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New Crop Development: The Canadian Experience

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INTRODUCTION

Canadian agriculture is based upon the introduction and successful adaptation of crop species into various regions of the country (Blade et al. 2002). The catalyst for successful expansion of spring wheat (*Triticum aestivum* L.) production in the prairie region was the introduction and development of adapted germplasm and region-specific agronomic management strategies. The continued success of the canola (*Brassica campestris* L. and *B. napus* L.) industry was brought about by a multidisciplinary approach involving biochemists, plant breeders, physiologists, pathologists, agronomists, nutritionists, and a great diversity of other expertise to create a unique oilseed crop (through the elimination of erucic acid and glucosinolates from the seed). Canada has a strong history of identifying new crop opportunities, and putting together the necessary expertise to ensure both production and market success.

Crop diversification in Canadian agriculture is experiencing a time of growth and excitement (all data for 2001). Chickpea (*Cicer arietinum* L.) area has increased dramatically in the past three years to 500,000+ ha. The production of both field pea (*Pisum sativum* L.; 1,460,000 ha) and lentil (*Lens culinaris* Medik.; 732,000 ha) has increased severalfold in the last decade. The rapid expansion of these three crops makes Canada their largest global exporter; Canada is also the world's largest exporter of mustard (*Brassica juncea* L.) and canaryseed (*Phalaris canariensis* L.). This production is primarily based in the prairie provinces of western Canada (Saskatchewan, Alberta, and Manitoba). In addition, the prairies have thriving dry bean (*Phaseolus vulgaris* L.) and sunflower (*Helianthus annuus* L.) industries, plus developing activity in spice production such as coriander (*Coriandrum sativum* L.), caraway (*Carum carvi* L.), and several *Mentha* essential oil crops (peppermint, spearmint). Many other potential alternate crop species are in various stages of commercial research and development; linola edible flax (*Linum usitatissimum* L.), fenugreek (*Trigonella foenum-graecum* L.), low-THC industrial hemp (*Cannabis sativa* L.), borage (*Borago officinalis* L.), and safflower (*Carthamus tinctorius* L.). Other parts of Canada have seen expansion in ginseng (*Panax quinquefolius* L.), cranberry (*Vaccinium macrocarpon* Ait.), and other nutraceutical crops with exciting value-adding opportunities (Blade and Mirza 2000).

Canada's diversification success has come about because of four major influences: (1) the need to diversify crop production in the face of large global surpluses in some of our primary crops; (2) Canada has a huge agricultural land area available with a diversity of climatic conditions for which suitable introduced crops can be found; (3) Canada's primary producers are motivated, knowledgeable growers who have been willing to take on new challenges; and (4) the Canadian research community, industry and commodity groups have developed focused, multidisciplinary programs to identify and develop new crops which have strong market potential.

WHAT IS CROP DIVERSIFICATION?

A new crop is a crop or crop product new to an area. New crop development is the adoption of a plant in a particular geographic region (for the purposes of production) so that it can be manipulated as a crop for the generation of some commercial product (for the satisfaction of consumers). The product has not previously been successfully produced from that plant in that region (Fletcher 2002). Small (1995) defined crop diversification as "programs of expanding the number of crops in a region, in the hope of increasing overall productivity and marketability." Wallis et al. (1989) noted that it was important to have a well-developed selection criteria to identify successful new crop industries in any region.

Although the idea will not be dealt with extensively in this paper, crop diversification can also involve conventional crops. This type of activity falls into a number of categories:

1. Adaptation of the crop to grow in new eco-regions. The development of adapted germplasm has resulted in greatly increased production of Argentine canola (*Brassica napus* L.) cultivars in the Peace

region of the province of Alberta (latitude 55°–58°N).

2. Research and development to identify unique components or constituents that can be extracted from conventional crops, such as the industrial extraction of beta-glucans from barley (*Hordeum vulgare* L.).
3. Development of cultivars which are adapted to specific production systems, such as varieties which perform well within organic cropping systems.
4. The use of transformation technologies to develop new types of conventional crops which have the capability of producing high-value products through the still-evolving tools of molecular biology (such as pharmaceutical products produced from modified oilseed crops). Development of such products must include a public education component regarding the value of such products, as well as a secure system of production to ensure no risk to conventional production and marketing systems.

WHY SHOULD CANADA DIVERSIFY?

Crop diversification is driven by several motivating factors (Connor 2001). These include:

Low Conventional Crop Prices

Efficient producers have a clear picture of how conventional crop prices will influence their profitability. When conventional crop prices fall due to overproduction and subsequent over-supply, they look for other alternatives (Thompson 1988). The overall goal of crop diversification is to increase profitability.

Innovation

The rapid inclusion of any new technology has provided a great opportunity for many industries. Producers and processors are always eager to get in on the "ground floor" of a new idea which promises to be lucrative. Due to the increased level of knowledge available through new resources such as the internet, and the international contacts and the interest of some producers much greater emphasis has been placed on the assessment of new crops to establish the potential of species from other parts of the globe.

Environmental Protection

The inclusion of nitrogen-fixing legumes, tree crops, fiber crops, and other bio-product crops in cropping systems can have advantageous effects. These benefits can be obtained by reducing the requirement for application of inorganic fertilizers, decreasing the need for forest fiber through annually renewable agricultural sources, increasing the potential for minimum tillage systems in annual cropping systems, and establishment of long-term perennial plantations.

Risk Reduction

The inclusion of several species in a crop production plan can have the advantage of buffering low prices in a specific crop. Diversification allows a producer to balance low prices in one or two crops with reasonable returns in other commodities.

Biodiversity

The additional advantage to increased numbers of crops is that the enhanced biodiversity can reduce problem insects and diseases as well as create new opportunities for innovative weed management through extended crop rotations.

Development of New Production Systems

The advent of minimum tillage systems created a new window for crop diversification. The switch from summerfallow to direct seeding encouraged the inclusion of additional grain legume area in western Canadian farming systems. Producers have also incorporated intercropping of annual crops (for both grain and fodder production) to maximize yield and quality (Blade et al. 2001).

Many articulate and persuasive arguments have been advanced to expand crop diversification in several parts of the world including Canada (Small 1995, 1999), the US (Janick et al. 1996; Janick 2001; Jolliff 1989, 1996, 1999), Australia (Jessop and Wright 1991), and Europe (Wallis et al. 1989; Anthony et al. 1993).

ECONOMICS OF CROP DIVERSIFICATION

Canada has a very small population relative to the types of crops that are grown in the country. Some people can be successful by selling relatively small volumes of culinary herbs, medicinal plants, and some niche-market products (organic grains, etc.) through direct marketing techniques (farmers markets) and local brokers and/or processors. The problem is that Canada also has a limited market due to its population (+30 million). Furthermore, Canada has almost 20 million ha of annual crops in an average season. That means that we need to look at markets beyond our borders to sell our production. This means that we must sell our crops in an international marketplace. Selling diversified crops and crop products in a global marketplace involves a number of challenges as indicated below.

Static Demand Levels

The global demand for a crop, such as canaryseed, has stayed constant for several years. This means that any small deviation in supply or demand will create large price swings in the market. When production falls due to weather conditions or low price, then the price increases. The increased price prompts producers to respond by producing more canaryseed, and the price drops (thus the adage, "nothing cures high prices like high prices").

Limited Global Demand

In many specialty crops, global trade is low because the market is limited. In the case of spice crops, such as caraway, world consumption has been very stable in the past decade. Unless new uses are identified for a crop, the world price will fluctuate rather dramatically due to relatively small volumes being traded. A drought in one part of the world, or a large crop due to superb growing conditions can have a major effect on price.

Product Replacement

End users of many specialty crops have limited their own risk by building flexibility into their processing systems. If the price becomes prohibitive (from a processor's viewpoint), then alternative sources of the constituent can be sought. The development of borage as a crop in western Canada (El Hafid and Blade 2002) to produce a specific fatty acid (gamma-linolenic acid) has been greatly influenced by offshore sources which can produce the same constituent from species such as evening primrose (*Oenothera biennis* L.).

Product Life Cycles

All products go through life cycles, and this is also true of crop-based industries. Small and Catling (1999) have identified four stages in the development of a new crop: (1) the initial phase is one where investment in research and development on the crop is costing the business money; (2) this eventually leads to enough profit that the expanding markets and profitability of the production make money for the enterprise; (3) this initial growth eventually reaches a plateau which is profitable, but exhibits little further growth; and (4) after a certain time period the competition from new groups vying for the same market and the loss of any technology advantage due to copy-cat businesses results in a decline in profitability until the industry becomes unviable.

This cycle can be influenced by new product development (made expensive due to the high cost of research), identification and cultivation of additional markets, and protection (if possible) of the intellectual property that is the basis for the commercial product.

WHY IS CROP DIVERSIFICATION SO DIFFICULT?

Crop diversification has met with only limited success in many parts of the world due to various reasons. At the risk of frightening readers here is a non-exhaustive list of why crop diversification does not work.

Business Challenges

Limited Knowledge of Markets. One of the major stumbling blocks for a successful crop diversification enterprise is limited knowledge of what the market wants (Babb 1990). The buyers may have very specific

requirements regarding desired quality and quantity of product. In addition, since the markets for some products are relatively small, no public information is available on market demand and global production.

Market Development. Crop diversification is a complex series of processes that requires a wide array of expertise. In many cases the production of the crop is the least problematic part of the exercise. In addition to agronomic competence, the grower needs to make connections with the industry, evaluate potential strategic alliances, work with customers who have high quality demands, and be capable of good logistical organization of his business to deliver what people want when they want it. If growers do not have an interest in doing this, or lack the business expertise then diversification opportunities may be difficult to convert into economic return. Boehlje and Schrader (1996) stated that agriculture was going to evolve into an industry driven by a "manufacturing approach," which would be characterized by the development of specific end products for dedicated end use. This would require alliances to be developed along the entire chain from crop improvement through production and processing to the consumer.

"Get Rich Quick" Mentality. The nature of many crop diversification headlines is that the new species is a ticket to riches and good fortune. This creates unrealistic expectations for current producers, and it is possible that the hype will draw in non-producers who will invest time and resources with limited understanding of the potential downside. Some new crops have developed unrealistic expectations due to intense media interest. These crops were subsequently identified as failures when they fail to meet inflated expectations.

"Catch-22 (No Markets: No Growers) Market Development." Many new crops could have a market success, but the end users do not have a steady supply of the crop (inconsistent volume or quality), so they do not set an attractive price to stimulate production. This leads to an unfortunate situation where capable and willing growers, and legitimate end users are available but not linked. No supply and no established market results in the crop not realizing its potential.

Limited Economic Information. Producers need some basic level of information regarding the cost of production and potential return for a specific crop. This type of information, especially in regard to potential yields and possible price per unit are often non-existent or of limited value due to the necessity for multiple estimations due to limited production and market information.

Protection of Investment in Research and Development. Many crop diversification ideas do not meet the criteria for protection of intellectual property. This is a significant problem if an individual or small group invests in the early phase of research and development. If they cannot protect their innovation, then all "copy cats" can start to compete when the crop reaches profitability. Methods of eliminating this problem are by developing protected cultivars with unique characteristics, or modifying the crop product through a patentable process.

Inflexibility of Growers and Users. Crop diversification is complicated enough without intransigence within the producers and processors of new crops. They must develop a mechanism for negotiating issues of quality and quantity of supply. For example, if a buyer wants a minimum volume to make a purchase, can several growers combine their shipments? This may be easier said than done, because pooling of product raises the issue of a grading system to ensure that all contributors are rewarded (or otherwise) for the quality of their crop.

Infrastructure Limitations. In many crops it is necessary to have storage facilities or different transportation requirements for handling unique crops (such as bean ladders for reducing breakage in pulse crops). It may also be necessary to store the harvest under unique conditions or do additional post-harvest drying which requires a crop-specific drying facility.

Lack of Investor Awareness/Understanding. As a business expands, it may be necessary to obtain external financing. Lending institutions and other venture capital firms are very hesitant to invest in something new and (in their evaluation) unproven. Lending groups want to see a track record of success within a sector, but some new crop products may be the first of their kind.

Research and Development Obstacles

Lack of Research Funding. Very little public funding is available for research and development of new crops. It takes a long, consistent effort to develop crop diversification opportunities into commercial products.

Limited Research Focus. The development of a new crop from initial fact-finding to product commercialization requires a substantial research effort. One limitation of crop diversification is that a crop may be taken on as a pet project by one researcher or a small group who have several other research projects in place. The resulting dilution of the work's ownership makes it hard for the group to seek external research support for "their" crop. In some cases, it is difficult to interest a researcher with the required expertise (e.g. pathology, etc.) because of the perception (by either the scientist or their research manager) that this is not a viable crop and the scientist's time would be better spent elsewhere.

Insufficient Coordination. Due to the large amount of effort needed in crop diversification, it is imperative that the research and development be coordinated. If more than one group is working on a species or product, some sort of strategic alliance must be developed. The difficulty is that when only a small existing market is available, no company wants to give up its perceived advantages to share with its competing companies. In the same manner, research groups must ensure that their work complements each other's work as opposed to re-inventing the wheel.

Insufficient Continuity. It is common in the development of new crops to have research and development move ahead in fits and starts. One researcher may embark on a valuable set of projects, but then move away without any further progress. Companies rise and fall in relation to specific crop and crop products, but no effort is ever made to pull together all the documentation and informal knowledge so that true progress on be built on both past failures and successes.

Limited Economic Botany. Every region has a wealth of indigenous species which may have some commercial potential, but knowledge of potential opportunities may be limited because no economic botanists are working in the region. Local species can contain unique compounds or constituents which might merit genetic development and agronomic evaluation.

Production Problems

Lack of Adapted Germplasm. Since the definition of crop diversification is that the plant does not traditionally grow in the region, it is very likely that imported germplasm will not be adapted for local growing conditions. A concentrated effort of screening and genetic development may be necessary, if the crop is to be successful (Simmonds and Smartt 1999).

Agronomic Ignorance. If adapted land races or cultivars are available, information may still be limiting for other aspects of agronomy (seeding date, seeding rate, depth of planting, fertility requirements, insect/disease/weed control, harvest methods and timing, post-harvest storage, etc.).

Climatic Limitations. Even adapted cultivars may be very regional in their adaptation. A crop that has success in one part of the province might be far too late in maturity in another region. In the case of field pea, cultivar recommendations are provided on the basis of potential precipitation since this will have a major effect on yield and height (which will influence subsequent harvest management of the crop).

Quality and Processing Issues

Commercialization Problems. A new crop may have success in a niche market when grown by one grower or processed in a small home-based facility. It can be difficult to scale-up the operation for reasons which include: technical roadblocks, investment capital, contracting of production, or maintenance of cash flow. It may take a large investment to capture the economies of scale which will make or break an enterprise.

Analytical Deficiencies. The requirement for many niche crops is to meet rigorous quality control standards (Gray et al. 2001). It can be very difficult (and very expensive) to find laboratories capable of providing the detailed chemical analysis that may be necessary to attract a buyer and ensure product quality. In some cases the active ingredient may be unknown in a specific crop. In other instances, the constituent may be known, but no internationally-recognized methodology is available to quantify the ingredient (leading to confusion of both buyers and sellers).

Policy Issues

Insufficient Political Support. Agricultural policy can have a significant effect on the viability of both producers and individual crops (Williams and Haq 1993). Diversified crops do not always have this kind of

advocacy. However, due to the changes and challenges within the agricultural sector over the past few years, the promise and potential for crop diversification is gaining credence at many levels of government.

Conventional Crop Orientation of Agricultural Programs. Many programs, such as crop insurance and emergency-product registrations, are exclusively focused on conventional crops.

No Lobby for New Crops. The current research environment is heavily weighted toward programs and projects where industry contributions can be invested in a matching system with public dollars. This is very effective for established, large-scale crop industries and companies, but the lobby for new crop research and the financial resources to leverage public research support is very limited.

Competition with Conventional Crops. The new crop industries must compete with conventional crops which produce starch, oil, and protein. New crops must attempt to succeed within a system that has evolved to favor conventional crops in areas such as transportation policy, research resources for production and value-added research, agricultural policy development, and competition for investment in new processing facilities.

Global Competition. Since all of the products grown from new crops originate in other parts of the world, international competition is a direct and major threat. It is possible that a promising industry will be hampered by unfair agricultural policies that affect producers in other countries. (The European Union subsidy on low-THC industrial hemp production makes it difficult for Canadian producers to compete.)

Other Reasons

Apathy. Many producers do not have any interest in crop diversification. This is not a bad thing; it is good news, if producers are prospering by the production of conventional crops. However, farmers may have an interest in diversification, but do not have the time (or in some cases the resources) to investigate new opportunities.

Consumer Tastes. Many diversification crops grow well in western Canada, but most of the markets exist outside of the region. The development of an increased domestic market for both human foods and products (herbs, spices, pulses) and feed markets (pulse crops as a replacement for soy meal) is a viable option for establishing "new" markets.

Regulatory Restrictions. Regulations restrict the commercial production of a limited number of species, with the most obvious examples being low-THC (non-psychoactive) hemp and poppies produced for food products. The Government of Canada collaborated with a wide variety of stakeholders and developed legislation in 1998 to make commercial low-THC hemp production possible, although the process is still encumbered by a detailed licensing process (Blade et al. 1999).

CANADIAN SUCCESS STORIES

With the litany of reasons why crop diversification does not work, it is amazing that Canada has had a number of tremendous success stories. These have come about through a dedicated research effort, viable commercial opportunities, and in some cases a bit of good fortune.

Canola

The greatest progress has been with rapeseed (*Brassica campestris* L. and *B. napus* L.). Rapeseed has been transformed from a minor forage crop in the 1940s to a source of marine oil (high erucic acid) in the 1950s to canola (a high quality edible oil) in the 1960s and 1970s (Busch et al. 1994). The area seeded to canola in Canada peaked at 5.5 million ha in 1999, and dropped to a forecast 3.9 million ha in 2001, due to the low prices for the large 1999 crop. The development of higher yielding cultivars that are herbicide tolerant and have higher levels of disease resistance should stabilize Canadian canola plantings at 4 to 5 million ha. Western Canada also has a large canola crushing capacity producing edible oil and canola meal (a protein source relatively high in lysine for livestock rations).

Pulse Crops

The second area of amazing progress is in the grain legumes with specific success in lentil, dry pea, and chickpea. In the past decade the production of these crops, along with dry beans, have multiplied several fold so that total exports for Canada will be over 4 million metric tonnes (t) in 2002. Canada is the world's leading

exporter of lentil, dry pea and chickpea.

Producers are convinced that grain legumes are useful in their cropping systems for the following reasons: (1) ability to reduce in-season nitrogen fertilizer application due to biological nitrogen fixation, (2) opportunity to break disease cycles of cereal crops, (3) observed increase in soil tilth due to inclusion of grain legumes, (4) possible fertility advantage to crops in subsequent seasons, (5) opportunity to increase cash flow through cash sales after harvest, (6) no involvement with marketing by the Canadian Wheat Board, and (7) good margins for pulse production rate of return in most parts of the prairie region of Canada.

Dry Pea. Dry peas were grown widely in Ontario in the 1800s, but production declined over the years, and crops with higher returns replaced them. After WWII, Manitoba seeded dry peas on a small area (up to 20,000 ha, Slinkard and Blain 1988). The wheat glut and resulting low price of wheat during the late 1960s stimulated crop researchers in Saskatchewan to evaluate potential new crops for the area. The abundance of a starch crop (wheat) and an oilseed crop (canola) suggested that a protein crop should be developed. Subsequently, dry peas were given top priority. The Crop Development Centre (CDC) was established at the University of Saskatchewan, jointly by the Province of Saskatchewan and the National Research Council of Canada (NRCC) in 1971. The Prairie Regional Laboratory, NRCC, developed two methods (wet and dry) for processing peas into pea flour, pea starch, and pea protein concentrate (Youngs 1975). Soon, two private companies started processing dry peas into pea products. Unfortunately, markets developed very slowly and the pea industry developed erratically. In the early 1980s, the European Union (EU) decided to become less dependent on imported soybean meal and corn gluten meal as sources of protein for their livestock industry, and switched to domestic peas as the major source. However, the European supply was inadequate, forcing the EU to import huge quantities of dry peas to fill the demand. Meanwhile, the Canadian pea producers were becoming experienced (A.E. Slinkard, R.S. Bhatty, R.A.A. Morrall, and A. Vandenberg, unpubl. data; Slinkard et al. 1990; Slinkard and Vandenberg 1993; Slinkard et al. 1994), and developed confidence in their ability to produce peas (Saskatchewan Pulse Growers 2000), if a market could be found. As a result, Canadian farmers were able to respond almost immediately to the high prices offered for peas by the EU (Slinkard and Vandenberg 1993), starting in the mid-1980s (Table 1). By 2001, Canada planted dry peas on a record 1.408 million ha (Agriculture and Agri-Food Canada 2001; Skrypetz 2001e), and will continue to plant over one million ha for the next few years. Cultivar development and release has increased rapidly since 1986, including many cultivars from Europe as well as from breeding programs in western Canada (Slinkard and Knott 1995).

Lentil. Pioneer Grain Co. Ltd. contracted the first commercial scale production of lentil in Saskatchewan in 1969, but production was limited and variable until 1977 (Slinkard and Vandenberg 1993). The first cultivar was common 'Chilean' lentil from the Palouse area of the US. The CDC evaluated various management

Table 1. Area seeded to new crops in Canada by 5-year periods, 1970–2000 (Agriculture and Agri-Food Canada 2001a, and previous issues; Saskatchewan Agriculture and Food 2001, and previous issues).

	Area (1000 ha)						
Crop	1970	1975	1980	1985	1990	1995	2000
Dry pea	33	29	49	74	122	798	1220
Lentil	0	0	42	72	132	327	688
Chickpea	0	0	0	0	0	2	283
Mustard seed	86	65	91	136	228	267	208
Dry beans	10	77	79	73	95	93	161
Canaryseed	0	4	36	49	123	146	164
Sunflower	27	25	135	52	64	48	74
Triticale	4	8	7	7	14	23	33
Buckwheat	33	16	56	13	27	14	15
Fababean	0	2	15	7	2	3	2

practices in small plots and developed a package of agronomic practices. Starting in 1977, several agronomic practices were demonstrated in "paired strip" trials (treated and non-treated) in commercial fields for three years. In 1977, one first-time producer applied several of the recommended practices in a timely and meticulous manner. He harvested 1800 kg/ha of lentil, twice the provincial average for the next 10 years. But this was only part of his good luck story. The lentil producing area of eastern Washington experienced a severe drought and the average yield was only about half of normal in 1977. The US lentil brokers had forward sold much of the anticipated crop and had no lentils to fill the sales contracts. Accordingly, they bid the average price of Canadian lentils up to a record $778/t (Slinkard and Vandenberg 1993). Lentil production in Saskatchewan literally exploded for the next several years. In Saskatchewan, the farm gate price per tonne of lentil has been more than double the farm gate price of red spring wheat nearly every year, starting in 1973. Consequently, the area devoted to lentil production in western Canada has increased in tandem until 2001, when lentil was planted on a record 1.408 million ha (Agriculture and Agri-Food Canada 2001; Skrypetz 2000c). However, this still is only part of the story.

The CDC planted the USDA Plant Introduction Station lentil collection at Saskatoon in 1972 and selected 10 accessions for further study. Individual plant selection and progeny testing resulted in the registration and release of 'Laird' lentil (large-seeded) in 1980 and 'Eston' lentil (small-seeded) in 1982 (Slinkard and Vandenberg 1993; Slinkard and Knott 1995). 'Laird' lentil soon became the preferred cultivar in major lentil markets and it was particularly well adapted to the Brown and Dark Brown soil zones of western Canada. 'Laird' lentil had partial resistance to ascochyta blight caused by *Ascochyta lentis*, but this disease was only a problem in wet growing seasons for the first 10–15 years and then chlorothalonil was registered and provided good disease control in most years. 'Laird' soon became the most widely grown lentil cultivar in the world and was grown on almost 500,000 ha in western Canada in 2000. After 20 years, it is slowly being replaced by higher-yielding, ascochyta-resistant cultivars. The area planted to lentil in western Canada should remain above one million acres for the next few years.

Dry Bean. In Canada, dry beans have traditionally been grouped into white (navy or pea) beans and colored beans (Skrypetz 2000b). Until recently, production was primarily white beans planted in Ontario. In the1960s, colored bean production started under irrigation in Alberta. Initially, the white bean cultivars planted in Alberta had poor cooking quality (turned mushy when canned in beans and pork), but recent cultivars developed in Alberta have acceptable cooking quality and production of white beans is increasing in Alberta (Saskatchewan Agriculture and Food 2001; Skrypetz 2000b).

Farmers in the Red River Valley of Manitoba are immediately down stream from a large dry bean growing area in North Dakota. Thus, it was only natural that dry bean production increased rapidly after the local sugar beet processing plant closed. In 2001, over 160,000 ha of dry beans were planted in Canada, over 50% of which were in Manitoba under dryland. Ontario production dropped to about 20% of the Canadian bean crop, while Alberta increased somewhat to 15%, mostly under irrigation. Dry bean production is expected to continue its westward shift.

Dry beans in Ontario and under irrigation in Alberta are planted in wide rows, cultivated for weed control and undercut at harvest. However, most of the dry beans in western Canada are planted on dryland in narrow rows, weeds are controlled by herbicides and the plants are direct combined. The CDC is developing early maturing cultivars with pods higher up on the plant, specifically for narrow-row production and direct combining.

Fababean. Fababeans were introduced to western Canada in the late 1960s, and became popular in some of the irrigated and more humid areas of western Canada during the late 1970s and early 1980s (up to 20,000 ha). However, the droughts of the late 1980s and the low prices almost eliminated fababeans from western Canada (Table 1). It is anticipated that new cultivars which have traits such as zero-tannin and earlier maturity could expand interest in faba bean in the future.

Chickpea. Two types of chickpeas are produced in Canada: (1) the large-seeded kabuli (garbanzo bean) with a thin, delicate colorless seed coat. Most of it is canned for the North American salad bar trade (a premium is paid for the larger-seeded cultivars) and (2) the smaller-seeded desi with a thick, tough colored seed coat. Most of the desi chickpeas are exported as whole dry seed to India and Pakistan.

The development of the chickpea industry in Canada is rather interesting, and follows a logical (although somewhat tortuous) progression:

Factor 1. Seed size of kabuli chickpea was unacceptable to the canning industry.

Results of preliminary trials by the CDC in 1978 and 1979 indicated that chickpea had potential as a new crop for western Canada. In 1980, the CDC, in conjunction with the New Crop Demonstration Fund of Saskatchewan Agriculture and Food (SAF), conducted a pilot project on chickpea production in the Brown and Dark Brown soil zones of Saskatchewan. Seed of 'UC 5' kabuli chickpea and 70% of the cash inputs were provided to seven farmers on 20 ha by SAF. The average seed yield was less than 500 kg/ha, due to thin stands (seed decay due to *Pythium* invasion of untreated seed) and late maturity. However, two fields in the Brown soil zone were subjected to severe drought stress, forcing early maturity, and yielded over 1000 kg/ha.

Subsequently, the CDC, in conjunction with the Canada Grains Council (1984), successfully applied for a 3-year grant from the New Crop Development Fund, Agriculture and Agri-Food Canada (AAFD). The primary objective of this project was to demonstrate the effectiveness of various agronomic practices in farmer's fields, using "paired strip" plots (treated and non-treated). Many treatments were so effective that differences could be readily detected, using this crude technique. In 1981, the 'UC 5' chickpea seed was treated with thiram, and twelve cooperating farmers planted 90 ha with an average yield of 600 kg/ha, again primarily due to seed decay by *Pythium*. In 1982, ten cooperating farmers planted 75 ha of 'UC 5' kabuli chickpea, but most fields failed to mature before the plants froze. Two fields were severely drought stressed, matured normally and yielded about 1800 kg/ha. Samples of these seeds were test canned by Libby, McNeil and Libby of Chatham Ontario, who reported that the canned chickpea seeds had excellent color, flavor, and texture, but that they "were undersize" and, thus, unacceptable to the canning trade. Apparently, the severe drought stress, required for normal maturity of 'UC 5' kabuli chickpea under Saskatchewan conditions, resulted in reduced seed size, and, at that time, no market was available for undersize kabuli chickpeas. Thus, two farmers had bins full of "undersize" chickpeas in storage for several years. Consequently, in 1983, the third year of the 3-year project, no commercial fields of 'UC 5' kabuli chickpea were grown in Saskatchewan.

Various agronomic treatments were evaluated in small plots and in "paired strip" tests in commercial fields over the three years. The conclusions were that metalaxyl effectively controlled *Pythium* seed decay and optimum plant stand was 40–45 plants/m^2. In addition, seedling emergence of kabuli chickpea was improved when the soil temperature exceeded 7°C since low-temperature imbibitional damage was reduced (Chen et al. 1983). Weeds were controlled by the use of trifluralin plus a graminicide. Progress had been made, but results indicated that UC 5 kabuli chickpea was too late maturing for commercial production in Saskatchewan, resulting in small seed size in those fields where drought stress was severe enough to force early maturity.

Factor 2. Even a trace of seedborne ascochyta infection is enough to destroy the chickpea crop within three years.

Research continued on the development of an earlier maturing kabuli chickpea with seed size acceptable to the canning trade. In addition, research was initiated on desi chickpea since it was more tolerant of low-temperature imbibitional damage (Chen et al. 1983) and matured earlier than kabuli chickpea. A wide range of desi and kabuli chickpea cultivars and various agronomic practices were evaluated throughout Saskatchewan in 1989 and 1990. The best lines were grown at six locations throughout western Canada in 1991. Results indicated that several cultivars of desi chickpea were adapted to the Brown and Dark Brown soil zones of western Canada. However, they were devastated by ascochyta blight at most sites, when the harvested (ascochyta-infected) seed was used to plant the second crop. Accordingly, a second chickpea project was initiated in 1989. The objectives were to (1) increase ascochyta-free seed of the best-adapted desi chickpea cultivar over the winters of 1990/1991 and 1991/1992 for regional testing in 1992 and 1993, and (2) conducting additional agronomic practices in small plots. Unfortunately, a low level of seedborne ascochyta infection was still present in the winter increases and the plots became infected at several sites in both 1991 and 1992. The most promising desi chickpea line (ascochyta susceptible) was increased and released in 1985 as 'CDC Marengo'. Intentions were to plant clean (ascochyta-free) seed under closely supervised conditions and under isolation, and develop a desi chickpea industry (Crop Development Centre 1992). Again, the seed had a low level of seedborne ascochyta infection and all fields became infected by ascochyta within three years. One

positive result was that a package of agronomic practices was developed for successful chickpea production in western Canada, as soon as an adapted ascochyta resistant cultivar was available.

Factor 3. Populations of adapted chickpea plants are developed with partial resistance to ascochyta.

In 1992, after an intensive screening of chickpea lines from the International Centre for Agricultural Research in the Dry Areas, the International Centre for Research in the Semi Arid Tropics and the USDA Western Regional Plant Introduction Station, several lines with partial resistance to ascochyta blight were identified. Some of these parental lines with partial resistance were crossed with the better adapted lines identified earlier. Segregating populations of these hybrids were evaluated for ascochyta resistance and yield in the ensuing years. In 1994, Fred Muehlbauer, USDA Pulse Breeder at Pullman, Washington, released 'Sanford' and 'Dwelley', two kabuli chickpea cultivars with partial resistance to ascochyta blight. These were tested against a wide range of F_2-derived F_4 lines segregating for partial resistance to ascochyta blight in 1995 and were competitive in yield (Crop Development Centre 1995; Slinkard and Vandenberg 1995a,b).

Factor 4. US cultivars are introduced and chickpea production explodes.

Already, in 1994, it was evident that several more years of selection and testing were required before any of the segregating populations would be ready for release. Thus, the decision was made to import the US kabuli chickpea cultivars 'Sanford' and 'Dwelley', since seed was readily available. Accordingly, in 1995, about a dozen farmers, mostly from the Brown and Dark Brown soil zones in Saskatchewan, agreed to share the costs of a truckload of seed of 'Sanford' kabuli chickpea seed from Washington. Sanford was selected because it was the earlier of the two cultivars. Only five of these inexperienced growers produced a successful chickpea crop and several of them were members of a crop club near Frontier, Saskatchewan in the Brown soil zone. In 1996, a semi-truck load of 'Sanford' and 'Dwelley' kabuli chickpea seed was received from Washington, half of it going to the crop club at Frontier, Saskatchewan. Muehlbauer also developed 'Myles', a desi chickpea with partial resistance to ascochyta blight, and other farmers introduced seed of it into Saskatchewan in 1996 and 1997. By 1997, chickpea was grown on 11,000 ha, increasing to 38,000 ha in 1998, 139,000 ha in 1999, 283,000 ha in 2000, and a forecast of 480,000 ha in 2001 (Agriculture and Agri-Food Canada 2001; Skrypetz 2001a). Initially, production was restricted to Saskatchewan, but some chickpea is now grown in the Brown and Dark Brown soil zones in Alberta. Western Canada has become a major producer and exporter of both desi and kabuli chickpeas in a short time and will continue in this role for the next few years.

Since these chickpea cultivars are only partially resistant to ascochyta blight, researchers and extension personnel have developed a program that tries to keep ascochyta inoculum levels low as long as possible in order to minimize disease losses. Growers are encouraged to get their planting seed tested for seedborne ascochyta infection and plant seed testing "none detected" in a 400-seed sample or as low as possible. The seed usually is treated with a mixture of thiabendazole and carbathiin to reduce seedborne ascochyta infection, or metalaxyl to control seed decay caused by *Pythium*, and the foliage should be sprayed 2 or 3 times with chlorothalonil and/or strobilurin to protect the foliage from infection. The chickpea field also should be isolated from chickpea stubble of the previous year by at least 2 km (4 km, if down wind). Successful chickpea production in western Canada requires top management with great attention to details and timing (Saskatchewan Pulse Growers 2000).

Spice Crops

Mustard is the most widely grown spice crop (condiment mustard) in Canada. Each year farmers in Canada plant between 200,000 and 300,000 ha (Agriculture and Agri-Food Canada 2001b) of three types of mustard: brown mustard [*Brassica juncea* (L.) Czern. & Coss.], oriental mustard (*B. juncea*) and white mustard (*Sinapis alba* L.). Canada is the second largest producer and the largest exporter of mustard (Skrypetz 2001b), primarily to Bangladesh and the US in bulk form (unprocessed). The Agriculture and Agri-Food Canada Research Station at Saskatoon is finalizing the development of a canola quality mustard, which is designed to expand the area adapted to edible oilseed crops in Canada due to the greater drought tolerance of mustard relative to canola. The extent of commercialization of this canola quality mustard will not be known for 10 to 15 years.

Caraway is the second most widely grown spice in Canada (about 15,000 ha). It is a biennial and suffers from aster yellows every year and from a fungal disease in wet growing seasons. Production will not increase until one or both problems are overcome. An annual form is occasionally grown, but it is rather low in percentage essential oil and very late maturing.

Coriander is the third most widely grown spice crop in Canada (about 14,000 ha). A fungal blight is a problem in wet growing seasons. Some selection work has been done and 'CDC Major' (a medium large-seeded type with 0.8% essential oil) and 'CDC Minor' (a small-seeded type with 1.1% essential oil) were released in 2000. A pedigreed seed program was established to help guarantee a known and repeatable seed source of a known quality. In addition, dormant seeding (just before soil freeze-up) has been successful and results in an earlier maturing crop. Production of coriander will vary with the price since production costs are low and the demand (price) varies from year to year.

Dill (*Anethum graveolens* L.) is grown to a limited extent. Again, production varies inversely with price, due to the limited demand. A new cultivar will be released in 2003, again to help guarantee a known and repeatable seed source of a known quality.

Anise (*Pimpinella anisum* L.) is grown on a limited scale in western Canada. It is very late maturing, making it a risky crop.

Fenugreek is grown on a limited scale in western Canada, as a forage crop in Alberta (Blade 2000) and as a seed (spice) crop in Saskatchewan. One company is using a patented process to produce an odorless, tasteless product high in soluble fiber for the health food market. A small breeding program at the CDC is trying to reduce the bitterness and develop an improved cultivar for the health food market.

Other New Crops

Borage is planted for its high concentration of oil (30%), which contains about 22% gamma-linolenic fatty acid (GLA), an essential fatty acid (El Hafid and Blade 2002). Borage was planted on a record 15,000 ha in 1999, but this over production plus importation of large quantities of a cheaper source of GLA as seeds of evening primrose resulted in very low prices and production likely will never again exceed 10,000 ha. Borage is an undomesticated plant and will require major breeding efforts to become competitive again.

Although some oilseed sunflowers and safflower are used for birdseed, the major birdseed in Canada is annual canarygrass, commonly called canaryseed in Canada. Canaryseed is planted on 110,000 to 200,000 ha each year in Canada, making Canada the leading producer and exporter of canaryseed (Skrypetz 2001c). Standard type canaryseed has a lemma covered with tiny, siliceous hairs, which break off during harvesting and processing, and are most irritating to anyone handling the seed. The CDC has developed a glabrous (hairless) cultivar ('CDC Maria'). This new glabrous type has been trademarked internationally as Canario. It is much denser that the standard type and over 10% more seed by weight can be packed in a shipping container and oiling and polishing of the canaryseed is no longer needed. Production is rapidly shifting to the Canario type

Industrial hemp is distinguished from drug hemp (marijuana) by having less than 0.3% tetrahydrocannabinol (THC) in the seed or the inflorescence of the female plant (Reichert 1994). Canada first licensed production of industrial hemp in 1997, the first time in over 50 years. A lot of hype and a major promotion in Manitoba resulted in the planting of at least 14,000 ha in 1999. However, the anticipated high value markets in the US for the seed, meal and oil never developed, due to embargoes, the irregular implementation of zero tolerance standards for THC and the requirement that all seed imports for birdseed must not contain any viable seeds. Consequently, production of industrial hemp dropped drastically in 2000 and 2001. A few producers are still persisting in their efforts to develop this crop because of its potential for edible oil, edible meal, and fiber.

Statistics are also available on Canadian production of sunflowers (Skrypetz 2000a) and buckwheat (*Fagopyron esculentum* Moench) (Skrypetz 2001d).

CONCLUSION

"Crop diversification: been there, done it"

Editorial, *Western Producer* newspaper (May 31, 2001)

In Canada there has been measured success in a number of crop diversification innovations (Small 1995, 1999) including: cereals and other grains (triticale, proso millet, wild rice, buckwheat, quinoa, amaranth); pulses (field pea, dry bean, lentil, chickpea, faba bean); oilseeds (canola, flaxseed, mustard, soybean, crambe); potential fodder species (sorghum, unique forage grasses, cicer milkvetch, fenugreek); vegetables (processing and seed potato, greenhouse expansion); culinary herbs (cilantro, garlic); fruits (introduced and indigenous); essential oil crops (peppermint, spearmint, catnip); medicinal species (echinacea, ginseng, many others); nutraceuticals (borage, sea buckthorn, antioxidant sources); fiber crops (flax, industrial hemp); energy/alcohol/pulp crops (hybrid poplars, switchgrass, willows); ornamental crops/revegetation (native wildflowers, indigenous species used for reclamation of pipeline right-of-ways). Furthermore, alternative production systems have been examined such as organic production and aquaculture.

Crop diversification is not a new concept in Canada. The fact is that significant success has been obtained in western Canada, and within the province of Alberta. The farm gate receipts from crops outside of the conventional portfolio added over $500 million to producers in the province of Alberta in 2001. Can crop diversification achieve additional success? Yes. Will the current financial crunch be solved only by diversification of crops? No.

In Western Canada, over 20 million ha are planted to annual crops. We will be producers of wheat, barley, canola and other conventional crops, such as oats and forages, for the foreseeable future. It is gratifying that "new crops," such as canola and the pulses, have added another large acreage set of choices for western Canadian producers.

However, the fact is that we still have to develop a national farm policy that ensures the long-term sustainability of our agricultural producers. The average age of the Canadian farmer is 49 years of age. Many of the potential opportunities within crop diversification are not attractive to many in the current demographic structure of our agricultural producers. Crop diversification is only one piece of a much more complex process which will lead to a renewed and optimistic outlook for the agricultural sector in Canada.

Many hurdles must be overcome to increase crop diversification in Canada. Research funding has been identified as a key to continued success (by both the federal and provincial governments), although the resources needed to make continued progress are still not adequate. Crop diversification initiatives must still compete with established crops for research funding and struggle to find industry money to "match" public investment. We face specific production issues as the area planted to some of these crops expands at an extraordinary rate. Markets continue to fluctuate as global competition increases. Global buyers need to understand that Canada is a long-term player in these markets, although we are now sometimes viewed as the "new kid on the block."

The past 30 years have resulted in tremendous expansion of crop diversification opportunities throughout Canada. We look forward to realizing our additional potential in the next decade.

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