developing in the bin.

Storing and Handling

To avoid heating in the bin, the crop should be cleaned of all green seeds and dockage before storage. With peas, a great deal of respiration occurs, especially shortly after harvest. The term "going through a sweat" is used to describe this period. Extra care should be taken to routinely monitor bins and to inspect for moisture buildup or spoilage. Aeration bins can be used effectively to deal with sweating problems and to cool the grain in fall and warm it in spring to relieve moisture problems due to condensation. Storage of pea seed at too high a moisture content can lead to germination and spoilage. Maximum storage periods at various moisture contents and temperatures are provided in *Chapter 2 - Table 18.*

Grading

The Canadian Grain Commission under recommendation of the Producer Trade Advisory Committee sets the standards for the pea grades (see TABLES 7and 8).

Fall Land Preparation

Pea straw is a good forage. Cattle can be turned into pea fields to graze stubble and straw or it can be baled. Threshed pea straw should be baled before rain occurs since the hollow stems fill with water, mold develops, and the value is greatly reduced for livestock feed. Chopping the pea straw with barley in a tub grinder will produce a high quality feed for overwintering cattle and sheep. However, removal of the straw from a field will greatly reduce the amount of nitrogen returned to the soil through decomposition of the pea straw.

When green or tough straw is combined, a straw chopper should be used. Uniform spreading and chopping of straw and chaff are critical, particularly in direct seeding systems, as poorly chopped pea straw will bunch up in most cultivators and seeders.

If disease problems in the pea crop were pronounced, it might be desirable to bury all the residue that might carry the disease. This practise can leave the soil prone to erosion, though cover crops can help to reduce the risk.

TABLE 7. Green Peas (Canada) - Primary and Export Grade Determinants.

Grade Name*	Standard of Quality				Maximum Limits							
							Damage					
	Minimum Reqm't for Colour	Other Classes	Bleached	Total Other Classes and Bleached	Foreign Material	Cracked Seed Coats Incl. Splits	Splits	Shrivelled	Heated	Insect-Damaged	Other Damage	Total Damage
No. 1 Canada	Good natural colour	About 0.5%	2.0%	2.0%	About 0.1%	5.0%	About 0.5%	2.0%	Nil	0.3%	2.0%	3.0%
No. 2 Canada	Fair colour	1.0%	3.0%	3.8%	About 0.2%	8.0%	1.0%	4.0%	About 0.1%	0.8%	4.0%	5.0%
No. 3 Canada	Off colour	2.0%	5.0%	6.5%	About 0.5%	13.0%	5.0%	8.0%	About 0.5%	2.5%	10.0%	12.0%
If Specs for No. 3 Canada are not met, grade:	No. 3 Canada	Up to 10.0%: Peas, Sample Canada (Green or Variety), Account Mixed Colours. Over 10.0%: Peas, Sample Canada, Account Mixed Colours	Peas, Sample Canada (Green or Variety), Account Bleached	Peas, Sample Canada (Green or Variety), Account Mixed Colours and Bleached	Peas, Sample Canada (Green or Variety), Account Admixture	Peas, Sample Canada (Green or Variety), Account Cracked Seed Coats	Peas, Sample Canada (Green or Variety), Account Splits	Peas, Sample Canada (Green or Variety), Account Shrivelled	Peas, Sample Canada (Green or Variety), Account Heated	Peas, Sample Canada (Green or Variety), Account Insect Damage	Peas, Sample Canada (Green or Variety), Account Damage	Peas, Sample Canada (Green or Variety), Account Damage

*The variety or colour may be added to and become part of the grade name.

TABLE 8. Peas (Canada) Other Than Green Peas - Primary and Export Grade Determinants.

Grade Name*	Standard of Quality		Maximum Limits								
						Damage					
	Colour	Peas of Other Colours	Foreign Material		Cracked Seed Coats Incl. Splits	Splits	Shrivelled	Heated	Insect-Damaged	Other Damage	Total Damage
			Ergot	Total							
No. 1 Canada	Good natural colour	1.0%	0.05%	Trace	5.0%	1.0%	3.0%	Nil	1.0%	3.0%	3.0%
No. 2 Canada	Fair colour	2.0%	0.05%	About 0.5%	9.5%	2.5%	5.0%	About 0.05%	1.5%	5.0%	5.0%
Extra No. 3 Canada	Fair colour	2.0%	0.05%	About 0.5%	13.0%	5.0%	5.0%	About 0.05%	1.5%	5.0%	8.5%
No. 3 Canada	Off colour	3.0%	0.05%	1.0%	15.0%	5.0%	7.0%	About 0.2%	4.0%	10.0%	10.0%
If Specs for No. 3 Canada are not met, grade:	No. 3 Canada	Peas, Sample Canada (Colour or Variety), Account Mixed Colours	Peas, Sample Canada (Colour or Variety), Account Ergot	Peas Sample Canada (Colour or Variety), Account Admixture	Peas, Sample Canada (Colour or Variety), Account Cracked Seed Coats	Peas, Sample Canada (Colour or Variety), Account Splits. Over 5.0% Splits and Over 3.0% Other Colours: Peas, Sample Canada, Account Mixed Colours and Splits	Peas, Sample Canada (Colour or Variety), Account Shrivelled	Peas, Sample Canada (Colour or Variety), Account Heated	Peas, Sample Canada (Colour or Variety), Account Insect Damage	Peas, Sample Canada (Colour or Variety), Account Damaged	Peas, Sample Canada (Colour or Variety), Account Damage

*The variety or colour may be added to and become part of the grade name.

Chapter 6

Dry Bean Production

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Dry Beans

Quick Tips - Dry Beans

Seeding Rate:	Variable, depending on seed size. Target 3 plants per square foot under irrigation, 4 plants per square foot dryland.
Seeding Depth:	2.5 inches.
Seeding Date:	4th week in May (10°C at 2 inches). Beans are extremely susceptible to frost.
Recommended Varieties:	Direct Harvest - CDC Nighthawk, CDC Expresso, CDC Whistler Undercutting or Swathing - Othello, Fargo, UI 906, AC Skipper
Best Performance:	Dryland - summerfallow on Moist Dark Brown soil. Irrigated - long growing season.
Rolling:	Within 3 days of seeding.
Registered Herbicides & Registered Fungicides:	Refer to Table 13, pages 2-23 and 2-24 or the Saskatchewan Agriculture and Food Crop Protection Guide.
Rotational Frequency of Dry Bean Production for Disease Control:	5 years for sclerotinia, 2 years for bacterial blight.
Undercutting or Swathing:	50 to 75% buckskin.
Direct Harvesting:	75% pods hard and dry and the rest at buckskin.
Storage Moisture:	15%.

Chapter 6

Dry Bean Production

INTRODUCTION

Common beans, called dry beans in western North America and field beans in eastern North America, are an ancient crop native to South and Central America. Today, dry bean production and trade volumes exceed that of any other pulse crop grown in the world. It is grown in subtropical or temperate areas throughout the world, and during the cool dry season in tropical areas. Major production areas are the Americas, east Africa, east Asia, and west and southeast Europe. Brazil is the leading producer of dry beans, followed by Mexico. In North America, approximately 2.5 million acres of dry beans are grown annually. North Americans consume more of them annually than any other pulse.

Dry beans are used almost exclusively as food. The seeds have a protein content of 22 to 24%. Like all pulses, beans are high in some amino acids and low in others, but are an excellent source of balanced protein when served along with cereal products. Beans are also high in dietary fibre and complex carbohydrates. The straw that remains after harvest is a valuable source of organic nitrogen.

Dry beans have been grown in Canada since the mid-1800's, with most production in Ontario. Saskatchewan was a dry bean producer in the 1920's and 1930's, but since the 1970's, most of the beans on the Prairies are grown under irrigation in Alberta and on dryland in southern Manitoba. Dry beans have made a limited come-back in Saskatchewan in the mid 1980's with the help of the Saskatchewan Irrigation Development Centre, and currently, 5000 acres of dry beans are grown annually. Most of the dry beans grown in Saskatchewan are in the pinto class, but it is possible to grow other market classes as well (TABLE 1).

The average yield of pinto beans is 1500 lb/ac under irrigation. Dryland yield levels are not yet established, but there are indications that 800 lb/ac should be possible.

THE DRY BEAN PLANT

Dry beans belong to the group that includes vegetable, snap, or green beans. The word dry refers to the dry edible seeds that are the commercial end product. There are several classes of dry beans including: pinto; great northern; navy, pea or white; small white; small red; pink; kidney; black; cranberry; white marrow; flat small white; and yellow eye (FIGURE 1). Lima and scarlet runner beans are a different species. Adzuki and mung beans are only distantly related. The most common bean class in North America is the pinto class which accounts for 40% of annual production and 65% of annual Alberta production. Some 70% of the pinto beans produced in North America are consumed domestically.

Unlike lentils, peas, chickpeas, and faba beans, the dry bean seeds do not remain below ground during germination. Instead, the cotyledons push up through the soil and are exposed. This type of germination makes the seedling more vulnerable to damage. **If the seed is buried too deeply, the plant may die if the seed separates from the shoot before it emerges. If the seedling shoot is damaged by frost, cutworms, or mechanical damage, there is no opportunity for regrowth and the plant will die (FIGURE 2).**

The first pair of true leaves are single leaves opposite each other on the stem. Subsequent leaves have 3 leaflets (trifoliolate) and are arranged on alternate sides of the stem. On average, a new leaf is produced every 4 to 6 days. Varieties with determinate growth habits (bush types) generally have 5 to 9 nodes on the main stem, and 2 to several branches. Varieties with an indeterminate growth habit (viny types) may have 12 to 15 nodes on the main stem. Vines are usually produced just before flowering is about to begin.

Flowers are carried on short flower stems in clusters at the bases of the leaves. Flowers range in colour from white to purple, and typically

Dry Bean

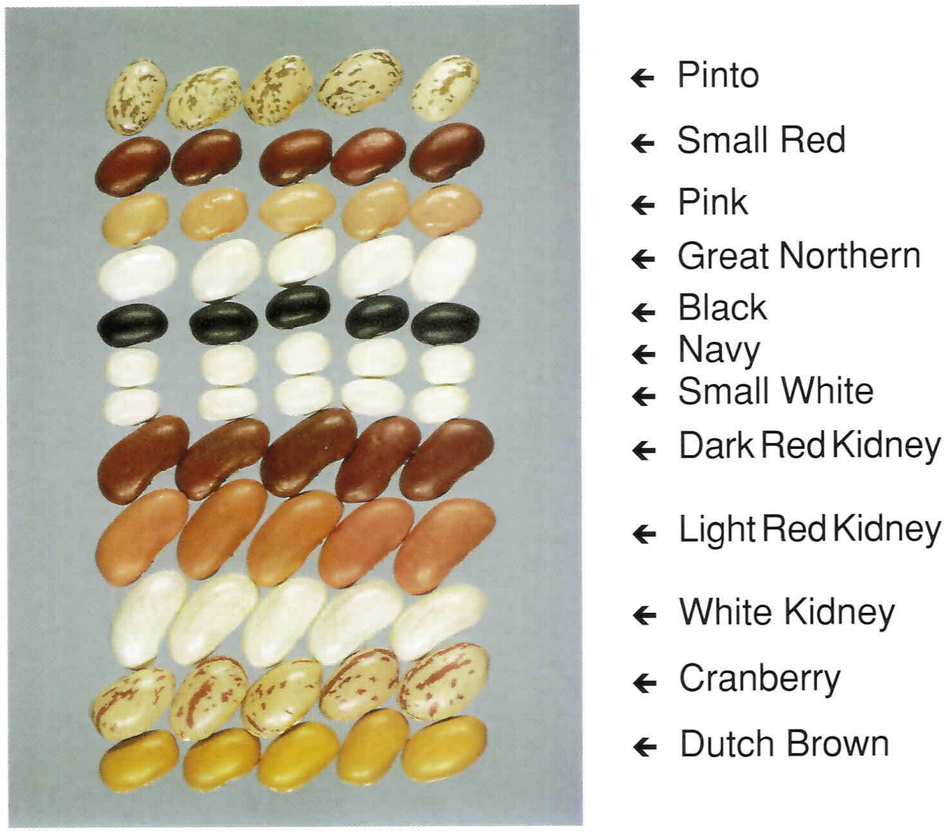

FIGURE 1. Different Market Classes of Dry Bean.

TABLE 1. Market Classes of Dry Bean.

Class	Seed Colour	g/1000 Seed	Main Canadian Production	Main Consumption
Pea = Navy = White	white	170 - 210	Ontario, Manitoba	United Kingdom
Kidney	light red, dark red, white	550 - 630	Ontario, Manitoba	North America
Black	black	170 - 210	Manitoba, Ontario	South America, Mexico, Caribbean
Cranberry = Romano	pink red on buff	500 - 570	Ontario	North America, Europe
Pinto	brown on cream	330 - 370	Alberta, Manitoba	USA, Mexico
Red	red	320 - 350	Alberta	North and Central America
Pink	pink	330 - 360	Alberta	North America
Yellow Eye	white with yellow eye	400 - 500	Eastern Canada, Ontario	Eastern North America
Great Northern	white	340 - 380	Alberta	Mediterranean, Middle East

From Ag Canada 1985; Bert Vandenberg, Personal Communication.

FIGURE 2. Emerging Bean Seedlings.

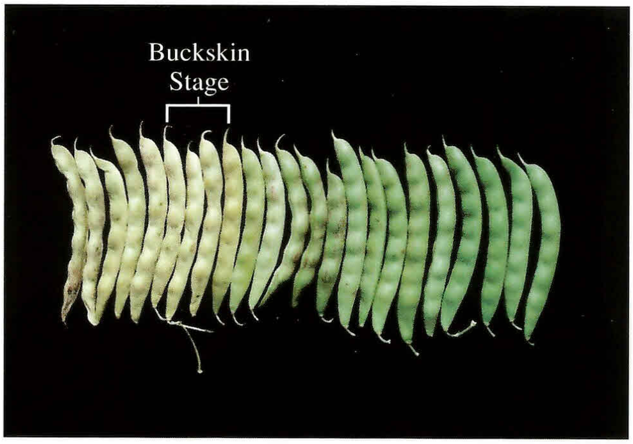

FIGURE 3. Buckskin Stage of Bean Pod Maturity.

self-pollinate before they open. Flowering lasts about 2 weeks and each flower can produce a single pod. Under heat and moisture stress, many of the pods abort, but under ideal conditions, each pod produces 5 to 8 seeds. Each pod grows longer as it fills and this elongation can carry the pod tips to ground level or below, which contributes to high harvest losses. Development of varieties with pods higher off of the ground is a major goal of bean breeding for Saskatchewan. **When the seeds have filled, the pods are fleshy and brittle, but as the seeds begin to mature, the pods turn yellow and become more flexible. This stage is referred to as the "buckskin" stage.** At maturity, the pods turn tan coloured and dry and harden (FIGURE 3).

ADAPTATION

Dry bean is a warm season plant and as such is very sensitive to frost. **Since the seeds emerge from the ground at germination, even a short exposure to frost will kill the plant.** Frost late in the season will also kill plants and cause quality losses in any seed containing more than 25% moisture. Due to its extreme sensitivity to frost, a major limitation to bean production is the length of the frost-free season. Most varieties require 90 to 120 days to mature.

Seed germination is best at soil temperatures above 10°C at seeding depth. Prolonged cool weather in the spring results in weak and disease prone plants, as growth slows at temperatures below 20°C. If temperatures drop below 8°C, or rise above 35°C during flowering, flowers and pods are likely to abort. Cool weather in the fall tends to delay maturity.

Dry beans require good moisture throughout the growth period. Moisture stress during flowering and early pod-fill can reduce yields. The plants cannot tolerate flooding. Even 24 hours in standing water severely reduces plant growth. If drainage is poor, or soil is compacted, bean roots suffer from oxygen deficiency.

Soils with even slight salinity should be avoided. If soil pH is higher than 7.5, bean plants are susceptible to micronutrient deficiency.

Dry beans are best adapted to dryland production on summerfallow in the moist Dark Brown soil zone and to irrigated production in areas with a relatively long growing season. Early varieties can be grown in the thin Black soil zone. Dryland production in the Dark Brown zone usually results in reduced yield, but offers the advantage that it should be possible to grow disease-free seed in our relatively dry climate. Such seed sells at a premium because bacterial blight is a common and potentially devastating disease in other areas of production. Saskatchewan growers are advised to obtain certified disease-free seed.

FIELD HISTORY

As with all pulses, field history is important for dry bean production. Refer to *Chapter 2 - Field History* for herbicide residue information. If the herbicides which may cause problems have been used, a field assay is recommended to determine if the product is still active. Either a chemical assay can be conducted or a test strip can be sown and grown to maturity in the year before beans are to be grown. Activity after 5 years is not uncommon. Products such as 2,4-D and Banvel have a shorter residual, but if these have been used for spring or fall control of winter annuals, damage may occur.

Sclerotinia in dry beans can be serious. To reduce the incidence of sclerotinia in areas where the disease is well established, dry beans should not be grown in rotation after dry beans, lentils, peas, faba beans, sunflower, mustard, or canola. The risk of sclerotinia decreases if these susceptible crops are separated by 3 to 5 years.

Dry beans are a very poor competitor with weeds. Steps should be taken to minimize weed problems before the crop is planted (see *Chapter 2 - Weed Management*). Fields with large populations of perennial weeds should be avoided.

An ideal bean field has soil that warms up quickly, is not a frost risk, and has 2 feet of moisture reserves (this is more commonly available in summerfallow fields). The field should also be free of salinity, perennial weeds, and stones.

VARIETIES

Varieties currently recommended for production in Saskatchewan are listed in TABLE 2. Comparative data for many varieties is still limited because regional testing is only just beginning. Varieties have distinct growth habits. Type I refers to determinate upright bush growth habit. Type II varieties are upright and indeterminate. Type III varieties are indeterminate but have a spreading canopy which may cause problems with low hanging pods at maturity. Most currently available pinto varieties (especially Othello) develop canopies with low-hanging pods. With swathing or direct harvest systems, this causes high harvest losses. Over the next several years, early maturing varieties with better canopy structure for direct harvesting will become available. The development of new varieties is an essential component in the improvement of dry bean production in Saskatchewan (FIGURE 4).

FIGURE 4. Dr. Bert Vandenburg at Work in a Bean Field.

CROP MANAGEMENT

Seeding Considerations

Seed selection is extremely important to crop quality. It may be necessary to order early to get quality seed. Only very early varieties mature reliably under our growing conditions. Seed imported from Idaho or California is less likely to carry bacterial blight. This disease is seed-borne, can destroy the crop, and should be avoided by purchasing certified disease-free seed.

Seed from Idaho is often below 12% moisture, and such seed is very susceptible to handling injury. Handling injury increases as the seed moisture decreases, and the damage is worse in cold weather. Damaged seeds may not germinate, may produce less vigorous seedlings, and are more susceptible to disease. **Seed is less sensitive to handling damage if the moisture content is increased to the 14 or 16% moisture range. Several methods of adding moisture are available.** If seed is obtained several weeks in advance of seeding, it can be stored in a warm and humid area. Alternatively, water can

TABLE 2. Main Characteristics of Dry Bean Varieties.

Variety	Type	Yield as % of Othello Pinto: Irrigation	Yield as % of Othello Pinto: Moist Dark Brown Soil Zone	Yield as % of Othello Pinto: Thin Black Soil Zone	Yield as % of Othello Pinto: Thick Black Soil Zone	Days to Flower	Days to Maturity	Pod Clearance (%)	Seed Weight (g/1000)	Growth Habit	Distributor	Certified Seed Supply in 1997
Othello	pinto	100	100	100	100	54	99	51	304	III	WA, ID dealers	yes
Fargo	pinto	98	95	100	109	52	97	53	324	III		yes
Earl'ray	pinto	73*	90*	86*	94*	51	96	69	351	I		yes
92121	pinto	84*	89*	83*	98*	55	102	83	309	I		no
HR6I-1608	pinto	88*	106*	104*	115*	55	96	62	301	II		no
US 1140	great northern	101*	106*	103*	120*	55	100	57	266	III	public	yes
92070	great northern	72*	85*	86*	110*	55	103	60	319	I		no
U1906	black	81	97	82	77	62	105	76	133	II	public	yes
CDC Expresso	black	58	82	81	94	49	98	87	176	I	Specialty Seeds	yes
CDC Nighthawk	black	66	69	74	76	61	103	77	161	II	Value Added Seeds	yes
Aspen	navy	78*	86*	78*	84*	60	112	87	158	II	R.T. Stow	yes
GTS 523	navy	70*	75*	81*	95*	54	97	75	150	I		yes
OAC Seaforth	navy	62	77	78	76	58	104	73	177	I	trade	limited
AC Skipper	navy	61	72	78	76	57	105	77	199	I	Klempnauer	yes
CDC Whistler	small white	66	85	79	68	62	111	81	138	II	Western Grower	yes

* Limited data
Growth Habit: I - determinate bush; II - indeterminate bush; III - indeterminate vine
Data from Saskatchewan Regional Trials in 1995 and 1996.

be added directly to seed bags at least a week before seeding. For this treatment, the bags and the water should be kept at room temperature, and the bags should be rotated regularly to distribute the moisture evenly. For most rapid hydration, wet sawdust can be added to the seed a few days before planting.

Dry beans require inoculation with the correct inoculant in order for the plants to fix nitrogen. To be effective, inoculant should be used prior to the expiry date and applied with a sticker. The inoculated seed should be protected from sunlight, and should be planted immediately (see *Chapter 2 - Inoculation*).

Seed treatment to control wireworms and seed and seedling diseases may be beneficial. Fungicidal seed treatments, especially Captan, can be toxic to the *Rhizobium*. Apron FL is effective for controlling seed rot. If a fungicidal seed treatment is used, it is especially important to seed immediately after inoculation. Any delay will increase contact between the fungicide and inoculant which can harm the *Rhizobium*. If fungicidal seed treatments are used, it is recommended to increase the amount of inoculant applied.

The probability of fully effective inoculation and high rates of nitrogen fixation is rather low. Accordingly, many growers apply nitrogen to reduce the risk of inoculation failure. Soil tests are recommended to determine if other nutrients are at appropriate levels. Excess nitrogen can delay bean maturity, make plants more susceptible to disease and insects, and may give weeds a competitive advantage. **On irrigated land, if soil tests indicate nitrogen levels below 50 lb/ac, up to 50 lb of nitrogen can be added, but not with the seed.** If phosphorus levels fall below 30 lb/ac, an additional 30 lb/ac may be added. **Seed placement of phosphorus or nitrogen in excess of 15 lb/ac may reduce yield.** An alternative is to use "Provide", a fungal inoculant that enhances phosphate uptake by plants. It can be seed placed either alone or along with phosphate, up to the maximum allowable amount, in order to arrive at an adequate phosphorus level.

Excess phosphorus may make zinc less available to the plant. Zinc deficiency is more likely, if soil pH is higher than 7.0 and if early season weather is cool and wet. While all beans require adequate zinc levels, navy beans are more susceptible to zinc deficiency than coloured beans. Zinc can be applied as a foliar spray onto the leaves or as a granular (FIGURES 5 and 6).

FIGURE 5. Bean Plot with Zinc Deficiency.

FIGURE 6. Bean Plant with Zinc Deficiency.

Bean plants are sensitive to spring frost at seeding time, and seeds will not germinate below 10°C. This increases the risk from early seeding. Ideally, beans should be seeded when soil temperatures reach 15°C at 2 inches depth. Only the earliest varieties will mature in our growing season. Delayed seeding increases the risk of delayed maturity and frost damage in the fall. **In most years, the ideal time for seeding is the 4th week of May.**

Bean seeds are large, and take in up their own volume in water as they germinate. A moist seedbed is required for rapid germination. A seeding depth of 2.5 inches is usually the best. Seeding closer to the soil surface may allow the seed to dry out before it absorbs enough water to germinate. Shallow seeding also increases the risk of lodging. Seeding too deeply increases the chance that the seedling will not be able to emerge intact.

Seeding rates depend on seed size which varies with variety and from year to year. A target plant density is 3 plants per sq ft under irrigation and 4 plants per sq ft on dryland. For Othello pinto bean, this requires an average of 65 to 85 lb/ac of seed under irrigation and 80 to 100 lb/ac of seed on dryland. For some types, a lower seeding rate is undesirable as it encourages more vegetative growth and delays maturity. Higher seeding rates can increase the severity of some diseases under irrigation.

Successful dry bean production can be obtained by two different production systems. The first is traditional row cropping commonly used in established production regions, often under irrigation. For viny varieties, including pinto beans, 22 or 30 inch rows often produce the highest yields and this spacing reduces the risk of sclerotinia under irrigation. The second system involves production in narrowly spaced rows (solid seeding) as is used in cereal production and is more common in the recently developed dry bean production areas on dryland. With this dryland production system, more upright bush varieties can be used in solid seeded plantings for traditional swathing or direct combine harvesting. Solid seeding can be used on dryland because sclerotinia is not usually a problem in the moist Dark Brown soil zone. In future, new technology for direct harvesting in combination with upright dry bean varieties will improve the harvestability of the crop by reducing shattering losses before and during harvesting.

Bean seeds must be handled very carefully to avoid damaging them. Even hairline cracks in the seed coat can reduce germination. Hoe drills or double disc drills can be used for seeding, providing the seed cup openings are large enough to accommodate the seed. Careful adjustment of the seeder and the use of a seeder with externally fluted seed cups can reduce seed damage. Air seeders can be especially damaging to the seed if they are not adjusted carefully. **Air seeder damage can be reduced by moisturizing the seed to above 15% moisture and setting airflow rates to the minimum required to prevent plugging. Reduced seed flow rates arrived at by slower ground speeds can also assist in this as they allow for correspondingly lower air speeds.** Reduced ground speed during seeding reduces the amount of injury to the seeds with all seeding equipment, and helps to assure accurate depth control. In row crop systems, plate planters or vacuum planters may be used for more precise seed placement.

In-Crop Considerations

For dryland narrow row systems, rolling, harrowing, or harrow-packing may be used to level the field. A level field free of projecting stones or soil ridges is important for harvesting which must take place right at the soil surface. Field levelling must immediately follow the seeding operation, or be done within 3 days of seeding to avoid breaking off the seedlings as they emerge from the soil.

Dry beans are probably the pulse crop least capable of competing with weeds. The plants are short, slow growing (especially in cool springs), and rarely produce a solid canopy. They are also very sensitive to weed competition. At Morden, 2 wild mustard plants per square foot reduced navy bean yields by 46 to 57%. At Lethbridge, less than 2 hairy nightshade per yard of row resulted in pinto bean losses of 13%, and 90 hairy nightshade per yard of row caused losses of 77%. Nightshade caused pinto bean losses, even if competing for only 3 weeks in the spring. A full 9 weeks of weed-free conditions after dry bean emergence was necessary before yield losses were avoided. This illustrates that a strong weed management strategy must be developed as part of any successful dry bean production plan (see *Chapter 2 - Weed Management*).

Interrow cultivation is a common practise in row cropped beans. The first cultivation is usually done when bean plants are at the 2- to 3-leaf stage. A second cultivation follows, if necessary, 3 weeks later. Interrow cultivation should be discontinued once the bean plants start flowering, and should not be undertaken when the plants are wet. The cultivations should be performed in a manner that minimizes creating furrows or soil roughness that could interfere with harvesting operations.

Refer to *Chapter 2 - Table 13* for specific herbicides registered. The registered herbicide options give broad spectrum control, but are not effective against all weed species. Note that Sencor is not registered for use in bean crops and will cause severe damage.

Insect damage has not yet been a problem for dry bean production in Saskatchewan. However, wireworms and corn seed root maggots are seed predators that cause problems in other areas. Seed is often treated with an insecticide-fungicide combination such as DLC that provides control of these insects. Insecticides used alone can reduce seed germination. The fungicide, in combination with the insecticide, reduces the toxic effect on the seed.

Grasshopper damage may be a problem in years of severe grasshopper infestation. Saskatchewan government forecasts indicate the risk each year. In the moist Dark Brown soil zone, risk is cyclical and rarely severe.

Dry bean plants are susceptible to a number of **diseases**, the most important of which are **sclerotinia** or **white mold**, and **bacterial blight**.

Sclerotinia, a major fungal disease of bean, can cause severe crop loss. The disease is most serious in crops with a dense canopy, in fields with a history of sclerotinia, and in cool (11 to 20°C) moist conditions. Crop losses will be highest when these conditions exist during or after flowering. The disease is almost always a problem under irrigation. Symptoms of the disease include lesions on pods, leaves, branches, and stems. The lesions are small, round, and initially green, but soon become larger, water soaked and slimy, and the affected plant parts dry and turn pale brown or white. Whole plants can be killed. A white cottony growth may cover the affected parts. After about a week, hard black bodies called sclerotia are formed (FIGURE 7). The sclerotia can survive in soil for more than 5 years. Bean plants become infected only after flowering has started. The fungus needs dead tissue to start growing and the fallen flowers provide a ready food source for the fungus. Control of sclerotinia is difficult if plants are lush and viny as disease spread from plant to plant readily occurs. **A rotation with several years between susceptible crops (especially other pulses, canola, mustard, sunflower, safflower) will reduce the likelihood of sclerotinia, but infection can be carried over in some weeds, and it is also spread by insects.** For currently available viny varieties, sclerotinia is less problematic in row crop systems than in solid field plantings as moisture retention within the canopy is reduced. Sclerotinia can sometimes be controlled by application of Benlate just prior to flowering or at the first bloom stage. Flower tissue and the inside of the canopy must be thoroughly covered for control to be effective.

FIGURE 7. Sclerotinia - White Cottony Growth on Stem Bases and Pods of Bean.

Bacterial blights (common blight, halo blight, and bacterial brown spot) can also be severe. Although the bacterial blight diseases can overwinter in the soil, the main source of infection is contaminated seed. Initial symptoms include water-soaked spots that gradually enlarge and leaves that wilt and die. Often leaves will appear burned, but will remain attached to the stems. Pods can develop lesions that ooze (FIGURE 8). Seeds develop yellow or brown spots and shrivel, and many are not viable. Seed contamination can take place both inside and outside of the seed. The disease develops most quickly at warmer temperatures (28 to 32°C) and under sprinkler irrigation. Hail storms accelerate spread of the bacteria. Seedlings from contaminated seed carry large numbers of bacteria and generally die early. Effective disease control includes the use of seed that is grown in bacterial blight-free regions or seed that is certified bacterial blight free. **A rotation with at least 2 years between bean crops will minimize bacterial blight disease carryover in the field.**

FIGURE 8. Bacterial Blight on Bean Plants.

Anthracnose is a major bean disease world-wide, but has not yet been a serious problem in western Canada. It is widespread only if there is frequent rainfall. Anthracnose is a fungal disease that is spread by seed, but can survive and be spread by crop residues and can, as well, be carried by wind-blown residues. **A rotation with 2 to 3 years of cereals reduces the risk of disease by reducing the quantity of infected debris.** The use of disease-free seed is also important.

Seedling blights, caused by three different fungi, cause the death of young seedlings. Symptoms include narrow red to brown streaks on young stems; leaf drop, mushy, discoloured, wilted seedlings with water soaked lesions from the roots to up the young stem; sunken lesions growing to completely girdle the stem, and cankers that become rough and dry. Each fungus is most active at a distinctly different temperature. **The use of high quality seed reduces the risk of seedling blight infection by favouring a rapid, uniform emergence.** Older plants are rarely at risk. Seed may be treated with Captan, Apron FL, or Thiram, but such treatments rarely increase yields. Irrigation between seeding and emergence increases the risk of seedling blight because it cools the soil and increases seed rot.

A rotation that includes sugar beet increases the risk, and cereals in the rotation reduce the risk. The fungi are common in the soil and survive for many years, but their numbers are reduced in years when no susceptible crop is grown.

Beans are susceptible to viral diseases, including bean common mosaic. These diseases have not been problematic in western Canada yet, but may develop as acreage increases. Symptoms of bean common mosaic virus include the presence of dark and light patches on the leaves, leaf rolling, leaf malformation, slow growth, and in severe cases, stunting and failure to pod. This virus is spread by aphids from clovers and in pollen.

Dry beans also can be affected by non-parasitic diseases. Baldhead is a condition that results from seed damage, resulting in a broken shoot with a dead growing point. The young seedlings do not have a growing tip and, therefore, do not develop. Dry bean plants are also very sensitive to herbicide injury, especially from the drifting of phenoxy herbicides such as 2,4-D, MCPA, or dicamba. Sun scald can be caused by intense sun after a rain or irrigation, and the entire plant may collapse without discolouring. Sun scald generally does not affect yield. Heat injuries are also possible from high temperatures heating sandy soil.

About 35% of North American dry bean production is under irrigation. In terms of water use, dry beans are intermediate between lentils and peas. When the seed bed is dry, irrigation may be used before seeding. Irrigation between seeding and emergence cools the soil, delays germination, causes soil crusting, and generally increases the chance of seedling diseases. Between emergence and flowering, bean plants are small and use little water. One to two irrigations may be necessary if rainfall is below average. Just before flowering when vines begin to form, the water level should be brought up to near field capacity. Flooding should be avoided as even short periods of standing water can delay growth and may even kill plants. **Yields are highest when no drought stress occurs during the entire period, from flowering to pod fill. Irrigation should be shut down if widespread sclerotinia develops, or when the seeds have formed.** Irrigation during crop ripening may delay maturity and increase the chance of disease.

Harvest

Two basic harvesting systems are used for dry beans: they are undercutting or swathing, and direct harvesting. Undercutting is effective, but requires specialized equipment. In contrast, direct harvesting results in significant harvest losses, but does not require specialized equipment. Growers must pay close attention to the crop development stage as harvest approaches because the timing of harvest operations is extremely important to minimize damage and losses, and to maximize quality. Dry bean plants, seeds and pods can dry down very quickly. In years with warm, dry weather and drought conditions near harvest, seeds can lose moisture at more than 5% per day after the seed moisture reaches 40%.

Undercutting

The traditional harvesting method for row crop bean production is to cut the bean plants below the soil surface with a knife, or a rod cutter, or a knife followed by a rod cutter (FIGURE 9). Once undercut, two or more bean rows are gathered together with a windrower or side delivery rake. If the beans are pulled, usually 6 to 8 rows are pulled and windrowed together. The crop is usually cut or pulled when 50 to 75% of the pods are in the buckskin stage. Cutting or pulling when pods are green, damp, and tough, such as in the morning, reduces shattering losses. When the crop is dry, it is threshed with a combine equipped with a pickup.

FIGURE 9. Undercut Plants in Row Crop Bean Production.

Although the undercutting method is much less prone to shattering losses, it has several disadvantages. The need to purchase new equipment has caused grower resistance to trying dry bean production in Saskatchewan, particularly on dryland. In addition, beans may rot in the swath if the weather is wet. The swath is vulnerable to wind damage because there is not enough stubble to anchor it in place. Separating the soil from the crop can be costly and difficult and can result in earth tag where the soil contaminates the seed surface. This harvesting method also exposes the soil to an increased risk of soil erosion.

Swathing is a feasible alternative to undercutting only if the pods clear the cutterbar. The usual stage for swathing is also 50 to 75% buckskin. Upright varieties which have been grown in narrow rows to encourage podding higher on the stem can be swathed with little difficulty. If stems are moist, knives may gum up and must be cleaned periodically. Swathing creates little soil disturbance, results in less earthtag and soil particles in the seed, and improves marketability.

Direct Harvesting

Straight combining has only recently been considered feasible. The pods of many pinto bean varieties hang down to the ground and even push into the soil surface. **A typical combine can only cut to within 40 mm (1.5 inches) of the ground. As a result, cutterbar losses can be 40 to 50% of yield.** Even with specialized lentil harvesting equipment such as flexible headers and air reels, the losses usually exceed 30%.

Cutterbar losses are high in dry beans because of the shape and characteristics of the plant. Dry bean stems and pods are generally positioned vertically making vine lifters largely ineffective. Although vine lifters may show some advantage, particularly if the crop is lodged, too many plants and pods are missed. Assuming 330 mg seed, a loss of 30 seeds per sq. metre (3 per sq ft) amounts to a loss of 100 kg/ha (90 lb/ac). **A new pinto bean variety with improved direct harvesting characteristics and a crop lifter designed specifically for dry bean will address the harvesting loss problem** (FIGURE 10). Both may be available in limited quantities in 1997.

FIGURE 10. A Prototype Bean Harvester.

Some bean growers are still choosing to direct harvest rather than to invest in undercutting equipment. Not only is the additional outlay of capital avoided, but gathering losses can be less than the weathering losses that sometimes occur when beans are exposed in the swath (FIGURE 11).

FIGURE 11. Straight Combining Beans.

Monitoring Crop Maturity

Direct harvesting can begin after the bean leaves fall off. The leaves of bean plants turn yellow and drop off naturally as the crop matures. Desiccation may be used to dry down the crop and weed top growth, but it will not increase crop maturity. Generally, the crop can be left standing until it is killed by frost which acts as a free desiccant. When weed problems are severe, tall weeds can be lopped off above the bean crop by high level swathing before harvest. Delaying harvest until after frost occurs generally has little negative effect on yield or quality. **The crop is ready for direct harvesting when roughly 75% of the pods are hard and dry and the remainder are yellow and flexible (the buckskin stage).** At this stage, the pods are generally 12% moisture and the seeds are near 18%.

Monitoring Crop Moisture Content

Pod and seed moisture content are two important factors that will determine the success of the direct harvesting operation. Once the crop matures past the buckskin stage, it becomes subject to the daily fluctuations in moisture content that can occur. At this stage, bean pods will take on or release moisture as quickly as ambient conditions change. The bean seed, with its thick seed coat, takes on and releases moisture much more slowly. A good pod moisture content range for harvesting is between 6 and 14%. Furthermore, the pod moisture content should always be at least 4% less than the seed moisture content for effective separation of the seed from the pod.

In early morning and late evening, bean pod moisture content may be high increasing the possibility of threshing and separating losses from the rotor or cylinder/straw walker. The problem is compounded further because cylinders and rotors are turning slow to avoid seed damage. In extremely moist situations, feeding of the crop material into the combine will be uneven causing clumps of material to pass through the combine.

As a typical harvest day progresses, pod moisture content will decrease improving threshing and separation. Appropriate combine settings should be made as necessary (see the equipment section). On an extremely hot and dry day, pod moisture content may decrease causing an increase in shatter loss. Furthermore, seed moisture content may drop below 12% increasing the risk of cracking or splitting the sample. A quick indication of low pod moisture content is obtained by watching for open pods at the cutterbar. Open pods are readily seen as the inside of a bean pod is lighter in colour than the outside. In these situations, harvesting may best be postponed until the evening or morning when crop moisture content is higher. Alternatively, a light irrigation can be used to moisturize the pods and reduce shattering losses. New harvest equipment technology and new varieties bred to minimize shattering will allow improved harvesting under drier conditions.

Equipment Considerations

The timing of the harvesting operation, combine adjustments, and condition of the combine components can be more important than the choice of which combine to use for harvesting dry beans. A floating cutterbar (flex header) is recommended because of the low nature of the crop. Air reels may help reduce losses by keeping the cutterbar clear of seed and loose plant material. Some pods may also be lifted if it is adjusted close to the ground. A parallel-state pickup reel may reduce losses by more gently entering the crop canopy than a bat reel. However, it will be largely unsuccessful at lifting pods above the cutterbar and is best positioned over the cutterbar and used only to keep the cutterbar clean.

Combine components should be checked carefully to ensure that they will not be contributing to seed damage. New rub bars and concaves should be used in cereal crops before harvesting beans to wear sharp edges down. Removal of concave blanks and wires may help in some situations by allowing the larger bean seed to fall through the concave more readily. Auger flightings should be checked for clearances that are too close and for sharp edges that will cause damage. After-market belt conveyors and bucket elevators are available, for some combines, which help to reduce seed damage.

Combine adjustments include running the cylinder or rotor as slow a possible for effective threshing and separation without damaging the seed. Follow the recommendations of the operators manual and then adjust accordingly. Keep the combine as near to capacity as possible. A soak test can be used to determine the level of damaged seed since it often cannot be seen visually. Soak 100 randomly chosen seeds in water for 5 minutes. Damaged beans absorb water more quickly and will swell in size. Combine adjustments are required if there are more than 5 damaged beans. Keep in mind that it is the peripheral speed of the cylinder or rotor that determines the potential for crop damage and generally plays a larger part in crop quality than concave clearance. Cylinder slow-down kits are available for some combines if required. The concave should be adjusted to its largest opening. Other important adjustments for minimizing seed damage include proper tensioning of the clean and return elevator chains.

Post Harvest Handling

Care should be taken to prevent seed damage after it leaves the combine. Some growers dump directly into bulk bags. A 38 x 38 x 48 inch bulk bag will hold a ton of beans. Belt conveyors and auger flighting with brushes are often used to transfer the beans to the bin. **Steel flighting augers are not recommended.** Bean ladders within the bin are also used to reduce the distance the beans must drop. Keep in mind that beans are more fragile as temperature drops.

POST HARVEST

Bean seeds are extremely sensitive to handling damage. The use of conveyor belts and bean ladders, rather than augers, minimizes mechanical damage. Even dropping the seed a short distance can cause problems. Storage in mini-bulk bags reduces the need for handling. Storage for more than a year reduces quality of some market classes (such as pinto, pink, and red) because the seeds will start to discolour.

Weed seeds and other dockage should be removed early to minimize heating and to increase the market appearance of the sample. Bean seeds should not be handled in cold temperatures or when very dry. Beans can be stored for a short period at 16 to 18% moisture, but for long term storage a level below 15% moisture is recommended. Drying temperatures above 38°C can reduce the germination of seed beans.

Grading

The Canadian Grain Commission under recommendation of the Producer Trade Advisory Committee sets the standards for the bean grades (see TABLES 3 and 4).

TABLE 3. Pea Beans (Canada) - Primary and Export Grade Determinants.

Grade Name	Standard of Quality	Maximum Limits								
		Foreign Material								
		Stones, Shale or Similar Material	Total Foreign Material	Contrast. Classes of Beans	Damage, Foreign Material, & Classes	Total Damage	Other Classes that Blend	Ergot	Sclerotia	Heated, Rotted, Mouldy
Extra No. 1 Canada	Uniform in size, of good natural colour	About 0.01%	About 0.05%	About 0.1%	1.0%	1.0%	1.0%	0.05%	0.05%	Nil
Canada Select	Fairly good colour	About 0.01%	About 0.05%	About 0.1%	1.5%	2.0%	1.0%	0.05%	0.05%	0.2%
No. 1 Canada	Reasonably good colour	About 0.05%	About 0.1%	About 0.1%	1.5%	2.0%	1.0%	0.05%	0.05%	0.1%
No. 2 Canada	Fairly good colour	About 0.1%	About 0.2%	1.0%	3.0%	4.0%	5.0%	0.05%	0.05%	0.2%
No. 3 Canada	Fairly good colour	About 0.2%	About 0.5%	1.0%	5.0%	6.0%	5.0%	0.05%	0.05%	0.3%
No. 4 Canada	Off colour	About 0.2%	About 0.5%	1.0%	8.5%	10.0%	5.0%	0.05%	0.05%	1.0%
		Over grade tolerance up to 2.5%: grade Pea Beans, Rejected, (grade) Account Stones	Over 0.5%: grade Pea Beans, Sample Canada, Account Admixture	Over 1.0%: grade Pea Beans, Sample Canada, Account Contrast. Classes	Over 8.5%: grade Pea Beans, Sample Canada, Account Reason	Over 10.0%: grade Pea Beans, Sample Canada, Account Reason	Over 5.0%: grade Pea Beans, Sample Canada, Account Other Classes that Blend	Over 0.05%: grade Pea Beans, Sample Canada, Account Ergot	Over 0.05%: grade Pea Beans, Sample Canada, Account Admixture	Over 1.0%: grade Pea Beans, Sample Canada, Account Heated or Mouldy Kernels

Notes: Tolerances for "ergot and sclerotia" are included in "Total Foreign Material".
Tolerances for "heated, rotted, mouldy" are included as "Damage".

Source: Grain Grading Handbook for Western Canada

TABLE 4. Beans other than Cranberry, Blackeye, Yelloweye, or Pea Beans - Primary and Export Grade Determinants.

		Maximum Limits								
		Foreign Material								
Grade Name	**Standard of Quality**	**Stones, Shale or Similar Material**	**Total Foreign Material**	**Contrast. Classes of Beans**	**Damage, Foreign Material, & Classes**	**Total Damage**	**Other Classes that Blend**	**Ergot**	**Sclerotia**	**Heated, Rotted, Mouldy**
Extra No. 1 Canada	Uniform in size, of good natural colour	Nil	About 0.05%	About 1.0%	1.0%	1.0%	1.0%	0.05%	0.05%	Nil
No. 1 Canada	Reasonably good colour	About 0.05%	About 0.1%	About 1.5%	1.5%	2.0%	3.0%	0.05%	0.05%	0.1%
No. 2 Canada	Reasonalby good colour	About 0.1%	About 0.2%	3.0%	3.0%	4.0%	5.0%	0.05%	0.05%	0.2%
No. 3 Canada	Fairly good colour	About 0.2%	About 0.5%	5.0%	5.0%	6.0%	10.0%	0.05%	0.05%	0.3%
No. 4 Canada	Off colour	About 0.5%	About 1.0%	8.5%	8.5%	10.0%	15.0%	0.05%	0.05%	1.0%
		Over grade tolerance up to 2.5%: grade Beans, Rejected, (grade) "class" Account Stones	Over 1.0%: grade Beans, Sample Canada (class), Account Admixture	Over 8.5%: grade Beans, Sample Canada (class), Account Contrast. Classes	Over 8.5%: grade Beans, Sample Canada (class), Account Reason	Over 10.0%: grade Beans, Sample Canada (class), Account Reason	Over 15.0%: grade Beans, Sample Canada (class), Account Other Classes that Blend	Over 0.05%: grade Beans, Sample Canada (class), Account Ergot	Over 0.05%: grade Beans, Sample Canada (class), Account Admixture	Over 1.0%: grade Beans, Sample Canada (class), Account Heated or Mouldy Kernels

Notes: Tolerances for "ergot and sclerotia" are included in "Total Foreign Material".
Tolerances for "heated, rotted, mouldy" are included as "Damage".

Source: Grain Grading Handbook for Western Canada

Chapter 7

Chickpea Production

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Faba Beans

Quick Tips - Faba Beans

Seeding Rate:	Variable, depending on seed size. Target 2 1/2 to 3 plants per square foot under irrigation; 4 plants per square foot dryland.
Seeding Depth:	2 to 3 inches.
Seeding Date:	Late April to mid-May.
Recommended Varieties:	CDC Blitz highest yielding on dryland. CDC Fatima highest yielding under irrigation. Orion on Black or Grey soils.
Best Performance:	Dark Brown under irrigation.
Rolling:	Not needed.
Registered Herbicides & Registered Fungicides:	Refer to Saskatchewan Agriculture and Food Crop Protection Guide.
Rotational Frequency of Faba Bean Production for Disease Control:	3 to 4 years for ascochyta, chocolate spot, and sclerotinia.
Swathing:	25% of plants with 1 or 2 black pods at base of stem.
Direct Harvesting:	16% seed moisture.
Storage Moisture:	16%.

Chapter 5

Faba Bean Production

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Chapter 5

Faba Bean Production

INTRODUCTION

Faba beans are probably native to north Africa and the near East and have been cultivated for about 10,000 years for both human food and livestock feed.

In Saskatchewan, faba beans have been grown since the early seventies, primarily for use on farm as livestock feed. It is now being grown and marketed for human consumption and bird seed as well. Faba bean seeds have a crude protein content of 24 to 30% which can be utilized by ruminants (cattle), although like all legumes, they are low in some of the essential amino acids and must be blended with other protein sources such as cereals or canola meal when being fed to hogs. When used for silage, faba bean has a protein content of 12 to 20%, and faba bean straw provides a valuable source of nitrogen for soil improvement. Faba beans have excellent N-fixing capability. Studies in Alberta indicated that faba bean stubble had 66 more lb/ac of nitrogen available to the crop than wheat stubble. Research in Manitoba indicated that wheat grown on faba bean stubble yielded twice that of wheat produced on wheat stubble. The average seed yield of faba bean is 1,000 to 2,000 lb/ac on dry land in the black soil zone and 2,000 to 3,500 lb/ac under irrigation.

THE FABA BEAN PLANT

Faba beans are divided into three groups based on seed size. Tick beans average between 300 and 550 g per 1000 seeds; horse beans average between 600 and 850 g per 1000 seeds; and broad beans vary between 1100 and 1650 g per 1000 seeds. Most seeds have a buff, grey-green or mottled brown seed coat, with a black, or occasionally white, area where the seed attaches to the pod (FIGURE 1).

Faba bean cotyledons (seeds) remain underground during germination, and this provides the seedling with excellent frost tolerance. If the main shoot is damaged, additional shoots may regrow from buds protected underground. Plants grow at a rate of about 1 node per week. Stems are strong and erect, and the plant can grow from 3 to 6 ft tall (FIGURE 2). The growth continues until the plant is stressed by drought or other factors.

Plants produce their first flowers at the 8 to 10 node stage, often when they are about 12 inches in height. This usually takes place in late June or early July. The flowers and pods are located along the stem from about 8 inches above the ground to the top of the plant. Faba bean plants flower prolifically, but only 15 to 35% of the flowers will produce mature pods. Most of the pods will contain 3 or 4 seeds. Although approximately 2/3 of seeds result from self-pollination, bees can trip flowers and have increased seed production in some studies.

ADAPTATION

Faba beans grow best in cool, moist conditions. High temperatures or low humidity cause the plants to wilt, and result in reduced seed set. Yields are greatly reduced by drought. Faba beans can tolerate only limited flooding and do not tolerate salinity. The optimal soil pH is from 6.5 to 7.5. Seedlings and maturing plants can tolerate frost, but the immature seeds are sensitive to frost damage.

Production in the Brown and Dark Brown soil zones is limited to irrigated areas due to the poor drought tolerance of faba beans. In the Black soil zone, production is limited by the length of the growing season. The short season is a major problem for seed production if the soil fertility is high as plants may not encounter enough stress to bring on maturity. Slow maturation can be partially offset by early planting as the seedlings tolerate frost well. Orion, the earliest maturing variety, is usually preferred for the Black soil zone. Faba bean is most often produced on summerfallow, but it can yield equally well on stubble, provided moisture reserves are adequate.

FIELD HISTORY

Accurate records of field history are very important in faba bean production. **Herbicide residues of Ally, Assert, Glean, Lontrel or Tordon can dam-**

Faba Bean

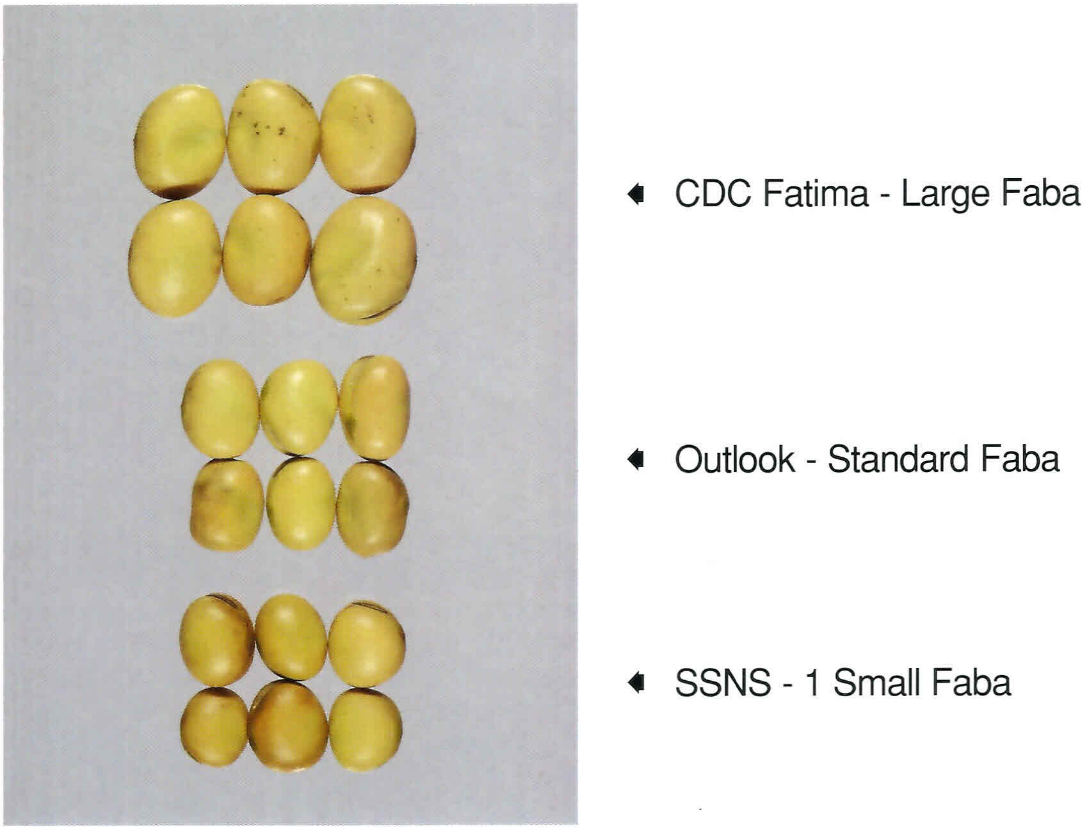

FIGURE 1. Faba Bean Seeds.

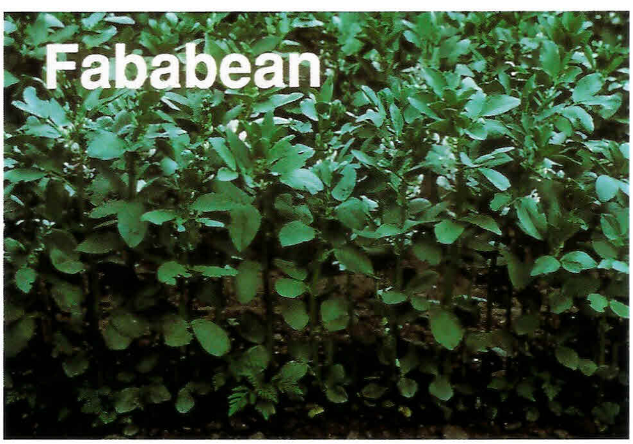

FIGURE 2. Faba Bean Crop.

age the crop. If these herbicides have been used previously in the field, a field assay is recommended to determine if the chemical is still present in toxic quantities. Either a chemical assay can be performed or a test plot of faba beans can be grown to maturity the year before the crop to determine if there is sufficient active residual herbicide to cause a problem. Residues of Glean or Tordon may be active for 5 or more years.

Faba beans are susceptible to some of the diseases common to other pulse crops, sunflowers, canola, and mustard. The risk of disease is reduced if these crops are separated by 3 to 5 years in the rotation.

Faba beans are not a strong competitor, and steps should be taken to minimize weed problems before the crop is planted (see Chapter 2 - Weed Management).

VARIETIES

At present, 6 varieties are recommended in Saskatchewan: Outlook, Aladin, Orion, Pegasus, CDC Blitz and CDC Fatima (TABLE 1). Other faba bean varieties, such as Chinese broad bean, are sometimes grown under contract. Orion is the earliest variety, followed by CDC Fatima and CDC Blitz. These are preferred for the Black soil zone, where early maturity is important. CDC Blitz is the highest yielding variety in dry land production while CDC Fatima is the highest yielding when irrigated. The "Varieties of Grain Crops for Saskatchewan" publication includes current variety information.

CROP MANAGEMENT

Seeding Considerations

As with all pulses, seed selection is important. Tests for germination, vigour, and disease level are recommended. Clean seed is very important.

Faba beans require inoculation in order to fix nitrogen. The inoculant should be of a strain specific for faba beans and it must be used prior to the expiry date. Inoculant should be applied with a sticker, and the seed should be protected from sunlight and sown within hours of inoculation (see Chapter 2 - Inoculation).

With proper inoculation, faba beans do not require supplemental nitrogen. Soil tests are recommended to determine if other nutrients are available at appropriate levels. Phosphorus is often recommended at application rates of between 20 and 30 lb/ac of phosphate. Faba bean is generally not harmed by application of seed placed phosphate.

Early seeding, mid-April to early May, is recommended for faba beans as the plants require a long growing season and the seedlings are very tolerant of frost. Faba beans can emerge from soils as cool as 5°C and can be successfully seeded as soon as the soil thaws to a depth of 4 inches. Seeding this early generally will result in higher yields and an earlier harvest in the fall. Research in Saskatchewan has indicated that yields are reduced on average 1 to 2% for every day's delay in seeding after April 25.

Faba bean seeds are large, and take up their own weight in water, so a moist seedbed is required. The seeds can be sown up to 3 to 4 inches deep if it is necessary to ensure adequate moisture for germination. However, when direct seeded, faba beans can be seeded shallower, provided they are placed well into the moist soil. Deep pre-seeding cultivation is not recommended as it dries the seedbed. Cloddy soil decreases seed to soil contact and reduces germination.

Seeding rates depend on the variety of faba bean used. An optimal seeding rate on dry land is about 5 to 8 seeds in each yard of row, at 6 inch row spacing. A reasonable rule of thumb to use in calculating seeding rate is that 1/3 x (the 1000 seed weight in grams) = lb/ac seed requirement. **Under irrigation, the seeding rate should be half the dryland rate.**

Table 1. Agronomic Characteristics of Faba Bean Varieties.

	Yield as % of Outlook		Average Maturity	Plant Height	Seeding Rate (lb/ac)		Seed Size
	Dryland	Irrigated	(days)		Dryland	Irrigated	(g/1000 Seed)
Outlook	100	100	120	medium	160 - 180	80 - 90	370
Aladin	102	107	122	tall	180 - 200	90 - 100	420
Orion	103	97	114	short	140 - 160	70 - 80	370
Pegasus	98	108	120	tall	170 - 190	85 - 95	390
CDC Blitz	106	98	116	tall	180 - 200	90 - 100	410
CDC Fatima	101	109	115	shortest	230 - 260	115-230	550

Faba beans are a very poor competitor with weeds. Increased seeding rates can improve the crop's competitive ability on dry land and reduce the impact of post-emergent harrowing. However, at high seeding rates, plants develop a thick canopy that may increase the likelihood and spread of disease. With a large seeded crop such as faba beans, increased seeding rates can be costly. When growing faba beans under irrigation, seeding rates can be reduced to reduce the potential for disease provided that weed control is adequate.

The large seeds are easily damaged. Even hairline cracks in the seed coat can reduce germination. **Disc drills, hoe drills, discers, or air seeders can all be used to seed the crop providing the seed metering system is capable of handling high volumes of large seed without damaging the seed.** Careful adjustment of the seeder, and the use of a seeder with external fluted seed cups with larger cup openings, can help reduce seed damage. Slower ground speed during seeding reduces the amount of injury to the seeds, and helps to ensure accurate depth control. **With air seeders, air velocities should be set to the minimum required to convey the seed without plugging the system. Excessive fan speeds and high air velocities may result in significantly reduced germination.** Since slower ground speeds reduce seed flow requirements, they also allow for lower air velocities which helps in overcoming this problem.

If the faba beans are intended as silage, it may be desirable to plant a cereal such as barley in a faba bean mixture. However, faba beans are a poor competitor with cereals and often will not do well in such a mixture. The compromise solution may be to plant strips of each crop, manage them separately, and harvest them across the strips. This method requires producers to seed alternate narrow strips and harvest at 90^0 to the direction of seeding to produce a mixed-crop of silage. Proper planning so that the narrow strips are matched to sprayer size may allow post emergent weed control. Harvesting at 90^0 to the seeding direction may be rough in some circumstances. Usually seeding at lower speeds will help solve this problem.

In-Crop Considerations

Faba bean pods are produced a minimum of 8 to 10 inches above the ground surface so rolling is not required.

As in other pulses, weed competition can severely reduce the yield of faba beans. For instance, in research plots at Saskatoon, 147 wild oat plants per square yard reduced seed yield 85% from 1802 to 268 lb/ac. Good weed management is necessary to obtain high yields (see Chapter 2 - Weed Management).

Delayed seeding sharply reduces seed yield and is not recommended as a weed control strategy. Deep pre-seeding cultivation is not advised for weed control as the faba bean seeds require a moist seed bed. Shallow cultivation may be useful in weedy areas. Pre-emergent harrowing firms and prepares the seedbed and improves the kill of winter annuals that survive pre-seeding and seeding operations. Harrowing during emergence is likely to damage seedlings. Once the seedlings are 2 to 6 inches tall, harrowing can again be considered. Harrowing with a tine harrow is most effective if it is done crosswise to the direction of seeding, at a ground speed less than 4 mph. Post emergent harrowing can cause damage to the faba bean plants, and increases the risk and spread of disease. These problems are reduced when the harrowing is done on a dry sunny day, the faba bean plants are somewhat wilted, and the harrowing is done at a shallower depth than the faba bean seeding depth.

When using the direct seeding method of production, winter annual or very early emerging weeds can be controlled by a burnoff with glyphosate (Roundup) before the crop emerges.

Herbicides registered for use in faba beans are indicated in Chapter 2 - Weeds.

Insect damage has not been a serious problem in faba beans. Blister beetles feed on faba bean shoots and buds, but damage is usually localized and control measures can rarely be justified on an economic basis. Grasshoppers can cause damage, but again, damage is usually minimal, and faba bean usually is not grown in areas where grasshopper populations are high. Aphids can be found on faba beans, but again rarely cause damage of economic importance. Aphids can spread bean yellow mosaic virus if the aphids are blown in to the field from infected plants.

Faba beans are susceptible to several diseases. Chocolate spot (*Botrytis*) produces numerous reddish-orange lesions on the leaves, stems and pods (FIGURE 3). If the infection is severe, the leaves can blacken and fall off.

FIGURE 3. Chocolate Spot (Leaf Lesions).

Aster yellows is a widespread disease in western Canada, but usually very few plants are affected with this disease. Leaves turn yellow, first in the areas between the veins, and then throughout the entire leaf. The leaves may die, and the upper pods may fail to set seeds. Eventually, the entire plant may die. The disease is transmitted by leafhoppers, a small plant-sucking insect that is carried by the wind.

Ascochyta blight appears as spots on leaves, stems and pods. The spots on the leaves tend to have distinct tan-coloured margins and tiny black fruiting bodies (pycnidia) at the grey centres of the spots (FIGURE 4). If the infection is severe, general blighting can occur and seeds become discoloured and shrivelled.

FIGURE 4. Ascochyta Blight (Spots with Pycnidia).

Seedling blight affects young seedlings, causing black lesions on the main stem and a pinched appearance. Eventually the seedling dies. Usually only scattered plants in a field are affected, but frequent planting of faba beans without adequate crop rotation could increase the prevalence of this disease.

Sclerotinia stem rot, powdery mildew, and bean yellow mosaic virus are not generally a problem for faba beans in Saskatchewan, but they do have the potential to cause damage. Powdery mildew usually affects only some of the plants in a field. Faba beans are a genetically diverse crop so not all plants are equally susceptible. Bean yellow mosaic virus is often carried by aphids, especially from clover and other perennial legume fields, but aphids are not usually prevalent where faba beans are grown.

In general, the best disease control is obtained by using a good crop rotation which separates faba beans from susceptible crops by 3 or 4 years, and by using disease-free seed. Most diseases spread more readily in humid conditions. Reduced seeding rates and good weed control reduce the density of plant growth and the humidity within the plant canopy. Diseases are often less severe if the soil is well drained. Diseases may survive longer when residues are left on the soil surface than when they are buried by tillage.

Herbicide damage, such as from 2,4-D, can easily be mistaken for a disease. Typical symptoms include stunting, cupping, clubbing, twisting and bending of the stem. Often plants nearest to a source of spray drift will be most affected. It may be useful to leave an untreated buffer zone adjacent to the faba beans. This zone can then be treated when winds are blowing away from the faba bean field.

Faba beans respond well to irrigation as early drought stress can prematurely hasten maturity and reduce both yield and nitrogen fixation. Irrigation can promote germination if the seedbed is dry. Although plants do not tolerate prolonged flooding, faba bean produces the highest yield if water is not limited at any stage. The period immediately before and during flowering is most critical. Excess water prior to bud formation will result in excess vegetative growth, tall plants, delayed maturity and reduced seed yields, but this may be acceptable if the crop is grown for silage production. Continued irrigation after flowering will usually result in continued pod set. Irrigation to maintain soil moisture above 60% of soil moisture capacity in the top 24 inches is recommended. A total of 22 inches of water is required during the growing season. A centre pivot irrigation system is less likely to damage the crop, which can grow to over 6 feet in height.

Harvest

Faba beans will shatter if left standing until maturity when the humidity is low. Alberta studies have found that chemical desiccants can increase drying in poor weather conditions, but they also increase the risk of shattering. **There are currently no chemical desiccants registered for use in faba beans (see Chapter 2 - Weed Management).**

Swathing is recommended when 25% of the plants in the field have 1 or 2 pods turning black. At this stage, the upper pods should be fully developed and the middle pods should be turning light green. The seeds at this stage have about 35 to 45% moisture content in the lower pods, and 55 to 60% moisture content in the upper pods. Earlier harvest can result in a significant yield reduction because the seeds have not filled sufficiently. With later harvesting, shattering losses will increase. Moist swaths may require 2 to 3 weeks of good weather to dry. When the stand is heavy, the cutting width should be reduced to allow for more rapid drying. If the crop is lodged, it may be helpful to swath in only one direction and to use a pickup reel.

For silage production, the swath should be allowed to wilt from 1 to 3 days, depending on the weather.

Threshing at 16% moisture reduces the need for drying after harvest, but increases the risk of shattering. **The seeds can be threshed at 20 to 22% moisture if a drying system is available. Faba bean seeds are easily damaged, so gentle treatment is recommended.** Damage is reduced if combining is done while the swath is moist from dew. Shattering losses at the pickup are reduced if the pickup speed matches the ground speed. Draper pickups have a gentler action than drum pickups and help to reduce bean loss. The initial combine settings suggested are concave clearances of 3/4 inch at the front and 3/8 inch at the back; a chaffer setting of 5/8 inch; cylinder speed between 300 and 500 rpm; a high fan speed; and adjustment for minimal return tailings. The combine unloading augers should also be run at low speed to avoid seed damage.

POST HARVEST

Faba beans are dry enough for storage at 15 to 16% moisture. This is approximately the moisture at which beans change from "cheesy" to hard in the bite test. Because faba bean seeds are large, drying too rapidly with hot air may cause the outside of the bean to crack. **Two stage drying with at least 8 hour storage between stages is recommended to reduce cracking if seed moisture exceeds 20% and if the faba bean is to be sold or used as seed.** This slower drying allows moisture from the inside of the seed to equalize throughout the seed between drying procedures. A maximum drying temperature of 32°C is recommended. If the seed is used on-farm as feed, cautious drying is not necessary.

To produce faba bean silage, the plants should be cut when the bottom pods turn black and the swath should be allowed to wilt from 1 to 3 days. Faba bean silage is very dark in colour.

Storing and Handling

Faba beans can be easily damaged so they require gentle handling (see Chapter 2 - Storing and Handling). The germination potential is maintained for longer periods if seed is stored at lower temperatures (below 20°C) and at lower moisture contents (below 14%).

Grading

Faba beans are graded sample if more than 1% of the seeds are heated, rotted, musty, or mouldy (Table 2).

TABLE 2. Primary and Export Grade Determinants for Faba Beans.

Grade Name	Degree of Soundness	Maximum Limits						
		Damage					Foreign Material	
		Heated and/or Rotted	Mouldy	Perforated Damage	Total	Splits	Stones or Shale	Total
No. 1 Canada	Reasonably well matured, of reasonably good natural colour	Nil	Nil	1.0%	4.0%	6.0%	About 0.1%	About 0.2%
No. 2 Canada	Fairly well matured, fair colour	3K	6K	3.0%	6.0%	9.0%	About 0.2%	About 0.5%
No. 3 Canada	Excluded from higher grades on account of immaturity, poor colour or damage, but considered cool and sweet	1.0%	2.0%	3.0%	10.0%	12.0%	About 0.5%	2.0%
If specs for No. 3 Canada are not met, grade:		Faba Beans, Sample Canada, Account Heated	Faba Beans, Sample Canada, Account Mouldy Kernels	Faba Beans, Sample Canada, Account Damaged	Faba Beans, Sample Canada, Account Damaged	Faba Beans, Sample Canada, Account Splits	Up to 2.5%: Faba Beans Rejected (grade), Account Stones. Over 2.5%: Faba Beans, Sample Salvage	Faba Beans, Sample Canada, Account Admixture

Note: The letter "K" in this table refers to whole faba beans in 500 grams.

Chickpeas

Quick Tips - Chickpeas

Seeding Rate:	Variable, depending on seed size. Target 4 plants per square foot.
Seeding Depth:	2 to 3 inches.
Seeding Date:	Late April to early May for desi (5°C at 2 inches). Second week of May for kabuli (10°C at 2 inches).
Recommended Varieties:	Kabuli: Sanford or Dwelley. Desi: Myles.
Best Performance:	On fallow on Brown soil and on cereal stubble on Dark Brown soils.
Rolling:	Not necessary.
Registered Herbicides & Registered Fungicides:	Refer to Table 13, pages 2-23 and 2-24 or the Saskatchewan Agriculture and Food Crop Protection Guide.
Rotational Frequency of Chickpea Production for Disease Control:	4 years for ascochyta.
Swathing:	Only late in the season to hasten dry down.
Direct Harvesting:	18% moisture in vines, pods, and seeds.
Storage Moisture:	15%.

Chapter 7

Chickpea Production

INTRODUCTION

Chickpeas are native to the Middle East and have been grown traditionally throughout the semi-arid regions of India and the Mediterranean. Today, chickpeas are the third most important pulse crop (after dry beans and peas) and make up 20% of the world pulse production. The traded volume is similar to lentils. Major producers of chickpeas include India, Pakistan, and Mexico. Turkey, Mexico, and Australia are major exporters. Spain, Lebanon, and the USA are major importers. Canada has a small domestic market for chickpeas and chickpea products. This demand is currently met by imports from Mexico, California, Australia, Turkey, and Malawi.

Chickpeas are used exclusively as food in many countries, though they are used as livestock feed in Mexico. The large, white-seeded type, known as kabuli chickpeas, or garbanzo beans, are a popular salad item. Traditional uses include boiling, roasting, or processing into hummus (a traditional dish in the Middle East.) The small, dark-seeded type, known as desi chickpeas, is used as split chickpeas in dhal or ground into flour. The seeds have a high oil content (> 5%) so chickpea flour goes rancid if stored without refrigeration for more than a few months.

Chickpeas have a higher yield potential than lentils in the Brown soil zone where small plot yields are close to 2,000 lb/ac which is 18% higher than lentils (FIGURE 1).

FIGURE 1. Chickpea Plants in a Plot Trial.

THE CHICKPEA PLANT

Kabuli chickpeas have large, round, cream to white seeds with a thin white (zero tannin) seed coat. The seeds are about twice the size of field peas (260 to 600 g/1000 seeds). They are usually sold whole, and larger seeds receive a higher premium. About 10 to 15% of the world's chickpea production is kabuli and the remainder is desi. Desi chickpea seeds are smaller (120 to 300 g/1000 seeds), more angular, and seed coats can vary in colour from green to purple, brown, or black. Desi chickpea plants usually are shorter, higher yielding, earlier maturing and more resistant to disease, frost and insect damage than kabuli chickpea plants (FIGURE 2).

The chickpea seeds remain below the ground during germination, offering the plant some frost tolerance and the ability to regrow if top growth is damaged. Chickpeas have an indeterminate growth habit and usually need drought stress to hasten maturity. On average, the plant produces a new node every 3 to 4 days, and flowers at about the 13 or 14 node stage. The plants are small, but the taproot extends to rooting depths similar to wheat.

Plants begin to flower approximately 50 days after they emerge. Kabuli chickpea flowers are white; desi chickpea flowers are pink to purple. Single flowers are formed on a short stem from the base of the leaf, and generally self-pollinate before they open. The mature pods contain one or two seeds. In general, plants mature in 100 to 130 days and reach a height of 8 to 16 inches, depending on the availability of soil moisture.

ADAPTATION

Chickpea is a cool season plant usually grown as a winter crop in India, the Middle East, Australia, and South and Central America. It grows best if daytime temperatures are between 21 and 29°C and nighttime temperatures are between 18 and 21°C. The best temperature for germination is 15°C, but, with desi chick peas, germination will begin at soil temperatures as low as 5°C. Kabuli is more sensitive to cold and should not be seeded into soil colder than 10°C at placement

Chickpea

← Large Kabuli

← Medium Kabuli

← Large Desi

← Small Desi

FIGURE 2. Chickpea Seed.

depth. Seedlings will tolerate light spring frost, but frost damage on immature seeds (especially of kabuli chickpea) prevents the seeds from turning from immature green to the desirable golden colour.

Chickpeas are relatively drought tolerant. The long taproot allows it to use water to a greater depth than other pulse crops. In the absence of disease, chickpeas perform best when there is between 8 and 12 inches of rainfall during the growing season, and when cropped on soils that are well drained. Chickpea production in Saskatchewan is best suited to the Brown and Dark Brown soil zones. **Ascochyta blight can cause devastating losses in all soil zones so only ascochyta resistant varieties should be grown.** Production problems with seedling blight are less likely in the Brown soil zone.

FIELD HISTORY

As with all pulses, field history is important for chickpea production. Refer to *Chapter 2 - Field History* to determine if herbicides have been used which may cause problems. A bioassay is recommended to determine if the residues of these herbicides are still active. Activity after 5 years is not uncommon. Conditions for breakdown and degradation vary from product to product and are dependent on environmental and soil factors.

Although the major disease of chickpeas is an ascochyta that is different from the strains which plague other pulses, it is advisable to grow chickpeas in a rotation that includes a variety of crops and in which chickpeas do not follow chickpeas or other pulses.

Chickpeas are a short statured crop with an open canopy which allows weeds to be very competitive as they easily grow through and above the crop canopy. Steps should be taken to minimize weed problems before the chickpea crop is seeded. Weedy fields, particularly those with perennial thistle, should be avoided (see *Chapter 2 - Weed Management*). **Note: There are currently no herbicides registered for use in chickpea production.**

VARIETIES

Several truckloads of late-maturing ascochyta-resistant chickpea varieties from the United States were imported early in 1996 and grown for seed. Limited amounts of seed of these will be available in 1997 and 1998 (TABLE 1). These kabuli chickpea varieties were Sanford and Dwelley. Sanford is very late maturing, and Dwelley is even later maturing. Neither Sanford nor Dwelley have large enough seed to merit the maximum premium price available for extra-large-seeded varieties exported from Mexico. The desi chickpea variety was Myles. The domestic market for desi chickpeas is very limited.

The Crop Development Centre has a winter increase of an early maturing, ascochyta-resistant kabuli chickpea variety and a limited supply of breeder seed will be available in the spring of 1997. Seed of a small seeded kabuli, identified as B90 with round seed shape, will be available in the spring of 1997 from Terramax of Qu'Appelle. Market acceptance of this type is not yet known. **All other chickpea varieties such as UC27 kabuli, CDC Marengo desi and all other non-pedigreed desi chickpea varieties are HIGHLY SUSCEPTIBLE to ascochyta blight and not recommended for production.** At present, production of these susceptible varieties is possible only under ideal ascochyta-free conditions by using ascochyta-free seed, strict sanitation to prevent infection, and a pre-harvest field inspection. Several improved ascochyta-resistant varieties of both desi and kabuli types are expected to be released in the near future.

CROP MANAGEMENT

Seeding Considerations

As noted, seed selection is extremely important to ensure crop quality. **It is especially important to use seed free of ascochyta and seedling blights and to seed only ascochyta resistant varieties.** Chickpea seed has an exposed embryo with the root tip protruding, so it is very susceptible to mechanical damage. Seed germination and seedling vigour should always be tested. (See *Chapter 2 - Table 5* for a list of seed test laboratories.)

Chickpeas require inoculation with the correct *Rhizobium* in order for the plants to fix their own nitrogen. (See *Chapter 2 - Table 7* for a list of inoculant products.) An effective, locally adapted innoculant has been developed and will be available in 1997.

Most imported chickpea seed has been treated with a fungicide such as Captan. Apron (metalaxyl) is registered in Canada as a seed treatment in chickpea for protection from seedling diseases such as seedling blight and seedling rot. **If the seed is treated, it should be planted immediately after inoculation as seed treatments can be toxic to the inoculant. The longer the inoculant is in contact with the**

TABLE 1. Ascochyta Resistant Chickpea Varieties Available in Saskatchewan.

		Yield as % of Sanford								
Variety	Type	Brown Soil Zone	Dark Brown Soil Zone	Ascochyta Blight Resistance	Height (cm)	Days to Flower	Days to Maturity	Seed Weight (g/1000)	Breeding Institution	Distributor
Sanford	kabuli	100	100	yes	51	54	114	411	USDA/WSU	public
Dwelley	kabuli	88	79	yes	47	55	117	478	USDA/WSU	public
B-90	kabuli	107	108	yes	47	54	112	254		Terramax
Myles	desi	112	110	yes	43	48	109	196	USDA/WSU	public

seed treatment, the less effective it will be. Granular inoculant is less likely to be affected by fungicidal seed treatment than liquid formulations.

With proper inoculation, chickpeas usually will not require supplemental nitrogen fertilizer. However, soil tests are recommended to ensure that other nutrients are at appropriate levels. If greater than 15 lb/ac of phosphorus is needed, it should be side-banded or placed before seeding as excess seed-placed phosphorus can damage the seedlings. Another alternative is to use "Provide", a fungal inoculant that can enhance phosphorus uptake by plants. It can be seed placed either alone or with up to the maximum allowable rates of seed placed phosphate in order to arrive at required phosphorus levels.

Some producers of chickpea in southern Saskatchewan report the occurrence of micronutrient (such as Iron, Manganese) deficiencies in patches in their fields. Symptoms of brown and dropping leaves began at pre-flowering stage, especially during periods of wet weather and in low areas of the field.

If symptoms of micronutrient deficiencies occur, plant tissue samples can be taken and analyzed by a soil testing laboratory.

Chickpea seedlings are tolerant of frost. Desi chickpea seed can germinate in soil as cold as 5°C, but seedling vigour is greater if soil temperatures are at least 7°C. Kabuli chickpea seed is more sensitive to cold soils and should not be seeded into excessively wet soil or in to soil with temperatures below 10°C at the placement depth.

Kabuli chickpeas are particularly susceptible to damage when seeded at low temperature in wet soils, as a result of excessively rapid water uptake during the first 24 hours after seeding. The thin seed coat of the kabuli chickpeas does not restrict the rate of water uptake, and cell membranes may rupture in the cells of the cotyledons. The seeds may even split in extreme cases and soluble nutrients may be forcibly extruded from the seed. Seed rotting fungi, especially *Pythium*, can then feed on these nutrients, infect the seed, and kill the seedling before it can emerge. A partial solution is to delay seeding until the soil warms up to 10 to 15°C whereby most seedlings can emerge before they are destroyed by *Pythium*. However, the registration of Apron FL, which is extremely effective against *Pythium*, now permits producers of kabuli chickpeas to treat their seed with Apron FL and seed the kabuli chickpeas during the first week of May. Early seeding helps to reduce frost problems in the fall as it allows the crops to mature earlier.

The recommended seeding date is mid to late April for desi chickpeas and the first week of May for kabuli chickpeas. Earlier seeding increases the risk of seedling blights and seed rots. **Apron FL seed treatment is very effective against seed rots, permitting early seeding to help offset the later maturity of currently available chickpea varieties.** Later seeding reduces plant growth, the duration of flowering, seed set, seed size, and ultimately yield. However, crop developmental stages become more compressed with later seeding with little effect on yield. In the Brown soil zone with desi chickpeas, there was no advantage found to a late April vs. early May seeding date, either in terms of maturity or yield.

Chickpea, especially kabuli chickpea, seeds are relatively large and must take up their own weight of water during germination, so seeding into moisture is important. A seeding depth of 1 to 2 1/2 inches is usually the best and seedling emergence is reduced by deeper seeding. The seeder must be tested to ensure that it is capable of uniformly distributing these large seeds without plugging or chipping or damaging the seed.

Target seedling populations are 3 or 4 per square foot. Seeding rates depend on the size of the seed used, but target rates of 80 to 95 lb/ac are recommended for desi chickpeas and 120 to 140 lb/ac for kabuli chickpeas. Narrow row spacing and even seed distribution are beneficial for even canopy growth and maturity. Thin stands generally increase weed problems and delay crop maturity.

In-Crop Considerations

Although chickpea plants are quite short, pods are generally formed several inches above the soil surface. **Post emergent rolling is not recommended due to the potential to damage plants and spread disease.**

Chickpeas are not strong competitors with weeds. Weeds often emerge through the short open chickpea canopy. Chickpeas are able to maintain yield in the presence of weeds better than dry beans, but they are less competitive than peas or lentils. Yield losses from weed competition may be as high as 100%.

Mechanical weed control in the chickpea crop is not recommended. Post-emergent harrowing can cause severe crop injury because the stems are stiff and woody at an early age and harrowing also spreads disease.

No herbicides are currently registered for use in chickpeas in Saskatchewan. Since chickpeas are a recently introduced crop with very little commercial acreage, herbicide manufacturers have little incentive to develop products for chickpeas or to add chickpeas to their labels. Minor use registration of Edge as a pre-emergent or Sencor as pre-emergent or very early post-emergent control may be possible in the future. The risk of crop injury is fairly high as Sencor burns off all the leaves when it is applied post-emergently. A number of products used for broadleaf control in other pulses (such as Basagran, Pursuit, 2,4-DB, MCPA) have caused severe injury to chickpeas in test plots. A number of herbicides including Poast, Select, and Assure show promise for annual grassy weed and volunteer cereal control and may be pursued under the minor use registration program.

The chickpea canopy is generally shorter than most weeds by mid-season. A non-selective herbicide applied with a wick applicator above the crop canopy may provide some weed control without crop damage, but yield loss will already have occurred by this point.

Insect damage is unlikely in Saskatchewan, although aphids can cause problems in other regions of the world because they may carry viral diseases. Aphids are usually not of concern in the Brown and Dark Brown soil zones. Grasshoppers are the main insect threat, but in general, they prefer to feed on cereal crops rather than on pulse crops. The glandular hairs on chickpea leaves, pods, and stems contain acids which further deter insect attack.

At present, chickpea production in Saskatchewan is severely limited by ascochyta blight. This seed-borne fungus can wipe out the entire crop. The symptoms include brown lesions on stems, leaves and pods. Dark fruiting bodies, called pycnidia, are formed in the lesions. The lesions may girdle entire stems, causing them to wilt and die. Infection is favoured by wet weather. Infected plants of susceptible varieties will die in 3 to 4 weeks. If weather then turns warm and dry, less severely infected plants may survive, but these will be delayed in maturity. The disease is seed-borne so the use of disease-free seed is critical. It can also survive for several years on infected crop residues in the soil. A rotation where chickpeas are not cropped more than once in 4 years is recommended. Ascochyta susceptible varieties of chickpeas should not be seeded within 3 miles of an infected field for 3 years in order to minimize the risk of infection from the residue. Even then, some ascochyta spores can be wind blown for many miles and cause a low level infection late in the season. **Bravo foliar fungicide is registered for control of ascochyta blight in chickpeas.** A number of applications may be needed to slow the spread of this disease (FIGURE 3).

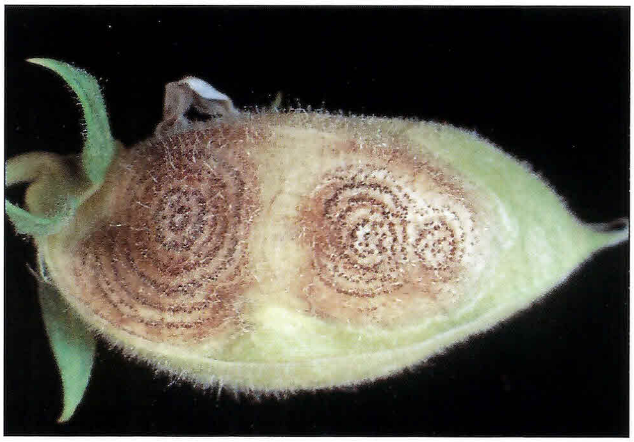

FIGURE 3. Ascochyta Blight on a Chickpea Pod.

Seedling blights are common in other regions of the world where they are commonly combatted with fungicide seed treatments. In drier areas, seedling blight disease build-up is unlikely.

Irrigation is not suitable for chickpea production in Saskatchewan because of maturity and disease problems.

Harvest

Chickpeas are a relatively short plant, but its pods are held several inches above the ground and do not readily shatter. This substantially reduces the difficulty of harvest. Chickpeas can be direct combined, or swathed and combined. To improve the ease of harvesting, chickpeas can be seeded into tall stubble (16" +). The plant increases in height due to reduced light intensity during early seedling development. This results in increased pod height.

Chickpeas can be swathed as early as 30% seed moisture without loss of yield or seed size, but best results usually occur if the crop is left until a majority of the pods are straw yellow. The swath can be combined when the vines, pods, and seeds are nearly dry (at 18% moisture). No desiccants are currently registered for use in chickpea in Canada.

The crop can be straight combined after vines, pods, and seeds have dried to about 18% moisture. The stage of the crop should be closely monitored as delayed harvesting increases the chances of weathered seed which makes the seed unacceptable to most processors and consumers.

The chickpea seedling root projects from the seed so rough handling can easily reduce germination, especially of the kabuli chickpeas. All harvesting and handling procedures should be done with the objective of minimizing seed damage. Cylinder speeds and ground speeds should be reduced and combine cylinder settings adjusted to accommodate this large, fragile seed. Air flow can be increased and sieves can be opened to reduce harvest losses.

Large, uniform, undamaged, light-coloured seeds are favoured by the kabuli chickpea market. Tan coloured, uniform sized seed is preferred in the desi chickpea market.

Seed should be stored at 15% moisture or less. Seed moisture testing metre conversion charts for kabuli chickpea are available from Saskatchewan Agriculture and Food Rural Service Centres.

Grading

The Canadian Grain Commission is in the process of developing standards for desi and kabuli chickpea grades.

References

Alberta. Dept. of Agriculture. 1988. Using 1000 kernel weight in crop management from seed time to harvest. Agrifax. Agdex 100/22-1. Alberta Agriculture, Edmonton, AB

Alberta. Dept. of Agriculture. 1987a. Dry pea production in Alberta. Agdex 142/20-6. Alberta Agriculture, Edmonton, AB

Alberta. Dept. of Agriculture. 1987b. Irrigation management of peas. Agrifax. Agdex 561-11. Alberta Agriculture, Edmonton, AB

Alberta. Dept. of Agriculture. 1982. Faba bean production in Alberta. Agrifax. Agdex 142/20-7. Alberta Agriculture, Edmonton, AB

Alberta Farm Machinery Research Centre (AFMRC). 1994. Pickett bean planter. Alberta Farm Machinery Research Centre, Lethbridge, AB. Report 711

Ali-Khan, S.T. and R.C. Zimmer. 1989. Production of field peas in Canada. Agriculture Canada Publication 1710/E. Agriculture Canada, Communications Branch, Ottawa, ON

Blackshaw, R.E. 1991. Hairy nightshade (*Solanum sarrachoides*) interference in dry beans (*Phaseolus vulgaris*). *Weed Sci.* 39: 48-53

Blackshaw, R.E. and R. Esau. 1991. Control of annual broadleaf weeds in pinto beans (*Phaseolus vulgaris*). *Weed Technology* 5: 532-538

Borstlap, S. and M.H. Entz. 1994. Zero-tillage influence on canola, field pea and wheat on a dry sub-arid region: Agronomic and physiological responses. *Can. J. Plant Sci.* 74: 411-420

Bremer, E. and C. van Kessel. 1992a. Plant-available nitrogen from lentil and wheat residues during a subsequent growing season. *Soil Sci. Soc. Am. J.* 56: 1155-1160

Bremer, E. and C. van Kessel. 1992b. Seasonal microbial biomass dynamics after addition of lentil and wheat residues. *Soil Sci. Soc. Am. J.* 56: 1141-1146

Bremer, E., C. van Kessel, and R. Karamanos. 1989. Inoculant, phosphorus and nitrogen responses of lentil. *Can. J. Plant Sci.* 69: 691-701

Buonassisi, A.J., R.J. Copeman, H.S. Pepin, and G.W. Eaton. 1986. Effects of *Rhizobium* spp. on *Fusarium solani* f. sp. *phaseoli*. *Can. J. Plant Pathol.* 8: 140-146

Campbell, C. 1995. Yield of lentil in a wheat, lentil continuous rotation at Swift Current. Agriculture and Agri-Food Canada, Swift Current Research Centre, Swift Current, SK. Personal communication.

Campbell, C.A. and R.P. Zentner. 1993. Soil organic matter as influenced by crop rotations and fertilization. *Soil Sci. Soc. Am. J.* 57: 1034-1040

Campbell, C.A., R.P. Zentner, F. Selles, and V.O. Biederbeck. 1992. Grain lentil is good for sustainability. *Prairie Steward* No. 8 (1992): 10

Campbell, C.A., R.P. Zentner, F. Selles, V.O. Biederbeck, and A.J. Leyshon. 1992. Comparative effects of grain lentil-wheat and monoculture wheat on crop production, N economy and N fertility in a brown Chernozem. *Can. J. Plant Sci.* 72: 1091-1107

Canada. Dept. of Agriculture. 1975. Growing and using faba beans. Agriculture Canada Publication 1540. Agriculture Canada, Ottawa, ON

Canada Grains Council. 1977. Faba beans. Information Bulletin No. 1. Canada Grains Council, Winnipeg, MB

Cowell, L.E., E. Bremer, and C. van Kessel. 1989. Yield and N2 fixation of pea and lentil as affected by intercropping and N application. *Can. J. Soil Sci.* 69: 243-251

Dean, J. Faba bean production. Field Crops Facts. Agdex 142. Manitoba Agriculture, Winnipeg, MB

Dean, J. and L. Slevinsky. 1993. Soil management for pulse crops. *The Pulse Beat* 6: 20-22

Derksen, D. 1993. Direct seeding of pulse crops. Saskatchewan Pulse Crop Development Board (SPCDB) *Pulse Newsletter* 9(2): 9

Evans, L.E. and A.E. Slinkard. 1975. Production of pulse crops in Canada. In: *Oilseed and pulse crops in Western Canada.* Harapiak, J.T. (ed). Western Co-operative Fertilizers Ltd. Calgary, AB. pp 287-324

Germida, J.J. 1988. Effect of herbicide stress on mycorrhizal symbiosis in field pea and lentil. In: *Proceedings of the 1988 Annual Meeting of the Saskatchewan Pulse Crop Development Board*, University of Saskatchewan, Saskatoon, SK

Graf, R.J. and G.G. Rowland. 1987. Effect of plant density on yield and components of faba bean. *Can. J. Plant Sci.* 67: 1-10

Grant, C.A. and G.P. Lafond. 1993. The effects of tillage systems and crop sequences on soil bulk density and penetration resistance on a clay soil in southern Saskatchewan. *Can. J. Soil Sci.* 73: 223-232

Gutek, L. 1991. Intercropping: field peas and oilseed crops. Saskatchewan Development Fund (SADF) New Ideas. Saskatchewan Agriculture and Food, Regina, SK

Gutek, L.H. 1985. Intercropping - Canola & peas. In: *Conservation for the Future. Proceedings of the Soils and Crops Workshop*, Feb. 18-19, 1985. Saskatoon, SK

Hickling, D. (ed). 1994. *Canadian peas: Feed industry guide.* Canadian Special Crops Association, Winnipeg, MB and Western Canada Pulse Growers Association, Regina, SK

Hnatowich, G.L. and K.G. Jamieson. Field pea nitrogen fertilization.

Hulbert, H.W. and G.M. Whitney. 1984. Effect of seed injury upon the germination of *Pisum sativum. J. Am. Soc. Agron.* 26: 876-884

Hulse, J.H. 1992. Nature, composition, and utilization of food legumes. In: *Expanding the production and use of cool season food legumes.* Muelhlbauer, F.J. and W.J. Kaiser (ed). Kluwer Academic Publishers, The Netherlands. pp 77-97

Hwang, S.F. 1990. Etiology of root rot diseases in field peas. Final report to Agriculture Development Fund (ADF). Project R-90-D-0602. Agriculture Development Fund, Regina, SK

King, W.J. 1981. Irrigation Extension Branch, Saskatchewan Agriculture and Food (SAF). Agronomic requirements of broadbeans. Extension Bulletin Pub. 81-06. Saskatchewan Agriculture and Food (SAF), Outlook, SK

Kondra, Z.P. 1975. Effects of row spacing, seeding rate and date of seeding on faba beans. *Can. J. Plant Sci.* 55: 211-214

Lafond, G.P., H. Loeppky, and D.A. Derksen. 1992. The effects of tillage system and crop rotations on soil water conservation, seedling establishment and crop yield. *Can. J. Plant Sci.* 72: 103-115.

Lafond, G.P., R.P. Zentner, R. Germida, and D.A. Derksen. 1993. The effects of tillage systems on the economic performance of spring wheat, winter wheat, flax and field pea production in east-central Saskatchewan. *Can. J. Plant Sci.* 73: 47-54

Lopetinsky, K. 1992. Faba bean production tips. *Pulse Crop News* Spring 1992: 11-12

Manitoba. Dept. of Agriculture. 1986. Field pea production in Manitoba. Manitoba Agriculture, Winnipeg, MB

McVetty, P.B.E., L.E. Evans, and J. Nugent-Rigby. 1986. Response of faba bean (*Vicia faba L.*) to seeding date and seeding rate. *Can. J. Plant Sci.* 66: 39-44

Miller, P. 1996. Preliminary data from Agriculture and Agri-Food Canada - SPARC on alternative cropping systems.

Olfert, O. 1995. Agriculture and Agri-Food Canada, Saskatoon, SK. Saskatchewan Pulse Crop Development Board Annual Conference 1995, Saskatoon, SK. Personal communication.

Oram, P.A. and M. Agcaoili. 1992. Current status and future trends in supply and demand of cool season food legumes. In: *Expanding the production and use of cool season food legumes*. Muehlbauer, F.J. and W.J. Kaiser (ed). Kluwer Academic Publishers, The Netherlands. pp 3-49

Park, S.J. 1989. Growing field beans in Canada. Agriculture Canada Publication 1787/E. Agriculture Canada, Communications Branch, Ottawa, ON

Prairie Agricultural Machinery Institute (PAMI). 1993a. Bourgault air seeder pulse seed handling. Prairie Agricultural Machinery Institute, Humboldt, SK. Research Update 702

Prairie Agricultural Machinery Institute (PAMI). 1993b. Moisturizing pulses to reduce damage. Prairie Agricultural Machinery Institute, Humboldt, SK. Research Update 704

Prairie Agricultural Machinery Institute (PAMI). 1992a. Air seeder damage to pulses. Prairie Agricultural Machinery Institute, Humboldt, SK. Research Update 668

Prairie Agricultural Machinery Institute (PAMI). 1992b. Conveying equipment for pulse crops. Prairie Agricultural Machinery Institute, Humboldt, SK. Research Update 660

Prairie Agricultural Machinery Institute (PAMI). 1992c. Lentil storage. Prairie Agricultural Machinery Institute, Humboldt, SK. Research Update 678

Prairie Agricultural Machinery Institute (PAMI). 1991a. Final report for minimizing bean harvesting losses. Prairie Agricultural Machinery Institute, Humboldt, SK. Report RH0191

Prairie Agricultural Machinery Institute (PAMI). 1991b. Norton inoculator and seed treater. Prairie Agricultural Machinery Institute, Humboldt, SK. Report 640

Prairie Agricultural Machinery Institute (PAMI). 1990a. Development of guidelines for selection and operation of bean conveying equipment. Prairie Agricultural Machinery Institute, Portage la Prairie, MB. Report RP0189

Prairie Agricultural Machinery Institute (PAMI). 1990b. Equipment innovations for inoculating pulse seeds. Prairie Agricultural Machinery Institute, Humboldt, SK. Report RH0189

Prairie Agricultural Machinery Institute (PAMI). 1990c. Pulse crop cutting equipment. Prairie Agricultural Machinery Institute, Humboldt, SK. Report 633

Rennie, R.J. and S. Dubetz. 1986. Nitrogen-15-Determined nitrogen fixation in field-grown chickpea, lentil, faba bean and field pea. *Agron. J.* 78: 654-660

Rowland, G.G., B.N. Drew, and F.A. Holm. 1985. Faba bean production in Saskatchewan. AgDex 142/10. Saskatchewan Agriculture and Food, Economics Branch, Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1995. Varieties of grain crops 1995. SAF, Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1994a. Alternative crop planning guide, 1994. FarmFacts, Saskatchewan Agriculture and Food (SAF), Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1994b. Dry pea production in Saskatchewan. Farm Facts, Saskatchewan Agriculture and Food (SAF), Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1994c. Guidelines for safe rates of fertilizer applied with the seed. FarmFacts, Saskatchewan Agriculture and Food (SAF), Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1989. When to swath and thresh special Crops. FarmFacts, Saskatchewan Agriculture and Food, (SAF), Regina, SK

Saskatchewan. Dept. of Agriculture and Food. 1970. Legume inoculation. FarmFacts, Saskatchewan Agriculture and Food (SAF), Regina, SK

Saskatchewan Pulse Crop Development Board (SPCDB) *Pulse Newsletters*

Saskatchewan Water Corporation (SWC). 1992. Production costs and yields - Irrigated crops 1992. Irrigation handi-facts. Saskatchewan Water Corporation (SWC), Outlook, SK

Saskatchewan Water Corporation (SWC). 1989. Irrigated production of green or yellow field pea. Irrigation handi-facts. Saskatchewan Water Corporation (SWC), Outlook, SK

Slinkard, A.E. and B.N. Drew. 1986. Dry pea production in Saskatchewan. AgDex 140/10. Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, SK

Slinkard A.E., A. Vandenberg, and P.J. Hucl. 1993. The Saskatchewan dry bean development program. Annual progress report. 1993. Sask. Pulse Crop Development Board (SPCDB), Regina, SK and Western Grains Research Fund.

Smith, J.A. 1988. Combine damage to dry edible bean seed. American Society of Agricultural Engineers.

Sokhansanj, S., A.A. Falacinski, F.W. Sosulski, D.S. Jayas, and J. Tang. 1990. Resistance of bulk lentils to airflow. Transactions of the ASAE 33(4):1281-1285.

Sonntag, G.J., D.A. Derksen, H.A. Loeppky, G.P. Lafond, and R.P. Zentner. 1997. Economics of diversified and reduced input rotations under zero- and conventional-tillage management. Agriculture and Agri-Food Canada.

Stevenson, C. 1995. Dept. of Soil Science, University of Saskatchewan. Saskatchewan Pulse Crop Development Board Annual Conference 1995, Saskatoon, SK. Personal communication.

Tang, J. and S. Sokhansanj. 1994. A model of thin layer drying of lentils. Drying Technology 12(4):849-867.

Tang, J., and S. Sokhansanj. 1993. Drying parameter effect on lentil seed viability. Transactions of the ASAE 36(3):855-861.

Tang, J., S. Sokhansanj, and F. W. Sosulski. 1991. Determination of the breakage susceptibility of lentil seeds. Cereal Chemistry 68(6):647-650.

Tang, J., S. Sokhansanj, F.W. Sosulski, and A.E. Slinkard. 1991. Effect of harvest methods on moisture content and quality of lentil seeds. Canadian Journal of Plant Science 72:451-456.

Tang, J., S. Sokhansanj, F.W. Sosulski, and A.E. Slinkard. 1990. Effect of swathing and moisture content on seed properties of Laird lentils. Journal of Plant Science 70:1173-1178.

Townley-Smith, L. 1995. Crop sequences involving peas in NE Saskatchewan. Final report summary to Saskatchewan Pulse Crop Development Board (SPCDB). Draft.

Townley-Smith, L., A.E. Slinkard, L.D. Bailey, V.O. Biederbeck, and W.A. Rice. 1993. Productivity, water use and nitrogen fixation of annual-legume green-manure crops in the Dark Brown soil zone of Saskatchewan. *Can. J. Plant Sci.* 73: 139-148

Townley-Smith, L. and A.T. Wright. 1994. Field pea cultivar and weed response to crop seed rate in western Canada. *Can. J. Plant Sci.* 74: 387-393.

United States Dept. of Agriculture, Agricultural Research Service (USDA-ARS). 1983. Description and culture of dry pea. Agricultural Reviews and Manuals ARM-W-37. Agricultural Research Service, Western Region, Oakland, CA

Vandenberg, A. and A.E. Slinkard. 1989a. The evaluation of field bean (*Phaseolus vulgaris L.*) as an alternative grain and seed production crop for irrigated regions of South-central Saskatchewan. Final report. Agriculture Development Fund (ADF), Regina, SK

Vandenberg, A. and A.E. Slinkard. 1989b. The potential for irrigated dry bean production in Saskatchewan. In: *Proceedings of the Soils and Crops Workshop*, Feb. 16 & 17, 1989, Saskatoon, SK. University of Saskatchewan, Saskatoon, SK. pp 503-509

Vandenberg, A., A.E. Slinkard, and P.J. Hucl. 1992. Determining suitable agronomic practices for short-season irrigated dry bean production. *J. Prod. Agric.* 5: 171-176

Vandenberg, B. 1991. Dry bean production under irrigation in Saskatchewan. Saskatchewan Irrigation Development Centre (SIDC), Newsletter Feb. 1991, Outlook, SK

Vandenberg, B. and N. Whatley. 1992. Tips for growing pinto bean on dryland. Crop Development Centre, Project Memorandum, University of Saskatchewan, Saskatoon, SK

Wall, D. 1993. Competitiveness of field pea cultivars with wild mustard. In: *Weed biology, ecology and weed management, technical reports*, Dec. 7-8, 1993. Expert Committee on Weeds, Saskatoon, SK. pp 70-73

Wall, D., G.H. Friesen, and T.K. Bhati. 1991. Wild mustard interference in traditional and semi-leafless field peas. *Can. J. Plant Sci.* 71: 473-480

Wall, D.A. 1993. Wild mustard (*Sinapis arvensis.L.*) competition with navy beans. *Can. J. Plant Sci.* 73: 1309-1313

Wright, A.T. 1990a. Quality effects of pulses on subsequent cereal crops in the northern prairies. *Can. J. Plant Sci.* 70: 1013-1021

Wright, A.T. 1990b. Yield effects of pulses on subsequent cereal crops in the northern prairies. *Can. J. Plant Sci.* 70: 1023-1032

Wright, A.T. and L. Townley-Smith. 1990. Pulses in rotation. FarmFacts. Saskatchewan Agriculture and Food (SAF) and Saskatchewan Rural Development, Regina, SK

Zapata, F., S.K.A Danso, G. Hardarson, and M. Fried. 1987. Nitrogen fixation and translocation in field-grown faba bean. *Agron. J.* 79: 505-509

Zimmer, R.C. 1985. A review of seed-applied pesticides and compatibility with rhizobia on legumes. In: *1985 Manitoba Agronomists' Conference Proceedings*, University of Manitoba, Dec. 11 & 12, 1985. pp 68-69

Zyla, Lloyd and W.B. Reed. 1993. Reduction of dry bean harvesting losses. University of Saskatchewan, Agriculture and Bioresource Engineering, Saskatoon, SK