# ECONOMIC IMPACT OF PLANT BREEDING AT THE CROP DEVELOPMENT CENTRE

## FINAL REPORT

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A report prepared for Crop Development Centre

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# Executive Summary

The Crop Development Centre (CDC) located at the University of Saskatchewan was established in the 1970's to improve economic returns for farmers and the agriculture industry in western Canada by improving existing crops, creating new uses for traditional crops, and developing new crops. This document reports on the contribution of the CDC's variety development program to the agricultural economy, and to broader economy across the three prairie provinces.

The economic contribution of CDC plant breeding and research programs depends on the performance of varieties released by the CDC and associated adoption of these varieties by producers across the prairie provinces. Our approach consistently used conservative assumptions, where required, which returns conservative results for the economic impact of the CDC.

**CDC Varieties Have an Overall 33% Acreage Share**

The CDC has released over 450 new varieties of wheat, durum, barley, oats, flax, field peas, lentils, chickpeas, canary seed, and dry beans since its inception. These CDC varieties have been adopted by producers and today (using the 2011 to 2015 period) they account for 37% of the acreage grown for these crops by producers in the three prairie provinces. In some crop kinds, such as lentils, CDC varieties account for 95% of acreage, with acreage at 85% for dry peas, 83% flax seed, 75% for chick peas, 73% for canary seed, 37% for barley, 25% for oats, and CDC's variety acreage share stands at 20% for all wheat. This acreage share signifies the CDC's importance to crop producers across the prairies. The high acreage share in pulse crops underscores the role that the CDC has played in the growth of the pulse crop sector.

Over this same time period, 45% of applicable prairie wide benefits resulting from plant breeding are attributed to these CDC varieties. This higher benefit share is because the crops with high CDC acreage share have higher annual yield increases attributed to plant breeding, on average, compared to crop kinds with low CDC acreage share. For example, the annual increase in Saskatchewan spring wheat yields due to newly released varieties is 0.45%, while this is measured at 0.74% for lentils and 1.99% for field peas in Saskatchewan. These yield increases are prior to further yield increases due to other agronomic factors.

**Economic Impact of the CDC**

Yield improvement obtained by producers through the release of newly developed CDC varieties increases farm output and these productivity gains have an impact throughout the prairie economy. The economic impact of the CDC can be summarized through a brief response to the six following questions asked by the CDC:

**1. Determine the impact of CDC varieties on producers' profitability from 1991 to 2015.**
Producer profitability increased by $3.8 billion over the 1991 to 2015 period as a result of CDC varieties provided to the marketplace. Based on the cumulative effects of plant breeding, in 2014 producer profitability was $411.6 million higher, a 23% increase that is attributable to CDC plant breeding activities. The annual increase in producer profitability is $17.9 million, with the largest yearly increases realized in field peas and lentils, followed by spring wheat.

**2. Determine the quantitative benefit and the return on investment from CDC variety development program from 1971 to 2015.**

The economic return to investing in plant breeding is provided by two measures: the internal rate of return (IRR) and the benefit-to-cost ratio (B/C). The inflation adjusted IRR is 13.9% when CDC expenditures since 1971 are considered with benefits captured starting in 1991 and considered out to 2015. Over this time period, the associated B/C is 7.1, which means that for every $1 million in investment in CDC plant breeding, the benefit to producers is $7.1 million – a significant return.

When benefits are extended out to 2030 (assuming no further release of CDC varieties after 2015), the IRR increases to 14.6% and the B/C ratio is 11.5. A B/C ratio of 3 is great – however a value of 11.5 is excellent.

The B/C ratio for some crop kinds is higher than this value of 11.5 for all crop kind varieties released by the CDC. For example, the B/C is 48.7 for lentils (IRR of 23.2%), 25.6 for field peas (IRR of 15.9%), and 3.8 for oats (IRR of 11.2%). In general, the B/C ratio and the IRR are higher when the annual yield gain is larger, the crop acreage base is higher, and the CDC acreage share is greater.

### 3. Determine the economic contribution of CDC crop varieties to the agricultural economy from 1991 to 2015.

Over the 1991 to 2015 period, gross farm output attributable to CDC plant breeding activities increased by $6.4 billion (a cumulative impact since 1991 in 2015 dollars). In 2014, for example, farm output was $740 million larger, a 16% increase based on the cumulative impact of plant breeding activities, with economic activity throughout western Canada larger by $1.5 billion due to the productivity gains attributed to CDC varietal development. This increased GDP by $668 million and supported an additional 5,934 full time jobs. Each year CDC varietal development activities have an incremental impact on the prairie economy as summarized in the following table.

| Farm Output | Producer Profitability | Economic Activity | GDP | Jobs |
|---|---|---|---|---|
| $32.2 M | $17.9 M | $64.5 M. | $29.0 M | 258 |

### 4. Determine the economic value of new markets created by new crop kinds and market classes released by CDC since inception to 2015.

Plant breeding activities at the CDC have been an integral part of pulse crop acreage expansion in western Canada. Compared to the 1991 to 1995 period, pulse crop acreage expanded by 4.9 million acres over the last five years. The higher margin over cost for many pulse crops allowed producers to capture another $59 million in annual producer profits and the higher pulse acreage added another $293 million in farm output in each of the last five years, when compared to having these additional acres remain in wheat and barley. The resulting higher level of economic activity through the prairie economy contributed to just under 100 new jobs each year, and at least $10 million in additional GDP each year. This impact is embedded within the CDC economy wide benefits reported above. This economic contribution highlights the impact of the CDC developing varieties for newly introduced crops kinds such as pulse crops.

### 5. Provide a comparison of the performance from other public breeding institutions.

Using the measures of IRR and B/C, the CDC preforms well in relation to other public breeding organizations. Some international plant breeding programs (e.g., CIMMYT, International Rice Institute) had larger measured IRR and B/C ratios; however the benefits of these programs applied over a much larger acreage base. The CDC results for pulse crops were comparable to Empraba's (in Brazil) performance for upland rice and soybeans, and were much larger than the dry bean breeding program at the University of Michigan (due to their limited acreage base). The CDC's performance compares favourably to other studies that calculated the returns to plant breeding in western Canada; with each study having slightly different methodologies.

**6. Determine the impact of leveraging investment from different sources on CDC operations and performance. This could include the direct economic contribution of CDC to job creation from the employment opportunities arising from its research program**.

For every $2 million invested by producer organizations, government and/or private sector interests, producer benefits increase by $23 million over a period of time. Across the prairie economy this expenditure contributes to additional economic activity of $78 million and associated GDP of $35 million, and requires 312 full time jobs to support the higher economic activity. The impact is not an annual impact; the impact is associated with the spending profile and occurs over a number of years.

**The CDC's Variety Development is Supported by a Number of Investors**

The government of Saskatchewan, the Western Grain Research Foundation (WGRF) and the Saskatchewan Pulse Growers (SPG) are examples of organizations that have made significant investments in the CDC. For example, over the last 10 years, the provincial government invested on average $5.7 million each year (40% of the total), the WGRF invested $2.0 million per year (14.2% of the total) and the SPG $1.3 million per annum (9.4% of the total). Currently, each of these organizations is investing larger amounts in CDC plant breeding and research activities.

Current CDC annual expenditures are in the range of $20 million per annum as a result of support from government, producer organizations and the private sector. Over time, based on our findings, this level of spending provides producer benefits that are 11.5 times as large, at $230 million, before considering the significant economy wide economic impacts.

**Crop Producers and Society Benefit Through Investments in the CDC**

Investing in the CDC provides considerable benefits to individual producers, the farm economy, and as well, provides significant benefits to the economy across western Canada, including creation of new employment opportunities. This report indicates that the returns captured by producers conservatively provide for a 14.6% IRR and a B/C ratio of 11.5 (both in constant 2015 dollars) when investing in the CDC.

With past results being indicative of future CDC impact, for every $1 million not invested in the CDC, the production sector foregoes $11.5 million in future benefits (discounted back to today). And these impacts at the producer level are before considering the benefits realized throughout the prairie economy (such as over 5,900 jobs and $1.5 billion in additional economic activity) due to the increase in farm productivity arising from the CDC's variety development programs.

# 1.0 Introduction

## 1.1 Background to the Project

The Crop Development Centre (CDC) was established within the Plant Sciences Department at the University of Saskatchewan in 1971 with a mandate (and mission) to improve economic returns for farmers and the agriculture industry of western Canada by improving existing crops, creating new uses for traditional crops, and developing new crops. This mission of the CDC continues 45 years later with CDC activities focused on integrating basic research with genetic improvement of field crops grown in western Canada. The CDC has released over 450 new varieties of wheat, durum, canary seed, barley, oats, flax, field peas, lentils, chickpeas, fababeans and dry beans since its inception.

Prior to the formation of the CDC in 1971, Saskatchewan did not have a research station with a focus on plant breeding. A rationale for establishing the CDC was to fill this void and enable crop diversification in Saskatchewan and across the prairies. The CDC began as collaboration between the University, the National Research Council (NRC) and the Saskatchewan Department of Agriculture.

For the first three years of CDC operation the NRC provided the funding for the scientists and support staff with an initial budget of $324,000, there were seven plant breeders on staff in 1974. Since then, funding of CDC activities has been from a variety of public, producer organization, and private sector sources. Examples in each category include Saskatchewan's Ministry of Agriculture and Food, the Western Grain Research Foundation (WGRF), Saskatchewan Pulse Growers (SPG), Quaker Oats, Viterra, FP Genetics, and Secan.

Today the CDC is able to release new varieties based on a professional staff of nine plant breeders and two pathologists, which are supported by a staff complement of over 200 staff and graduate students supported by multi-source funding equivalent to $20 million in annual expenditures.

The CDC through its plant breeding program has made significant contributions to the development and progress of production agriculture in western Canada. For example, supported by producer funding, the CDC has been instrumental in the development of the pulse sector in western Canada. As well, CDC varieties in certain sectors account for a significant share of planted acreage.

Various studies have reported on the returns to plant breeding in western Canada which indirectly indicate the contribution of CDC expenditures and plant breeding activities to grain farmers in western Canada. One study estimated the internal rate of return (IRR) associated with WGRF expenditures[1] on wheat and barley to range from 25% to 44%. A study for SPG[2] indicated a 40% IRR for their investment in genetic improvement of pulse crops which equates to a $28 dollars of benefits to pulse growers for each dollar invested by SPG into genetic improvements. A number of CDC wheat and barley varieties provided for the benefits captured in the WGRF estimates of return and most of the pulse crop acreage in western Canada is planted to varieties developed by the CDC.

[1] A report funded by WGRF entitled *"Returns to Research: Western Grains Research Foundation Wheat and Barley Variety Development*" prepared by Richard Gray, Cecil Nagy and Alper Guzel (October 2012)
[2] A report funded by SPG entitled *"Returns to Pulse Crop Research & Development and the Management of Intellectual Property Rights*" prepared by Richard Gray, Cecil Nagy, Viktoriya Galushko and Simon Weseen (December 2008)

## 1.2 Project Objectives

The economic impact of the CDC on Saskatchewan agriculture and more broadly on the western Canadian agriculture economy to date has not been available. The CDC commissioned the JRG Consulting Group and SJT Solutions[3] to provide such information to demonstrate the economic impact of CDC plant breeding activities using a benefit cost analysis approach. The project objective that guides the research and analysis is "*to determine the contribution of CDC plant breeding to the agricultural economy of Saskatchewan and Western Canadian provinces*." The economic impact being measured is based on the crop kinds of wheat, barley, oats, flax, dry beans, canaryseed, chick pea, lentils and field peas.

In support of this overall project objective, the associated project scope issues included the following:

1. Determine the economic contribution of CDC crop varieties to the agricultural economy from 1980 to 2015.
2. Determine the impact of CDC varieties on producers' profitability from 1980 to 2015.
3. Determine the economic value of new markets created by new crop kinds and market classes released by CDC since inception to 2015.
4. Determine the quantitative benefit and the return on investment from CDC variety development program from 1971 to 2015.
5. Provide a comparison of the performance from other public breeding institutions.
6. Determine the impact of leveraging investment from different sources on CDC operations and performance. This could include the direct economic contribution of CDC to job creation from the employment opportunities arising from its research program.

## 1.3 Overall Approach to Estimating the Economic Impact of the CDC

Benefit cost analysis compares the benefits of a project (e.g., building a bridge), registering a product (e.g., crop protection material or a feed additive) or the impact of a set of activities such as plant breeding at the CDC, with benefits compared to associated costs. Benefit cost analysis (BCA) provides summary measures such as (1) the benefit-to-cost ratio (B/C) which indicates the benefits associated with a dollar (or million dollar of expenditure) and (2) the internal rate of return (IRR) which is the return (or interest rate) which has the stream of benefits equal to the stream of costs. For example, the above mentioned study conducted for the WGRF measured an IRR of 28% associated with WGRF spending on barley variety development. Benefit-to-cost ratios and IRR for CDC plant breeding for major crop kinds (e.g., barley, chickpeas) and for consolidated CDC plant breeding activities are provided in this report. Annex A provides additional detail[4] on the various considerations in a BCA and the BCA methodology used in this report.

Costs are overall annual CDC expenditures over the 1971 to 2015 period. These costs are considered on a crop kind basis. In recent years CDC financial records allow for capturing CDC costs by crop kind between 2005 and 2015. Prior to 2005 overall CDC costs are allocated to each crop kind based on an estimate of the amount of annual effort was dedicated to plant breeding of a

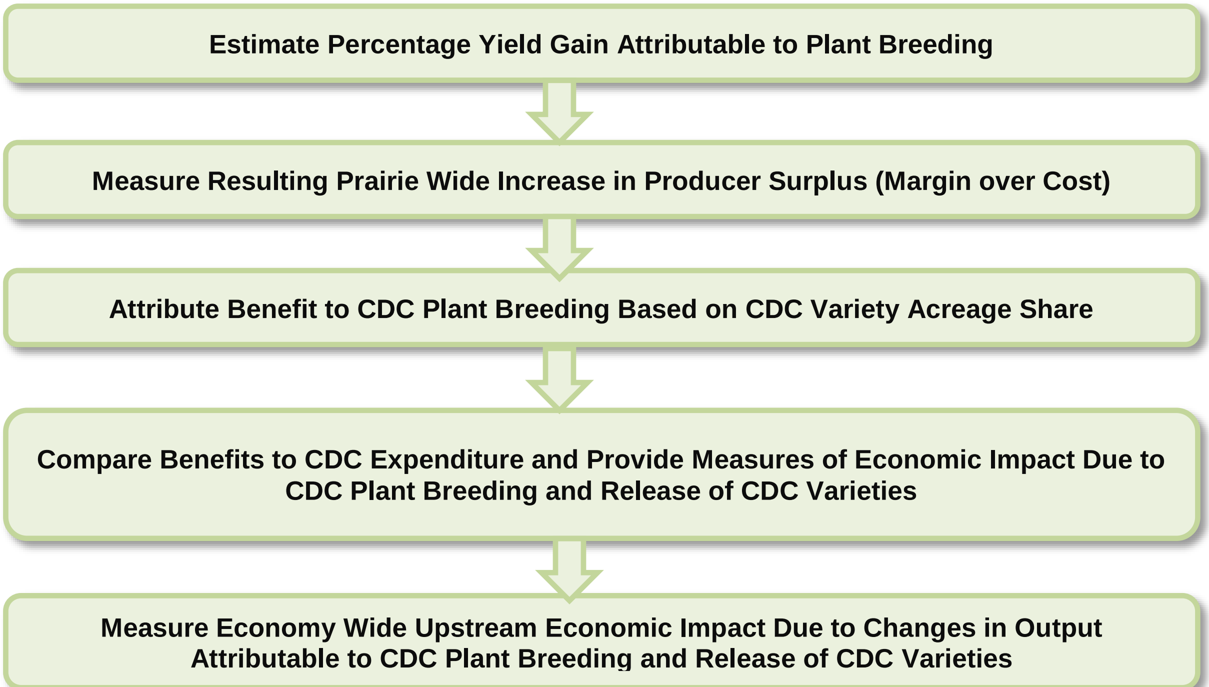
[3] Team members included John Groenewegen of the JRG Consulting Group, who has a Ph.D. in agriculture and applied economics (University of Minnesota), Shelley Thompson of SJT Solutions who also has a Ph.D. in agriculture and applied economics (University of Minnesota) and Richard Gray, who has a Ph.D. from the University of California, Berkley, a professor in agriculture and resource economics at the University of Saskatchewan.

[4] This detail includes accounting for net present value (NPV) and real versus nominal dollars and matching costs to benefits.

particular crop kind. Many plant breeders only developed varieties for one crop kind (such as spring wheat). Annex B provides some additional detail on CDC expenditures on plant breeding over the 1971 to 2015 period.

The overall process used for measuring the benefit and economic impact of CDC's plant breeding activity is summarized in Figure 1.1 below.

***Figure 1.1 Process Used to Measure the Benefit of CDC Plant Breeding***

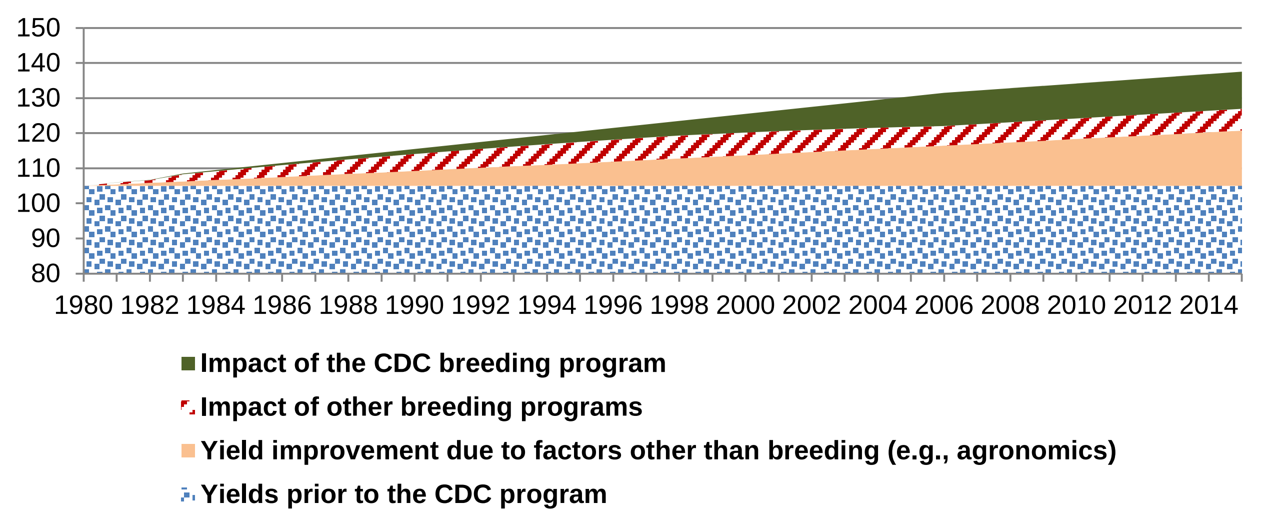



The benefits considered in this BCA is primarily yield improvement based on new varieties released by the CDC. Measuring the benefit of CDC plant breeding activities requires comparing the known fact base of CDC plant breeding activities with a “counterfactual”. The counterfactual is that the CDC did not exist over the 1971 to 2015 period. The benefits being measured are benefits attributed to the CDC when a comparison is made to the counterfactual of no CDC. The counterfactual – of no CDC – requires an assumption and a methodology to measure crop yields that occur in the absence of CDC varieties.

Figure 1.2 provides a perspective on the factors contributing to yield improvement over time. For example, yield gain over time is due to both plant breeding and to other factors such as agronomic and improved management practices. In Figure 1.2, the brown area and the blue-dotted area capture the yields that were observed prior to CDC plant breeding activities (the blue-dotted area) as well as improvements yields on pre-CDC varieties due to improved agronomics and farm management practices (the brown area in Figure 1.2). Evidence suggests that approximately 50% of yield gains are due to varietal development and the other 50% is due to improved agronomic and management practices (the brown shaded area).

The impact of plant breeding by the CDC and other breeding organizations is the green area and the red-hatched area. Our methodology attributes back to the CDC (the solid green area) the overall prairie wide benefit of plant breeding based on the ability of CDC varieties to capture market share as observed through seeded acreage data.

***Figure 1.2 Impact of CDC plant breeding and other factors on crop yield trends***




The methodology used to provide a measure of CDC benefit is a two-step process. The first step measures the overall benefit of plant breeding by all plant breeding institutions for the subject crop kinds (varieties of crop kinds released by the CDC that are within the scope of this study). The second step attributes the appropriate portion of these overall benefits to the CDC based on the acreage share of CDC varieties in each year. For example, if the CDC accounts for 25% of spring wheat acreage in 2015, then 25% of the 2015 spring wheat benefits is attributed to the CDC[5].

For any crop kind, the overall yield improvement is measured as the year-over-year increase in yields attributable to plant breeding. The approach is based on performance trial yields for varieties with significant acreages, with their yield indexes compared to the first check variety used for annual performance trials.

An index of 106 indicates a yield that is 6% higher than the current check variety (which has an index of 100). For each year these performance trial yields are weighted based on actual acreage shares of these varieties based on plantings by producers in each province. The result is an acreage weighted yield index series over a given time period (e.g., 1991 to 2015 in Saskatchewan), from which an annual increase attributable to plant breeding is calculated. For example, annual increase in yields attributable to plant breeding is 0.39% for oats in Saskatchewan.

Overall benefits of plant breeding are measured by constructing an acreage-weighted variety index using the performance trial results and annual acreage shares for the prominent varieties for each crop kind. A prairie wide value of annual change due to plant breeding is determined using an annual weighting of the provincial acreage share for each crop kind. This prairie wide yield index series is used to determine the overall benefit of plant breeding in any given year.

The trend in this yield index captures the increase in yields attributable to plant breeding, with the annual increase a measure of yearly gain. These values are used across all planted acreage and actual yields as captured by Statistics Canada for each of the crop kinds (and classes where required). If an acreage weighted yield index for spring wheats has a value of 103 for a given year, when the base year index (e.g., has a value of 101.5 and is a measure of the counterfactual), this means that yields are 1.5% higher, which is the measured yield improvement in a given year due to plant breeding.

[5] Some detail on Saskatchewan acreage share by breeding institution is provided in Annex C.

A prairie-wide yield improvement (e.g., 2.5 bu./acre) is then valued using the price of spring wheat (e.g., $5.00/bu.) and all spring wheat acreage (e.g., 16 million acres) to measure the increase in the value of production due to plant breeding in a given year (e.g., for a value of $200 million). The resulting increase in aggregate producer surplus (comparable to margin over operating costs) is also calculated to capture the increase in producer benefits attributable to genetic improvement. The increase in producer surplus is a fraction of the increase in value, such as 20% or $40 million.

Assuming that CDC varieties of spring wheats accounted for 25% of acreage then the benefits attributed to the CDC would be $10 million in that year. The CDC acreage share of a crop kind reflects the importance of CDC varieties to production agriculture, since grain farmers are choosing in the open market these CDC varieties to maximize their on-farm earnings. If the CDC did not exist, then these acres planted to CDC varieties would need to use varieties provided by other plant breeding organizations.

The annual benefits are valued in nominal terms and all values are adjusted into constant dollar terms using an inflation index (e.g., the CPI) to reflect values in 2015 dollars. This stream of annual benefits attributable to CDC plant breeding activities (e.g., over the 1991 to 2015 period) are then compared to the costs incurred by the CDC in support of plant breeding. Measures such as the benefit-to-cost ratio (B/C) and the internal rate of return (IRR) can then be calculated to illustrate the economic impact of CDC plant breeding activities[6].

The increase in output value due to adoption of CDC varieties increases economic activity in upstream sectors based on the corresponding higher level of expenditures by producers (on inputs and household consumption). Additional employment is required to support this higher level of economic activity, which also has an impact on prairie wide GDP.

## 1.4 Organization of the Report

This report is organized in the following manner. The next chapter (2.0) provides some context for the CDC by indicating the size and scope of CDC activities. This chapter provides a high level view of CDC expenditures ion plant breeding and the importance of CDC to Saskatchewan agriculture by highlighting the share of acreage by crop kind planted to CDC varieties.

In chapter 3.0 the increase in yields attributable to plant breeding is provided for each of the crop kinds using Saskatchewan data as illustrative examples. For some crop kinds, the yield gains have been significant and the CDC has been only the only organization releasing new varieties, such as for some pulse crops.

The benefit cost analysis of CDC plant breeding is the focus of chapter 4.0, where the benefits attributed to CDC plant breeding are provided for each of the crop kinds analyzed. These benefits are compared to the costs and benefit-to-cost ratios are provided along with associated internal rates of return by crop kind. A consolidated CDC view across all crop kinds is also provided.

Chapter 5.0 covers specific project objectives which are not addressed in the above chapters such as (1) the CDC impact on the agricultural economy, (2) CDC impact on producer profitability, (3) CDC impact on new crop kinds and classes, (4) comparing the CDC's economic benefit to reporting findings for other public breeding institutions, and (5) leveraging of investments at the CDC.

[6] Additional detail on how benefits are calculated along with related assumptions are provided in Annex D and Annex E.

# 2.0 The Crop Development Centre

The Crop Development Centre (CDC) was formed in 1971 as a unit of the University of Saskatchewan's Department of Plant Sciences. Today the CDC has 9 plant breeders developing new varieties for wheat, barley, oats, flax and a number of pulse crops. This chapter provides some context for the importance and contribution of the CDC. A brief history of the CDC is first provided, which is followed by an overview of financial support provided by a variety of organizations and companies to support CDC's plant breeding efforts. The acreage share of CDC varieties within Saskatchewan for a number of crop kinds is also provided to illustrate the importance of the CDC to Saskatchewan agriculture.

## 2.1 A Brief History of the CDC

The CDC was formed in 1971 by the Saskatchewan government to address the plant breeding gap in Saskatchewan, since the province did not have a research station with a focus on plant breeding. The CDC began as collaboration between the University of Saskatchewan, the National Research Council (NRC) and the Saskatchewan Department of Agriculture, and continues to operate within the Plant Sciences department at the university. The mandate of the CDC was to increase the diversification of crops and their products for the farmers and agriculture industry of Saskatchewan by improving existing crops, creating new uses for traditional crops and introducing new crops.

The CDC began operations with seven plant breeders, with Dr. D. Knott (Durum Wheat), Dr. B. Harvey (Malt Barley), Dr. G. Hughes (Spring Wheat), Dr. A Slinkard (Field Pea and other Pulses), Dr. D.B. Fowler (Winter Wheat), Dr. G Rowland (Alternate Crops), and Dr. J. Berdhal (Feed Barley).

In 2016, the CDC has eight plant breeders, which include Dr. P. Hucl (Spring & Specialty Wheat & Canaryseed), Dr. A Vandenberg (Lentil and Fababean), Dr. T. Warkentin (Field Pea & Soybean), Dr. C Pozniak, (Durum & High Yielding Wheat) Dr. B. Tar'an (Chickpea), , Dr. H. Booker (Flax) Dr. A. Beattie (Feed & Food Barley and Oat), Dr. B. Biligetu (Forage crops); as well as two pathologists (Dr. S. Banniza and Dr. H. Kutcher). Dr. K. Bett (Dry Bean) is a professor in the Department of Plant Sciences whose breeding program is in the CDC.

A listing of all of the plant breeders over the 1971 to 2015 period by crop kind focus is summarized in Table 2.1. For example, chick pea breeders included Dr. Slinkard over the 1971 to 1996 period, Dr. Vandenberg over the 1997 to 2000 period, Dr. Warkentin over the 1999 to 2005 period and Dr. Tar'an since 2006.

***Table 2.1 CDC Plant Breeders, 1971 to 2015***

| Crop Kind and Class | Plant Breeders |
|---|---|
| **Feed Barley** | J. Berdhal (1971 - 1975); B. Rossnagel (1976 - 2009); A Beattie (2010 - 2015) |
| **Malt Barley** | B. Harvey (1971 - 2005); B. Rossnagel (2001 - 2009); A. Beattie (2010 - 2015) |
| **Oats** | B. Rossnagel (1976 - 2009); A Beattie (2010 - 2015) |
| **Field Pea** | A. Slinkard (1971 - 1996); T. Warkentin (1999 - 2015) |
| **Chick Pea** | A. Slinkard (1971 - 1996); A. Vandenberg (1997 - 2000); T. Warkentin (1999 - 2005); B. Tar'an (2006 - 2015) |
| **Lentil** | A. Slinkard (1971 - 1996); A. Vandenberg (1997 - 2015); |
| **Dry Bean** | A. Slinkard (1971 - 1996); A. Vandenberg (1997 - 2007); K. Bett (2008 - 2015) |
| **Fababean** | G. Rowland (1971 - 1991); A. Vandenberg (2008 -2015) |
| **Flax** | G. Rowland (1971 - 2008); H. Booker (2009 - 2015) |
| **Canary seed** | A. Slinkard (1980 - 1996); P. Hucl (1995 - 2015) |
| **Soybean** | T. Warkentin (2012 - 2015) |
| **Spring Wheat** | G. Hughes (1971 - 1988); P. Hucl (1989 - 2015) |
| **Durum** | D. Knott (1971 - 1994); S. Fox (1996 - 2001); C. Pozniak (2002 - 2015) |
| **Winter Wheat** | D. Fowler (1971 -2004); |
| **High Yielding Wheat** | C. Pozniak (2002 - 2015) |
| **Specialty Wheat** | R. Baker (1977 - 1994) P. Hucl (1995 - 2015) |
| **Forage Crops** | B. Biligetu (2014 - 2015) |

## Number of Varieties Released by the CDC

These plant breeders released over 450 new varieties since the CDC was formed 45 years ago. Feed and malt barley accounting for 20% of these new releases with 93 varieties released since 1971. As reported in Table 2.2, this is followed by lentils with 79 new varieties offered to the market.

***Table 2.2 Number of CDC Varieties Released Since 1971 by Crop Kind***

| Crop Kind | Number of Varieties Released | Share |
|---|---|---|
| **Barley** | 93 | 20% |
| **Lentils** | 79 | 17% |
| **Field Peas** | 69 | 15% |
| **Wheat, excluding durum** | 66 | 14% |
| **Dry Bean** | 42 | 9% |
| **Oats** | 35 | 8% |
| **Chick Peas** | 24 | 5% |
| **Flax** | 22 | 5% |
| **Durum** | 11 | 2% |
| **Canary seed** | 8 | 2% |
| **Fababeans** | 7 | 2% |
| **Total** | **456** | **100%** |

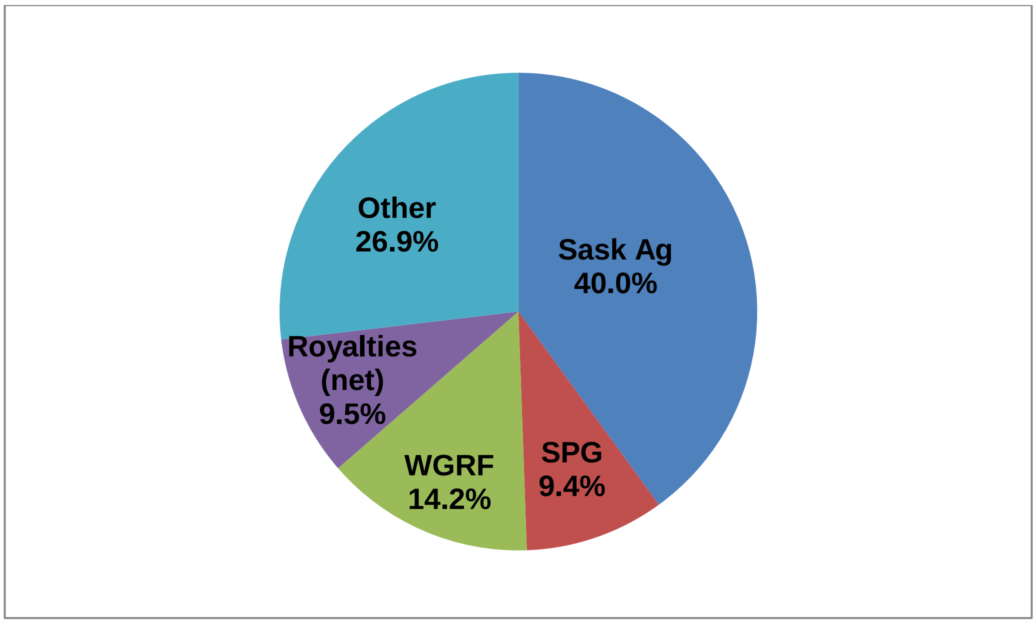
## 2.2 Funding of CDC Plant Breeding and Associated Research Activities

Over the last 10 years, annual CDC spending on plant breeding has increased from $8.1 million to $20.4 million, with a 10 year average expenditure of $13.7 million.

**CDC Source of Funds - Ten Year Average**

Over the last 10 years, the major sources of funds for CDC plant breeding and associated research activities have been provided by the provincial government (at 40.0% of the total over the last 10 years), the WGRF (14.2%), royalty income (9.5%)[7], and SPG (9.4%). Figure 2.1 illustrates the distribution of CDC funding sources for the most recent 10 year period, with $13.9 million[8] as the 10 year average[9]. By way of contrast, for the first three years of CDC operation the NRC provided funding for the scientists and support staff with an initial budget of $324,000.

***Figure 2.1 Distribution of CDC Revenue Sources, 2006 to 2015***




The provincial government provided just over $100 million to the CDC in support of research and variety development activities over the last 30 years. This support has been through program areas such as Strategic Research Programs (SRP), CDC Program Budgets, funding of specific research projects, and capital contributions for necessary infrastructure.

The Western Grain Research Foundation (WGRF) contributed $2.0 million per year over the last 10 years ($3.0 million per annum over the last 5 years), with the majority of funds based on the wheat and barley check-offs. Since 1984, the WGRF contributed $33.7 million in support of research and plant breeding.

Royalty income has progressively increased over the last 5 years from $1.7 million to $2.9 million per annum. A total of $26.8 million in royalties has been captured by the CDC since 1982, with $1.7

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[7] This is net royalty income, after distributing royalty funds to partners (e.g., WGRF, private companies).

[8] Average revenues can exceed average expenditures resulting from royalty reserves in some breeding programs

[9] If the last 5 year period is used, the average annual revenues increases to $17.3 million, with a higher share attributable to the provincial government and the WGRF, with absolute funds from all sources at least as large as with a 10-year view.

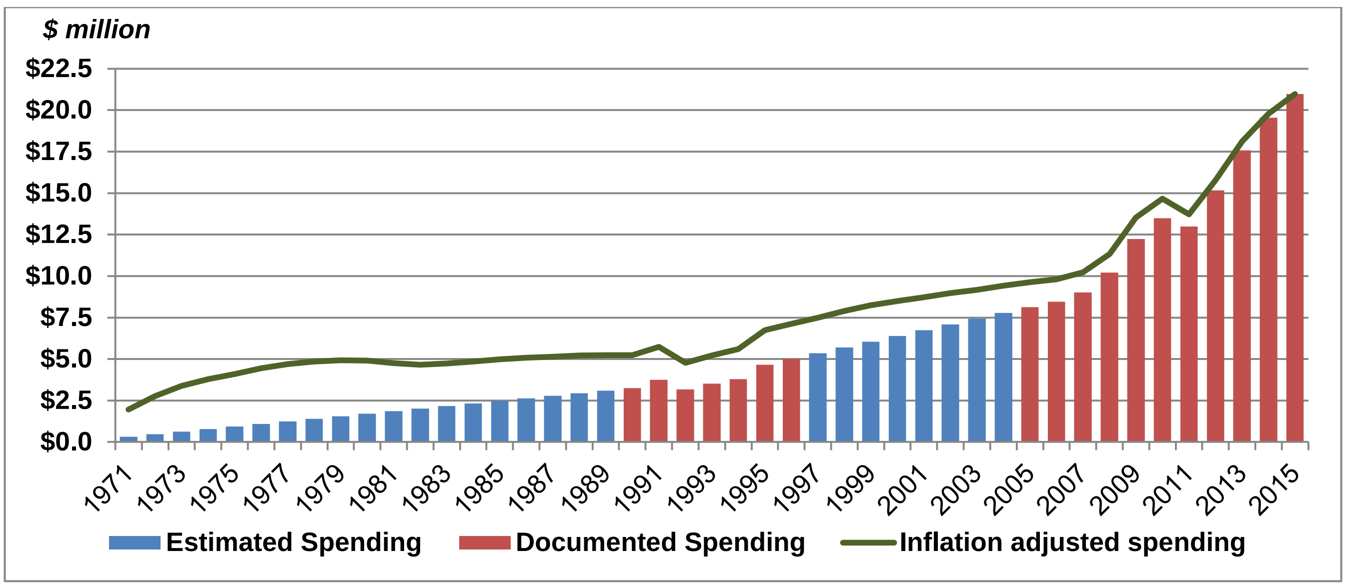
million from seed sales into the US market. Some of the royalty income is shared with partners (e.g., WGRF and private companies) based on funding agreements; in 2015, of the $2.9 million collected, $2.5 million was retained by the CDC. Over the last 10 years net royalty proceeds accounted for 9.7% of annual expenditures, (with a similar percentage when considering the last 5 years). Royalty payments are source of funds for continuation of plant breeding activities at the CDC.

Saskatchewan Pulse Growers (SPG) has provided significant funding for the pulse breeding program since 1997 and has the exclusive commercialization rights for CDC pulse crop varieties. Over the last 10 years, average yearly SPG funds utilized by CDC averaged out at $1.34 million. SPG and CDC signed the current 15-year pulse crop breeding Agreement in 2005. The funding for the first five-year term of the agreement was $6.2 million. The funding for the second five-year term increased to $9.2 million. Over the last 5 years, SPG funding provided $1.5 million each year in support of pulse crop breeding programs. Since 1997, more than 110 pulse crop varieties developed by the CDC have been released through SPG's variety release program.

## CDC Expenditures on Research and Plant Breeding over Time

A view of CDC spending on plant breeding over time is provided in Figure 2.2. The data for the 2005 to 2015 period is based on the financial information system used at the university, and the data for the 1990 to 1996 period is based on CDC Annual Reports, where details on annual budgets are provided. CDC Annual Reports from 1997 to 2004 do not have detail on annual expenditures (or budgets), with the result that the data for 1997 to 2004 is based on a linear interpolation between the two known data sets (and shown in blue in Figure 2.2).

***Figure 2.2 CDC Expenditures on Research and Plant Breeding, 1971 to 2015***




Similarly, annual expenditure data could not be accessed for the 1971 to 1989 period, aside from the initial contribution by the NRC is 1971 of $324,000. The data in the Figure from 1972 to 1989 is an interpolation between these known data points[10].

[10] The resulting expenditure estimate is above the amount of funds provided by the provincial government (based on the years 1985 to 1989 with spending by Saskatchewan agriculture provided since 1985).

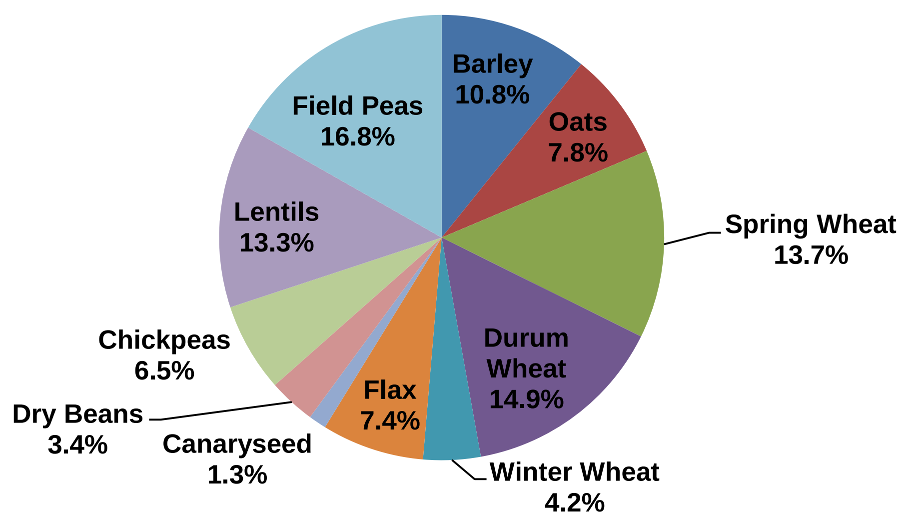
Over the 45-year period of 1971 to 2015 cumulative expenditures at the CDC on variety development totals $257 million for the crop kinds under consideration. In constant 2015 dollars, this amount to $348 million[11], an average of $7.8 million per annum. This is well below current spending on plant breeding, illustrating the phenomenon of CDC increasing in size and scope since inception. The solid line in Figure 2.2 shows the CDC's spending pattern in inflation adjusted funds.

A subsequent chapter shows that the benefit of the CDC's crop breeding program well exceeds the $348 million in cumulative (inflation adjusted) spending.

## Research and Plant Breeding Expenditures by Crop Kind

As noted above, CDC expenditures on research and plant breeding for the crop kinds investigated in this report averaged out at $13.7 million per annum over the last 10 years. The distribution of spending by crop kind over this 10-year period[12] is illustrated in Figure 2.3, with field peas[13] having the largest share at 16.8%, followed by durum wheat at 14.9%, spring wheat at 13.7%, and lentils at 13.3%. The lowest level of spending on plant breeding was with canaryseed at 1.3% (which began in 2008). This distribution by crop kind is based on the various funding sources allocated to each of the breeding programs.

***Figure 2.3 Distribution of CDC Expenditures by Crop Kind, 2006 to 2015***




Limited data is available on CDC expenditures by crop kind prior to 2005, with some detail available over the 1990 to 1996 period. These data points plus the focus of the CDC plant breeding program in these years are used to allocate total CDC spending by crop kind in these missing years.

[11] Using the CPI (all items) to adjust from nominal dollars to real (2015) dollars.
[12] Over the 2005/06 to 2015/16 fiscal years at the CDC, the financial information system used at the University of Saskatchewan had the necessary detail to summarize annual CDC expenditures by crop kind. For this project 2015/16 fiscal year data was applied to the 2015 calendar year.
[13] This distribution of expenditures can be contrasted with the distribution of varieties released by crop kind. For example, 17% of the varieties released by the CDC were lentils, with lentils accounting for 13.3% of spending over the last 10 years the CDC released (8% of estimated spending over the 45 year period). In the case of barley, 20% of released varieties were barley varieties, which accounted for 10.8% of expenditures over the last 10 years, and 15% over the 45 year period.

## 2.3 Acreage Share of CDC Varieties in Saskatchewan

The CDC has made significant contributions to Saskatchewan agriculture through the release of varieties in a number of crop kinds, with these varieties having a high adoption rate within the province. In some crop kinds, a large portion of acreage within Saskatchewan is planted using CDC developed varieties.

**Barley**

In the 1990's, CDC malt barley varieties accounted for 76% of malt barley acreage plantings in Saskatchewan[14]. This large acreage share was due to CDC Harrington, a 2-row malt barley developed by CDC scientists Dr. Brian Rossnagel and Dr. Brian Harvey (a professor in the Department Plant Sciences), which was registered in 1981. As shown in Figure 2.4, this variety accounted for 75% of malt barley acreage in 1991. Another CDC variety, CDC Manley enabled the CDC to maintain a high market share in the province. In recent times, CDC Copeland is the leading malt barley variety with one-third of planted acreage. All CDC malt barley varieties account for 37% of planted acreage in Saskatchewan over the last decade, which compares to a 75% acreage share in the prior 10 year period[15].

***Figure 2.4 Acreage Shares of CDC Malt Barley Varieties, Saskatchewan, 1991 to 2015***

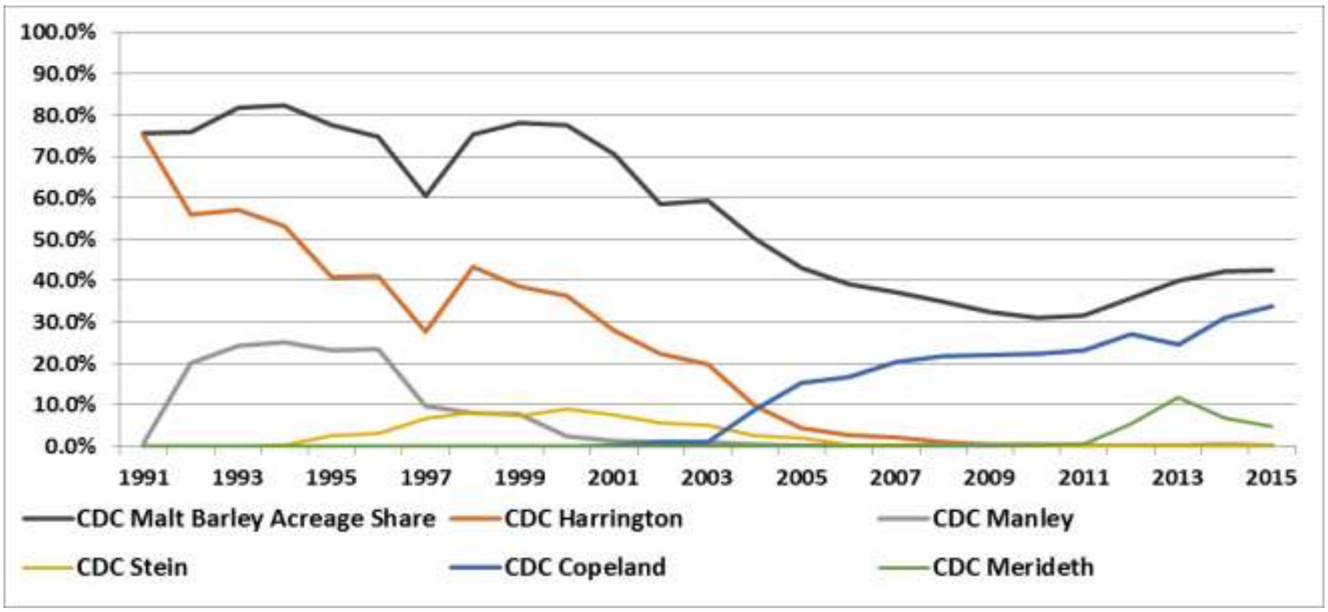
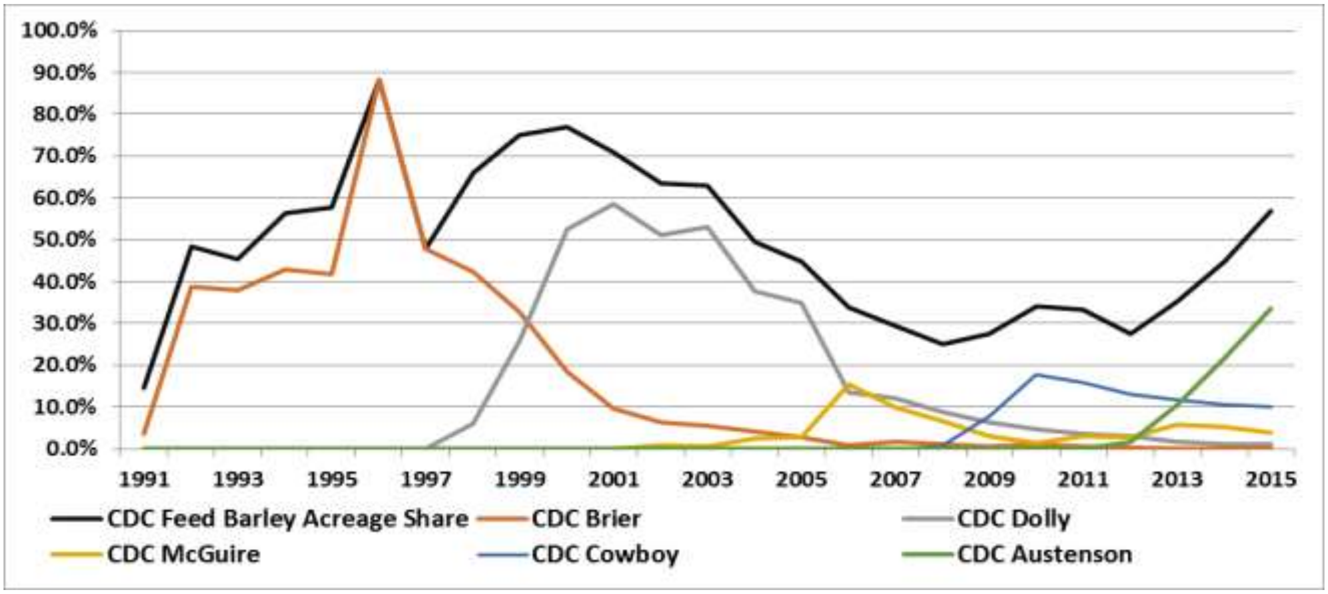



Figure 2.5 provides a comparable view for leading CDC feed barley varieties; with all CDC feed barley varieties accounting for 65% of feed barley acreage in in the 1995 to 2006 period, and 35% on the 2006 to 2015 period. The leading feed barley variety was CDC Brier in the 1990's, followed by CDC Dolly, with CDC Cowboy and CDC Austenson the prominent CDC feed barley varieties planted in Saskatchewan in the last few years.

[14] The acreage share data is based on crop insurance data, which reports acreage insured by variety.

[15] The acreage share by product developer (institution) is provided in Annex C for a number of crop kinds.

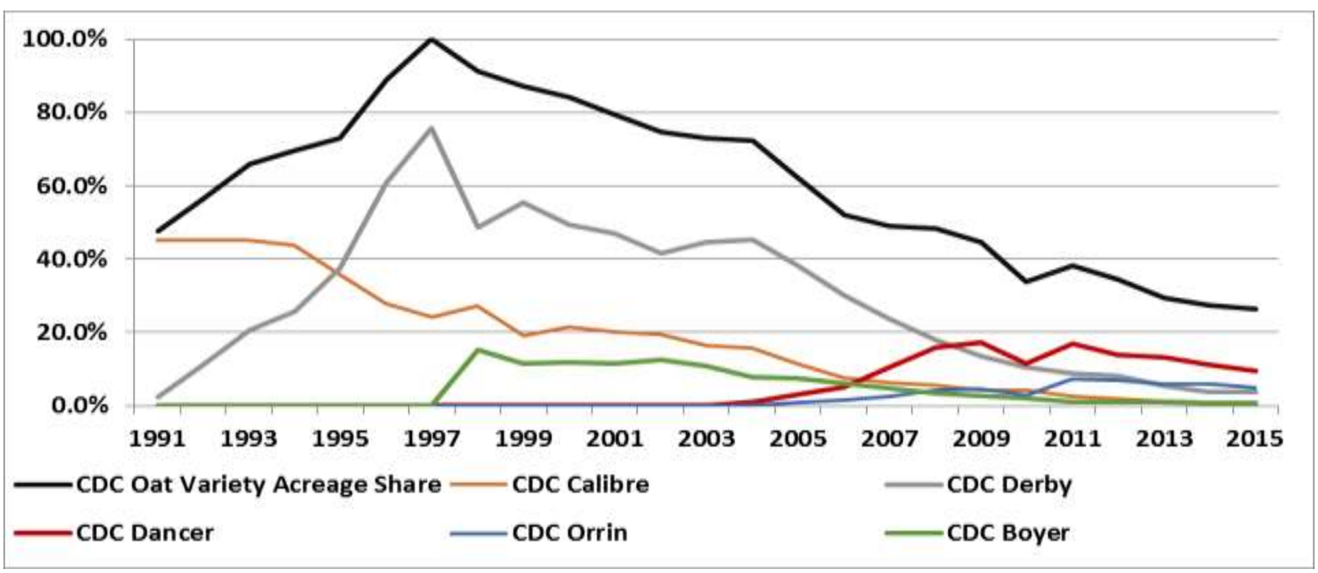
***Figure 2.5 Acreage Shares of CDC Feed Barley Varieties, Saskatchewan, 1991 to 2015***




## Oats

The CDC released 35 new oat varieties since 1991, with CDC oat varieties being planted on 26% of Saskatchewan oat acreage in 2015. As shown in Figure 2.6, the CDC had an acreage share of over 80% in the 1996 to 2000 timeframe. In 1991, CDC Calibre (released in 1983) was the dominant CDC variety and represented over 40% of planted acreage. CDC Derby was available in 1988 and accounted for 75% of all oat acreage in Saskatchewan in 1997. In 2015, with approximately 1 million acres of oats in Saskatchewan, the most frequently planted CDC oat varieties are CDC Boyer (Released in 1994), CDC Orrin (released in 2001), CDC Dancer (released in 2000), CDC Minstrel (released in 2007), and CDC Derby. The loss in CDC market share in oats since 1999 is being replaced by varieties developed by AAFC.

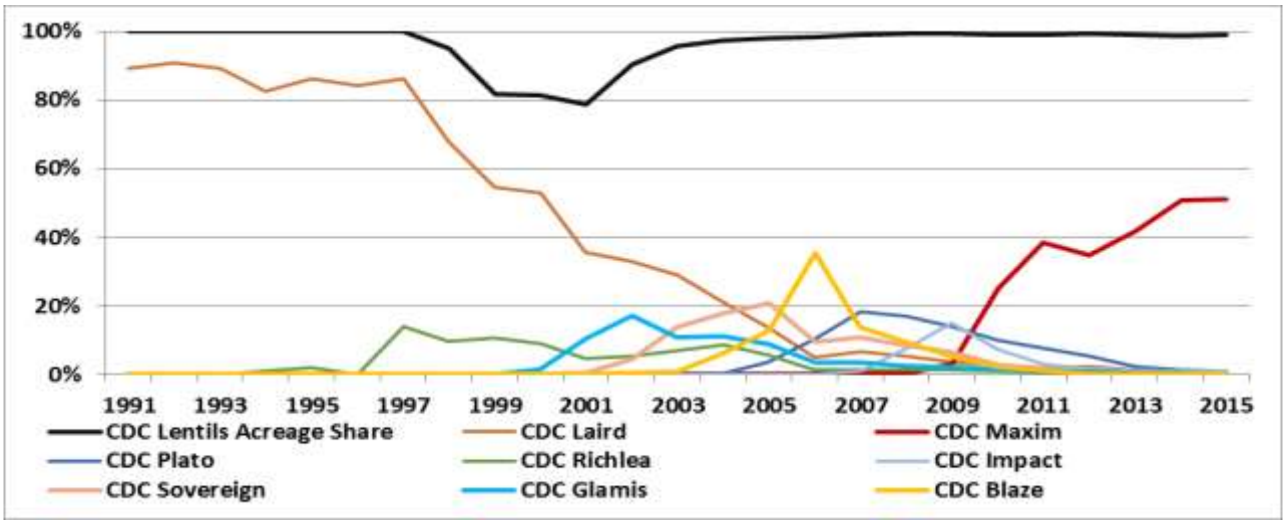
***Figure 2.6 Acreage Shares of CDC Oat Varieties, Saskatchewan, 1991 to 2015***



## Lentils

Lentil production increased in Saskatchewan from a few thousand acres in the 1970s to over five million acres in 2016. Dr. Al Slinkard developed the large-seeded Laird lentil variety registered in 1978, which was the dominant variety in the 1990's. By 2002, CDC Blaze was the dominant variety, which was replaced by CDC Maxim by 2010, as illustrated in Figure 2.7, with 51% acreage share in 2015. A large number of the 79 lentil varieties released by the CDC are planted by Saskatchewan pulse growers, with CDC varieties capturing more than 98% of planted acreage, aside from the 1998 to 2004 period when the Crimson variety (from Washington State) was used. Saskatchewan production on 3.0 to 5.0 million acres accounts for 95% of Canadian lentil production, and is the world's largest exporter of lentils.

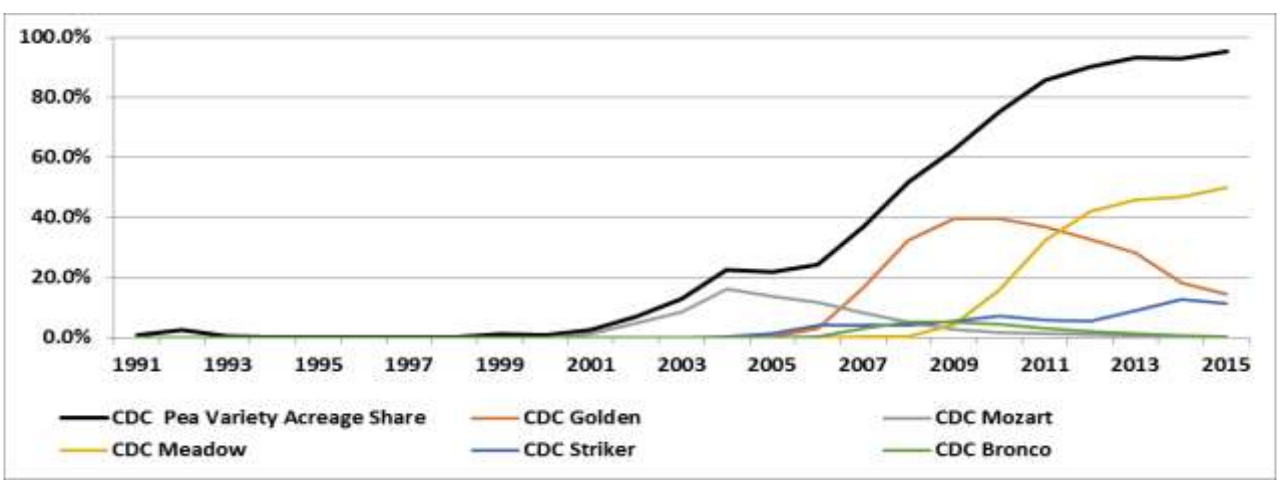
***Figure 2.7 Acreage Shares of CDC Lentil Varieties, Saskatchewan, 1991 to 2015***




## Dry Peas

The first CDC pea variety was released in 1986 (CDC Bellvue), which captured 2.5% acreage share in 1992. CDC's acreage share in Saskatchewan increased substantially from less than 1% in 2000 to 95% by 2015, as shown in Figure 2.8. This advance was led by CDC Mozart (released in 1999) and CDC Golden (released in 2003) with 40% of Saskatchewan acreage in 2009 and 2010, and CDC Meadow (released in 2006) with a 50% market share in 2015. Saskatchewan is also the world's largest exporter of dry peas with 2.5 to 3.0 million acres in production.

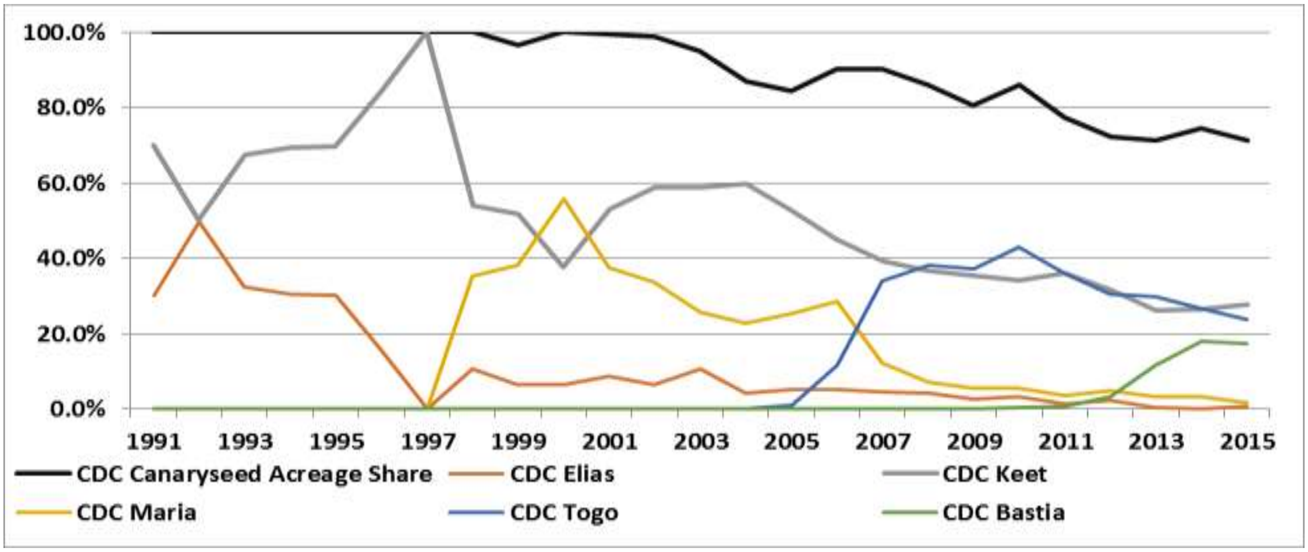
***Figure 2.8 Acreage Shares of CDC Dry Pea Varieties, Saskatchewan, 1991 to 2015***



## Canaryseed

The first canary seed varieties (Alden and Keet) were released by Dr. Slinkard the CDC in 1983 followed by CDC Elias in 1988, with CDC Elias and CDC Keet accounting for all seeded acres in Saskatchewan between 1991 and 1997 (see Figure 2.9). Other institutions provide canary seed varieties and by 2015, CDC varieties still accounted for more than 70% of planted acres in Saskatchewan. CDC Keet has remained a popular variety with other 25% acreage share in 2015, with acreage in CDC Togo (released in 2004) and CDC Bastia (offered to the market in 2007) with a 45% combined acreage share in 2015. Between 200,000 and 300,000 acres are in production.

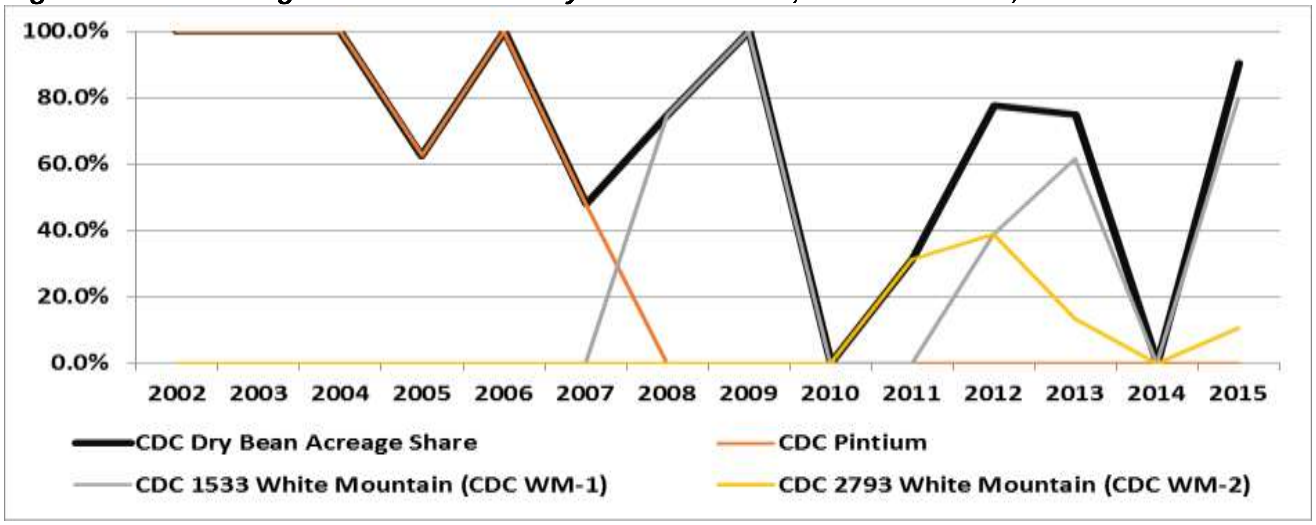
***Figure 2.9 Acreage Shares of CDC Canaryseed Varieties, Saskatchewan, 1991 to 2015***




## Dry Beans

The CDC released its first dry bean variety in 1995, which was CDC Expresso and CDC Nighthawk. In 2002, when crop insurance data is first available for dry beans, CDC Pintium (released in 1999) accounted for all of the known dry bean varieties planted in Saskatchewan (see Figure 2.10). In some years all acreage was to known varieties, with the CDC 2002 to 2015 average at 54%, with 2010 the exception where none on the varieties were reported on the insured acreage. CDC WM-1 (released in 2009) accounted for the majority of acreage in 2013 and in 2015. Production occurs on 5,000 to 15,000 acres each year in the province. The other two provinces produce more dry beans.

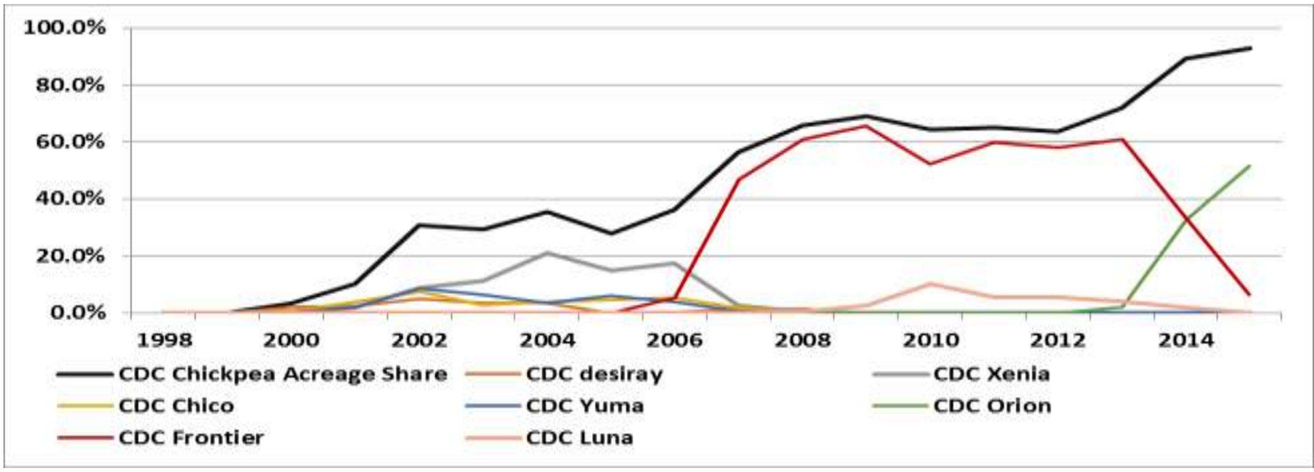
***Figure 2.10 Acreage Shares of CDC Dry Bean Varieties, Saskatchewan, 1991 to 2015***



## Chickpeas

The CDC released 24 chickpea varieties, beginning in 1994, with the CDC's share of acreage planted to chickpeas in Saskatchewan increasing from no measureable share in 1998 to over 90% of planted acreage in 2015. Prior to 1997 there was in chickpea production, which is now between 100,000 to 200,000 acres. The initial success can be attributed to CDC varieties such as CDC Desiray (released in 1999), CDC Xena (released in 1998), and CDC Yuma (released in 1997). CDC Frontier (released in 2003) enabled CDC acreage share to increase past the 50% point in 2007, with this variety accounting for more than 60% of chickpea acreage in the 2008 to 2013 period, CDC Orion (released in 2010) had a 51% market share in 2015, as shown in Figure 2.11.

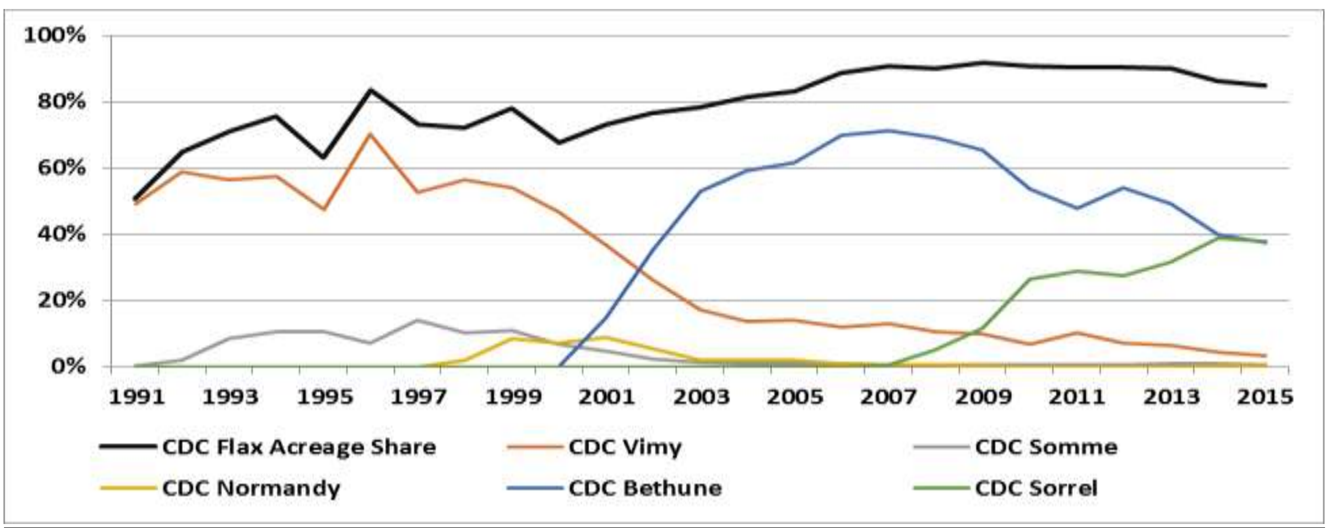
***Figure 2.11 Acreage Shares of CDC Chickpea Varieties, Saskatchewan, 1991 to 2015***




## Flax

The CDC released 22 varieties of flax beginning in 1986 with CDC Vimy (bred by Dr. Rowland), and in the period of 1991 to 1995 this variety accounted for 50% of all flax acreage in Saskatchewan. As shown in Figure 2.12, CDC Bethune, which was released in 1998 accounted for over 60% of provincial flax acreage in the 2005 to 2009 period. In 2015, CDC Bethune and CDC Sorrel each accounted for just under 40% of all flax acreage. Starting in 1991 all CDC varieties were planted on 50% of Saskatchewan's flax acreage, which increased to 90% and represented 85% of provincial acreage in 2015. Flax production can exceed 1 million acres in Saskatchewan.

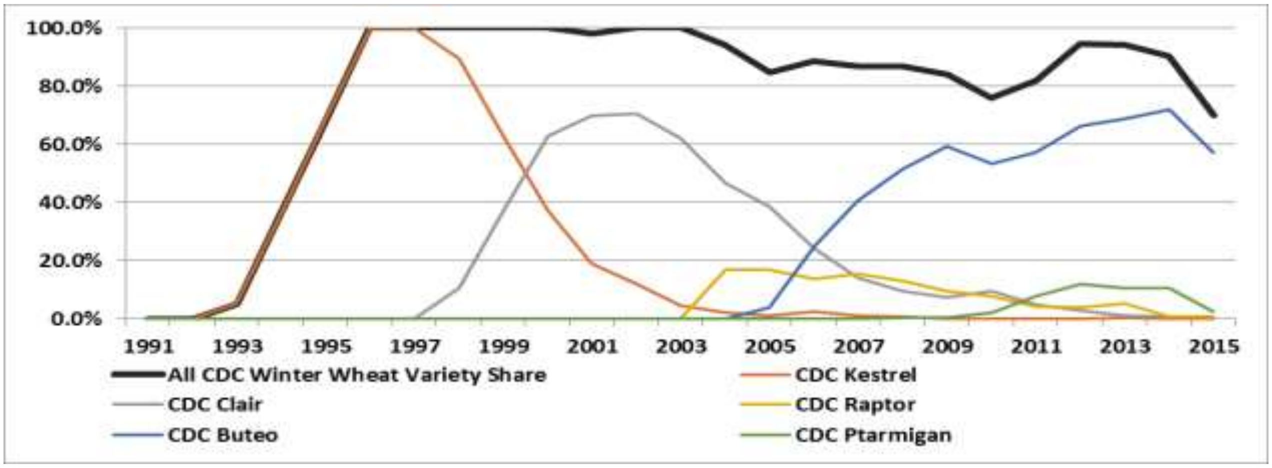
***Figure 2.12 Acreage Shares of CDC Flax Varieties, Saskatchewan, 1991 to 2015***



## Winter Wheat

The CDC made significant contributions to the winter wheat industry in Saskatchewan and across the prairies. Over the last 10 years, CDC winter wheat varieties accounted for 85% of the winter wheat planted in Saskatchewan, and in the 1996 to 2005 period accounted for 98% of winter wheat acreage in the prior 10 year period. Figure 2.13 shows the acreage share for Saskatchewan winter wheat over the 1991 to 2015 period. Dr. Brian Fowler was the plant breeder who bred CEC Kestrel, the first winter wheat varieties released by the CDC in 1991; by 1996 this variety accounted for all winter wheat acreage in the province. CDC Clair was released in 1995 achieved a 70% acreage share in the 2001/02 period. CDC Buteo was released in 2001 and had a 70% market share in the 2013 /14 period.

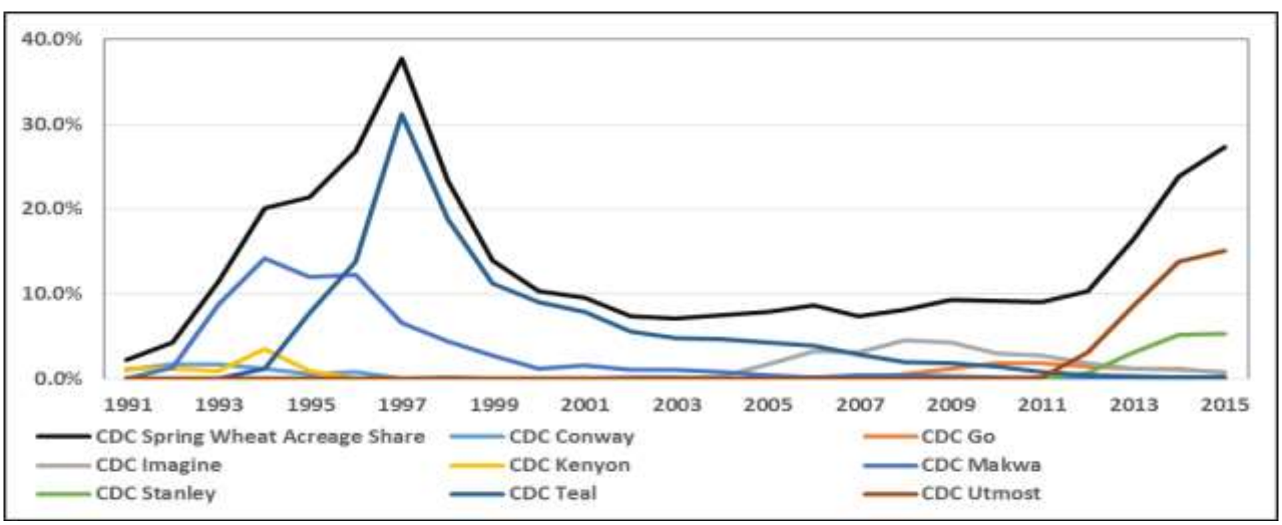
***Figure 2.13 Acreage Shares of CDC Winter Wheat Varieties, Saskatchewan, 1991 to 2015***




## Hard Red Spring Wheat

The first hard spring wheats released by the CDC in the late 1980's were bred by Dr. G. Hughes, with CDC Makwa accounting for 14% of Saskatchewan acres in 1994. This variety and CDC Teal enable CDC wheat varieties to account for 38% of provincial hard red spring acreage in 1997. More recently CDC Utmost and, CDC Stanley enable CDC varieties to account for 27% market share in 2015. Over the last decade, the CDC acreage share was 13%, with AAFC the prominent developer of hard spring wheat varieties.

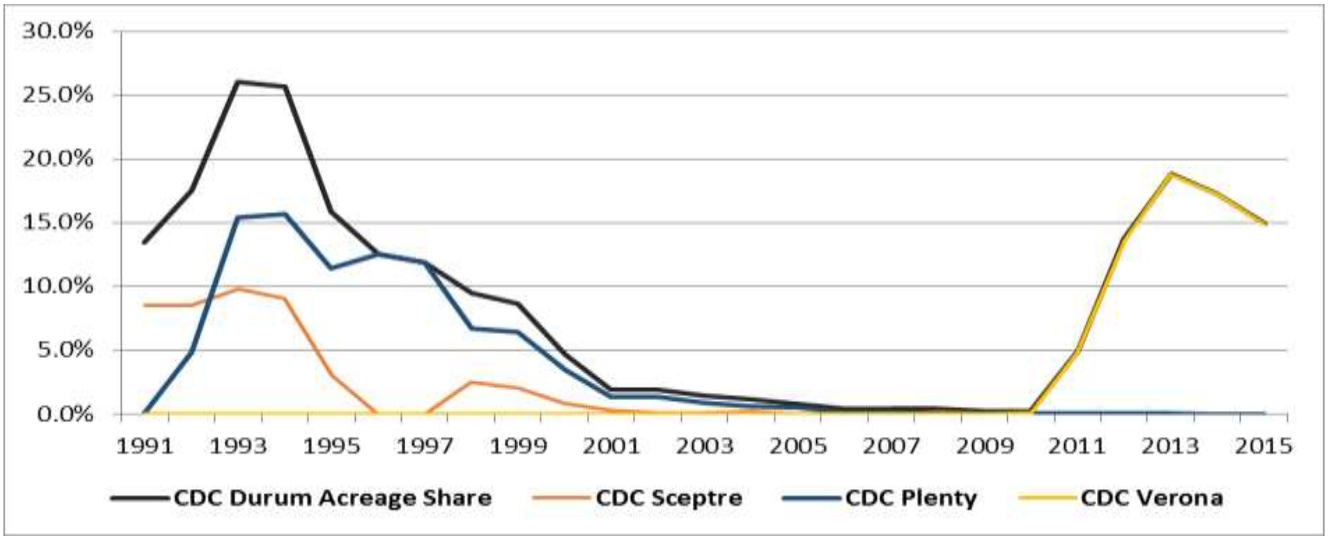
***Figure 2.14 Acreage Share of CDC Hard Spring Wheat Varieties, Sask., 1991 to 2015***



## Durum

The CDC released 11 durum varieties since inception, with CDC Sceptre released in 1985 and in the early 1990's had just under 10% market share. CDC Plenty (released in 1990) was planted on 15% of the acres shortly thereafter (see Figure 2.15). The release of CDC Verona in 2008 was the dominant CDC variety planted by 2010 and accounted for just under 20% of durum acreage in Saskatchewan in 2013. Between 2001 and 2010, the CDC had minimal acreage share with AC Kyle, AC Strongfield and AC Avonlea essentially the only varieties planted in that period.

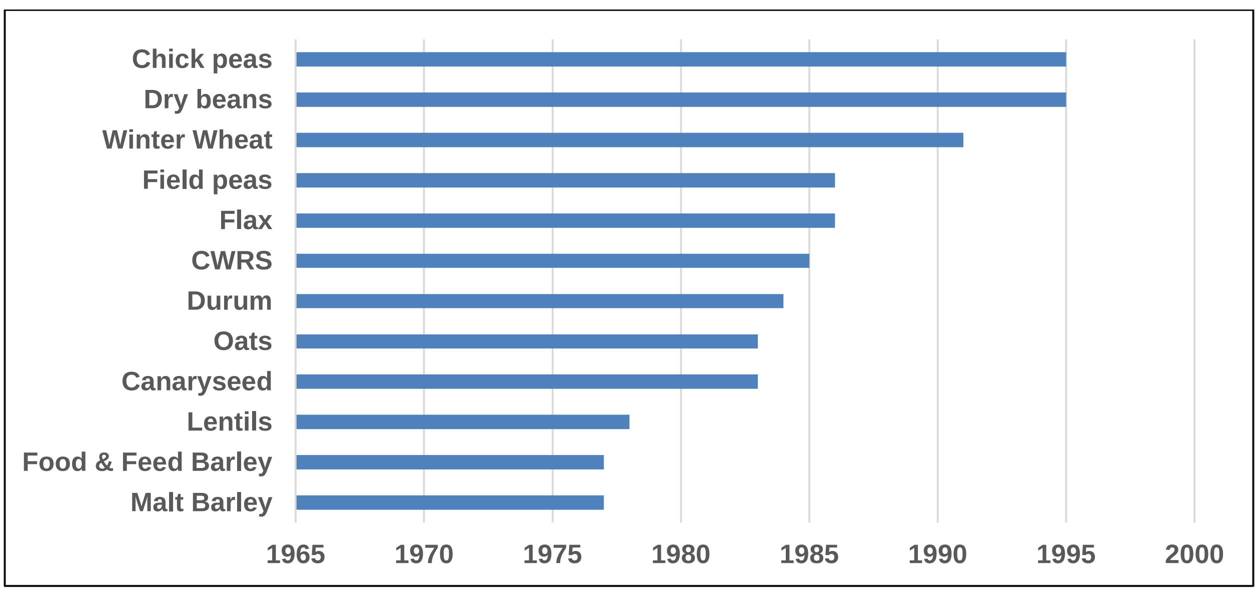
***Figure 2.15 Acreage Shares of CDC Durum Varieties, Saskatchewan, 1991 to 2015***




## First Year of Release of CDC Varieties

Since 1971, the CDC has released many new varieties. Figure 2.16 provides a summary of the year the first variety was released for each crop kind. For crop such as barley, the first release was in the 1970's, with most occurring in the 1980's (e.g., flax, oats), with the first winter wheat, chickpea and dry bean variety released in the 1990's

***Figure 2.16 Year of First CDC Variety by Crop Kind***



# 3.0 Crop Yield Increases Attributable to Plant Breeding

Realized crop yields at the producer level have been increasing in western Canada since 1991 by 0.36% per annum to just over 2% per annum, depending on the crop kind. The first data column in Table 3.1 shows the annual growth rate between 1991 and 2015 for all of western Canada. These yields are prairie wide averages as reported by Statistics Canada. The growth rates in Table 3.1 are compound annual growth rates using the following formula when the applicable time period is 1991 to 2015:

- CAGR = $(Y_{2015} \div Y_{1991})$^[1 ÷ (2015-1991)] - 1

Where $Y_{2015}$ and $Y_{1991}$ are the yield levels (or index) for 1991 and 2015. The values for $Y_{2015}$ and $Y_{1991}$ are 5 year averages to allow for smoothing of the beginning and end points. For example, actual yields in 1991 could be well below (or above) trend in 1991, which would create an upward (or downward) bias in the computed annual growth rate in yields.

***Table 3.1 Trend Percentage Increases in Yields to 2015***

| Crop | Trend Annual Increase Using Prairie-Wide Producer Realized Yields | | Trend Annual Increase Using Acreage Weighted Sask. Variety Performance Trial Data | |
|---|---|---|---|---|
| | *%* | *time period* | *%* | *time period* |
| Lentils | 1.16% | 1991-2015 | 0.74% | 1981-2015 |
| Field peas | 0.88% | 1991-2015 | 1.99% | 1991-2015 |
| Dry beans | 1.25% | 1991-2015 | 0.29% | 2002-2015 |
| Chick peas | 2.13% | 1995-2015 | 0.65% | 1998-2015 |
| Canary seed | 0.36% | 1991-2015 | 0.26% | 2007-2015 |
| Flax | 0.48% | 1991-2015 | 0.48% | 1991-2015 |
| Oats | 1.20% | 1991-2015 | 0.39% | 1991-2015 |
| Barley | 0.60% | 1991-2015 | 0.39% | 1991-2015 |
| Winter wheat | 0.86% | 1991-2015 | 0.45% | 1991-2015 |
| All spring | 1.46% | 1991-2015 | 0.46% | 1991-2015 |
| Durum | 0.86% | 1991-2015 | 0.50% | 1991-2015 |

Source: Prairie wide results based on analysis using CANSIM data (010-0010) and Variety Performance Trail data for Saskatchewan

The third column provides a summary of increases in crop yields using Saskatchewan variety performance trial data. Variety performance trial data, where yields are indexed to a check variety, was obtained for the prominent varieties which had a reasonable acreage share in any of the 1991 to 2015 time period. Variety yield indexes where adjusted to have all varieties in all years indexed relative to the check variety that existed in the initial year (usually 1991), such as Katepwa for hard red spring wheat[16].

Yield indexes are relative and in the case of CWRS in Saskatchewan, the variety Carberry is the current check variety, which is given an index of 100 (for its per acre yield) and the yield measured for other varieties are expressed as an index in relation to Carberry[17], with CDC Titanium VB having an index of 111 and CDC Kernen an index of 106. In 1991 AC Katepwa was the check variety, with

[16] A check variety can be used for 10 years with a comparison to the other tested varieties indexed to a check variety.

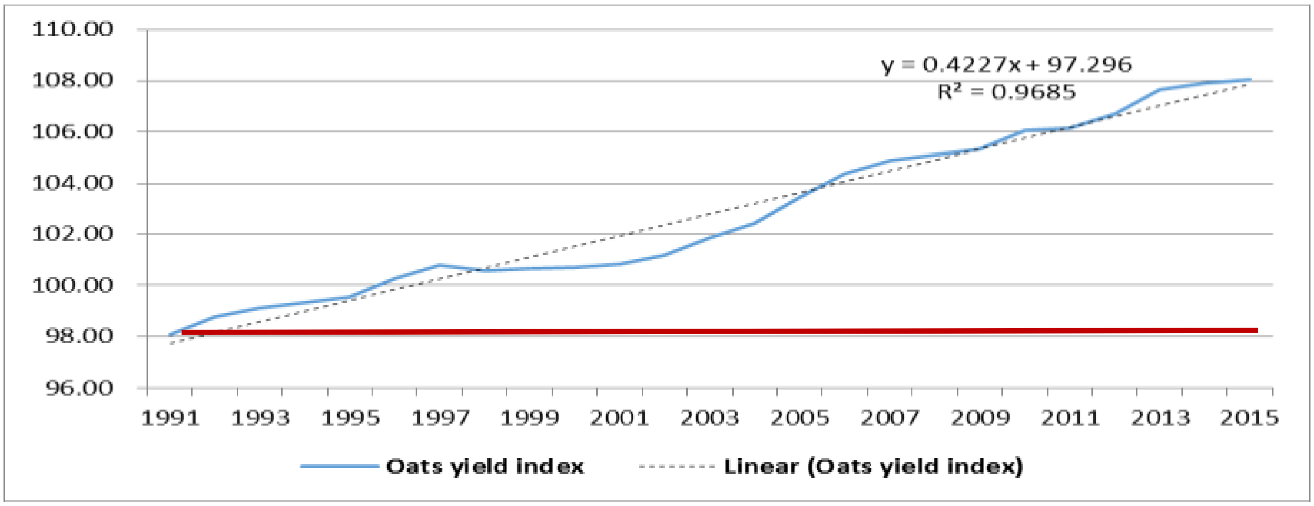
[17] The values provided are for Areas 3 and 4 in Saskatchewan for data published in the 2016 SaskSeed Guide.

AC Carberry having an index of 110.8 in relation to AC Katepwa, which implies that CDC Kernen has a yield index of 117.4 in relation to the AC Katepwa variety. This indicates that CDC Kernen yields are 17.4% higher than the first variety check used in our analysis.

The resulting yield index for each variety was multiplied by its annual acreage share (as reported using crop insurance data) to construct a 1991 to 2015 yield index series[18]. Figure 3.1 shows the trend in the yield index for oats. The associated trend line indicates that yields increased by 0.42 units each year, on average. The trend data indicates that performance trial yields (after weighting by acreage share using producer plantings) increased each year, which illustrates the impact of both plant breeding activities and adoption of new varieties by oat producers.

The associated growth rates in Table 3.1 (for gains due to plant breeding) are computed using the above growth rate formula with the use of a 2 year average for beginning and ending computed yield index values. The annual yield increase is 0.39%. A two year average is used to smooth out any potential beginning and end point irregularities, which may have a downward (or upward) bias effect on measure annual yield increases due to plant breeding.

***Figure 3.1 Trend in Acreage Weighted Saskatchewan Variety Performance Trial Oat Yields***




The increase in yields as measured using performance trial data and variety specific acreage plantings (using annual crop insurance data) capture the yield increases realized by farmers due to plant breeding. Using the performance trial data eliminates any yield increase attributable to improvements in agronomics and associated technologies, and using actual reported acreage shares of crops by specific varieties captures the adoption of each variety by farmers.

## The Counterfactual

This variety performance trial data is used to measure the benefits of plant breeding, capturing both genetic improvement and adoption by farmers. This is the factual in our analysis. The counterfactual is the yield index for the base year (such as 1991). The yield in the base year represents yields that can be expected with no further release of varieties with genetic improvement. Using Figure 3.1 as an illustration, in 2015 the yields due to plant breeding programs have a value of 108, while the counterfactual has a yield value of 98 in 2015 (illustrated by the red line, which is a continuation of the yields observed in the base year). The oat yield gain in 2015 in Saskatchewan is 10% (108 ÷ 98) due to plant breeding.

[18] Annex E illustrates how the performance trial data was used to create an overall yield index attributable to plant breeding.

**Growth in Farm Level Yields Exceeds Variety Performance Trial Yields**

The growth rate in oat yields of 1.2% realized by farmers (see Table 3.1) is greater than the 0.39% annual growth based on performance trial data. As a general rule of thumb, trends in farm level yield should exceed the trend growth rate in performance trial yields. This is due to the fact that over time farm-level yield increases will reflect the contribution of (1) improved genetics due to plant breeding, (2) improvements in agronomic and farm management practices, and (3) improvements in planting and harvesting equipment. In the case of variety performance trials these latter two factors are held constant as varieties are compared to each other and to a check variety.

Referring back to Table 3.1, the growth rates in yield observed at the farm level are greater than those measured as attributable to only plant breeding. For example, the growth in chick pea yields was 2.13% across the prairies, while this was measured at 0.65% for yield increases attributable to plant breeding.

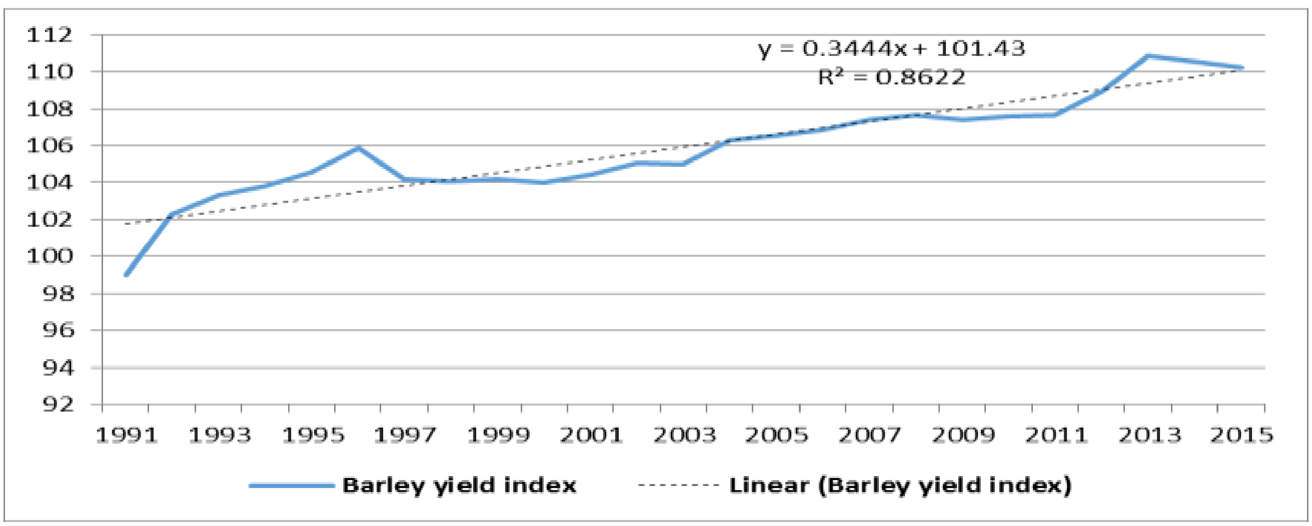
## 3.1 Trends in Saskatchewan Variety Performance Trial Yields

The trend in oat yields in Saskatchewan since 1991 attributable to plant breeding efforts is illustrated above in Figure 3.1. The following charts provide a comparable view of yield increases due to plant breeding, using Saskatchewan data.

**Barley**

As noted in Figure 3.2, barley yields have increased by 0.34 points when compared to the check variety in 1991, which was CDC Harrington. The annual growth rate in yields has been 0.39% based on performance trial data since 1991, which compares to farm level increases of 0.60%.

***Figure 3.2 Barley Yields - Acreage Weighted Saskatchewan Performance Trial Trend***



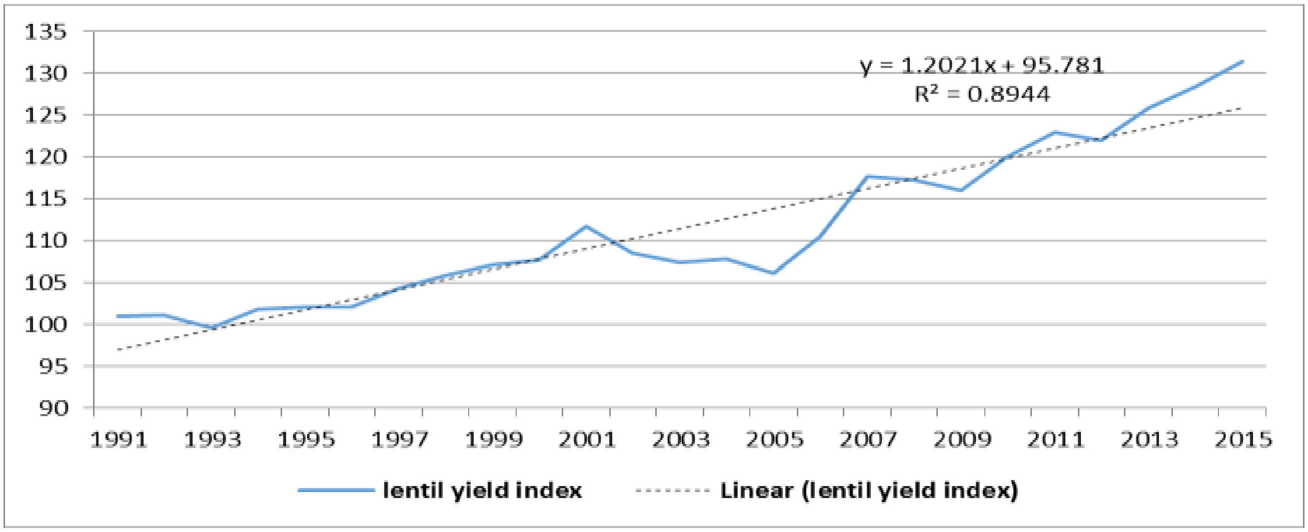

This annual increase of 0.39% is the factual used to characterize yield increases attributable to only plant breeding activities. The counterfactual is that these annual increases in yields, which were on average 0.39% per year, did not occur. The counterfactual will have some yield increases (e.g., 0.21% based on 0.60% - 0.39%) which is due to other factors such as improved agronomic products and practices.

## Lentils

CDC Laird, which had 89% acreage share in 1991 in Saskatchewan[19], was the check variety between 1991 and 2007, with CDC Milestone the check variety starting in 2008 and CDC Maxim the check starting in 2013. When using the 1991 to 2015 time frame the growth in yields attributable to plant breeding is 1.05%. Since Laird and Eston were the only varieties grown in 1991 and both were released to the market prior to 1991 (with acreage over 500,000 acres), the index attributable to CDC Laird and CDC Eston in 1991 should also apply in 1981. Using 1981 as the starting point, the annual growth rate is 0.74% per annum (using 2 year averages in the CAG formula). This value of 0.74% will be attributed to lentil plant breeding.

The counterfactual is no increase in yields beginning in 1991 that can be attributable to plant breeding.

***Figure 3.3 Lentil Yields - Acreage Weighted Saskatchewan Performance Trial Trend***

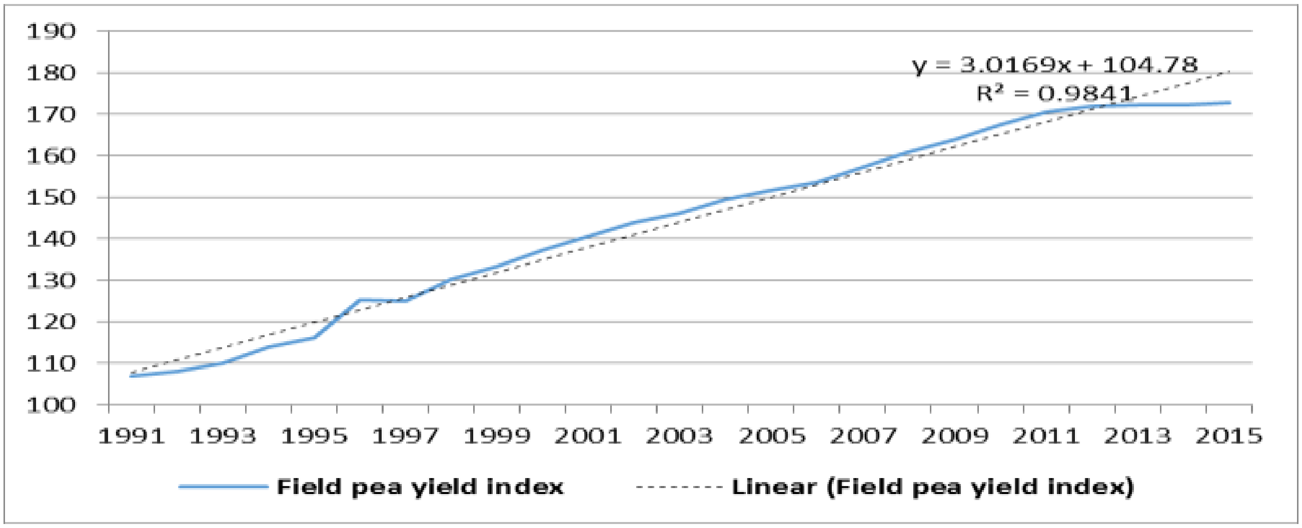



## Dry (Field) Peas

Saskatchewan has been growing dry peas since at least the early 1970's. In 1991 there were 500,000 acres. Variety yields from performance trials for dry peas has shown significant growth since 1991, when AC Century was the check variety (with an index of 100). Since then the acreage weighted index for 2015 is over 170. The can be explained by CDC varieties such as CDC Meadow with a yield index of 177 when compared to AC Century, and CDC Stricker (161), and CDC Golden (169), which has been the check variety since 2014. The annual growth rate is measured at 1.99% since 1991, suggesting significant returns to producers arising from plant breeding efforts. The CDC did not have any significant market share in dry peas until the early 2000's.

[19] The only lentil varieties registered in Canada were from the CDC until 2003. The Saskatchewan Crop Insurance data shows only CDC varieties being insured in 1991.

***Figure 3.4 Dry Peas Yields - Acreage Weighted Saskatchewan Performance Trial Trend***



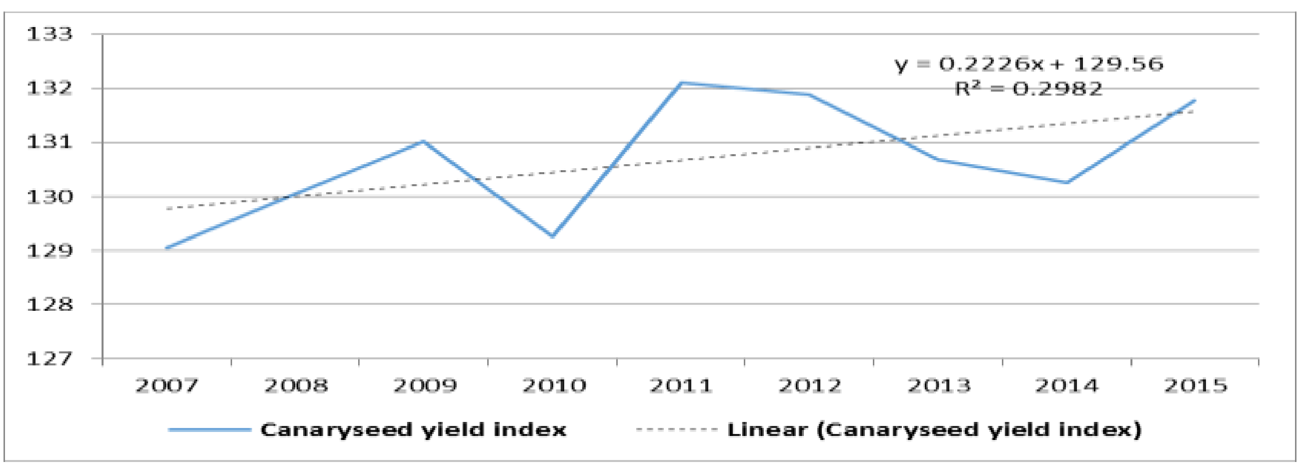

Of interest, the annual increase in yields since 1991 using variety performance trial data at 1.99% is larger than the growth in farm level yields over the same time period, which is 1.22% (based on 2 year averages) and 0.88% based on 5 year averages. This a variance can be explained by the large increase in dry pea acreage since 1991, from 0.5 million acres in over 2.5 million acres, with potentially lower yields on areas not as ideally suited to peas in relation to the area planted in 1991.

**Canaryseed**

Performance trial data for canaryseed varieties became available starting in 2007, with the performance trial data showing a 0.26% growth rate (using 2015 and 2007 yield data). Statistics Canada published canaryseed acreage beginning in 1986. Since 1991 farm level yields have increased by 0.36% per annum.

CDC Maria was the check yield in 2007 (index of 100), with this variety first released in 1997. The CDC released CDC Alden, CDC Keet and CDC Alias in the 1980's. The acreage weighted index of 129 in 2007 suggests significant genetic gain since 1997. Figure 3.5 shows the trend in the yield index, with an associated compound growth rate of 0.14% (based on 2 years of data for ending and starting points) and 0.26% with only the year (of beginning and ending points).

***Figure 3.5 Canaryseed Yields - Acreage Weighted Saskatchewan Performance Trial Trend***

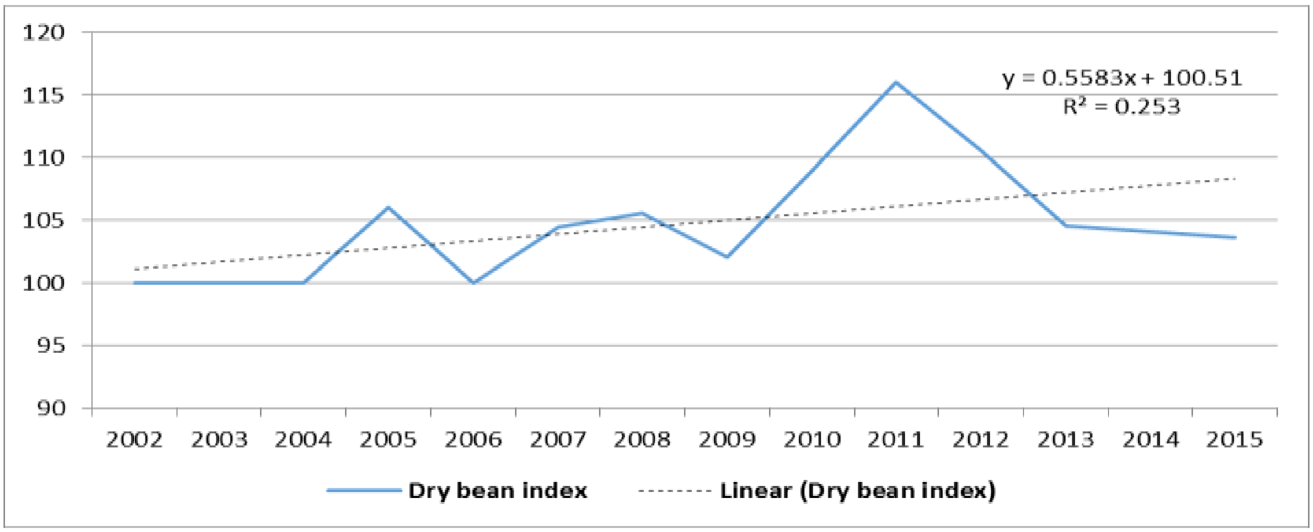


Canaryseed was produced on 235,000 acres in 1991 supported by the CDC varieties released in the 1980's. The benefit of plant breeding over this time period will be based on a 0.26% annual increase in yields, with the counterfactual of no yield increase after 1991 due to breeding. As noted in Table 3.1, over this same time period farm level yields increased by 0.36% per annum

**Dry Beans**

Dry beans are planted in Saskatchewan[20], with production in the prairie regions since at least 1991. Crop insurance data for Saskatchewan acreage was first provided in 2002, with the acreage weighted trend in yield shown in Figure 3.6. The variety CDC Pintium has been the check variety since 2002, which was USDA Othello between 1996 and 2001 (and a yield index of 96 compared to CDC Pintium (at 100)). The estimated compound growth rate is 0.29% per annum. This compares to a 1.25% annual increase observed across prairie farms.

***Figure 3.6 Dry Bean Yields - Acreage Weighted Saskatchewan Performance Trial Trend***

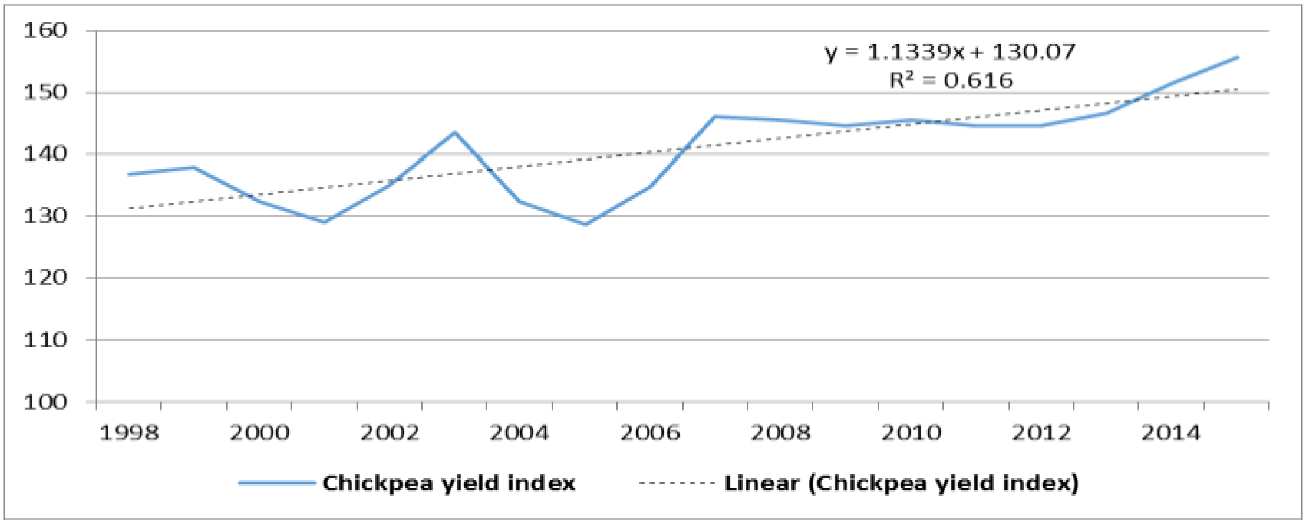



**Chickpeas**

Chick pea production in Saskatchewan was first reported by Statistics Canada in 1997, with the CDC releasing the variety CDC Marengo in 1994. Crop insurance data by variety was first published in 1998, with the variety USDA Sanford used as the check variety (index of 100). Figure 3.7 shows the trend in the acreage weighted performance trial data, with the compound growth rate being 0.65% yield increases per year. This compares to the 2.13% increases observed at the farm level.

[20] Statistics Canada does not track dry bean acreage, yield and production in Saskatchewan. It began tracking dry beans in 1991 in Alberta and in 1992 in Manitoba.

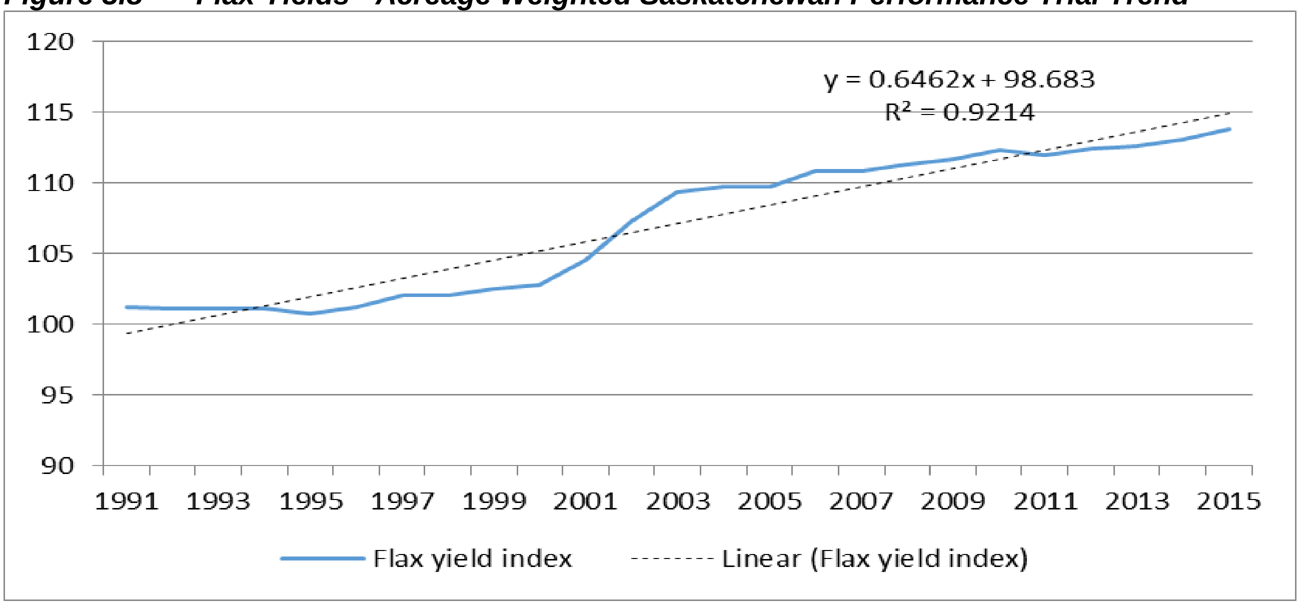
***Figure 3.7 Chickpea Yields - Acreage Weighted Saskatchewan Performance Trial Trend***




## Flax

In 1991 AC Norlin was the check variety for flax (index = 100), with acreage weighted performance trial data indicating a trend increase of 0.65 units. The annual growth rate (based on using two years of data for the beginning and ending years) attributable to plant breeding efforts is measured at 0.48%. The variety CDC Vimy became the check variety in 1999 and was replaced by CDC Bethune in 2006. The latter has a yield index value of 113 (in relation to AC Norlin at 100) and CDC Vimy has an index value of 102 (in relation to AC Norlin).

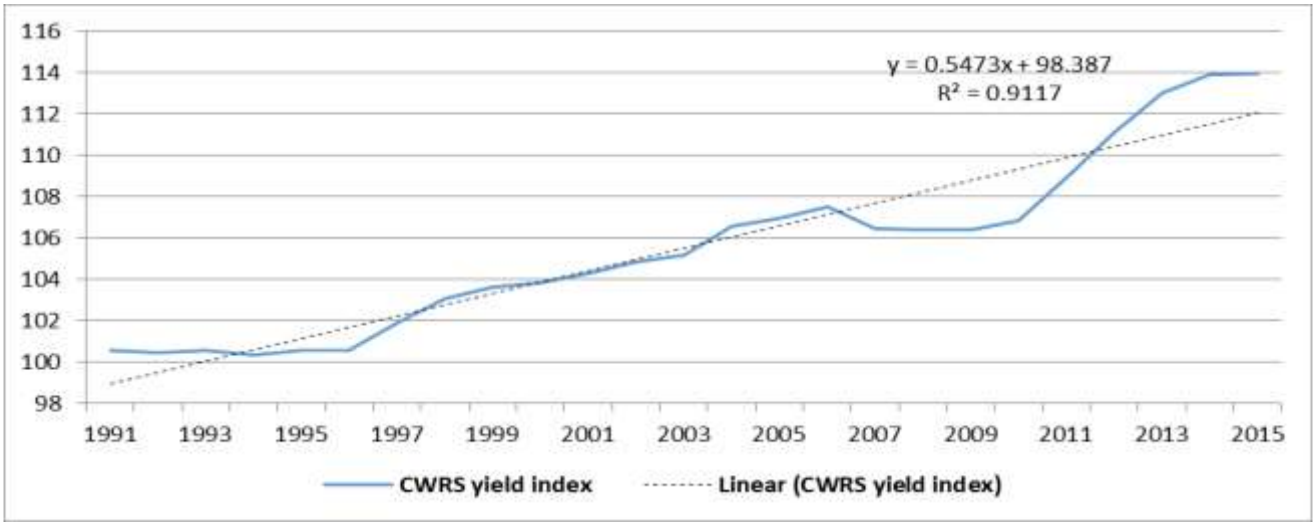
***Figure 3.8 Flax Yields - Acreage Weighted Saskatchewan Performance Trial Trend***



## Spring Wheat

Yields for all spring wheats increased by 0.46% per annum using our methodology, which compares to 1.46% across the prairies at the farm level. The check variety was Katepwa in 1991 (index = 100), with the current check AC Carberry having an index of 110.8 in relation to Katepwa. CDC Utmost, which has an 18% weighting in the 2015 index, has a yield index of 119.7, when compared to Katepwa (at 100).

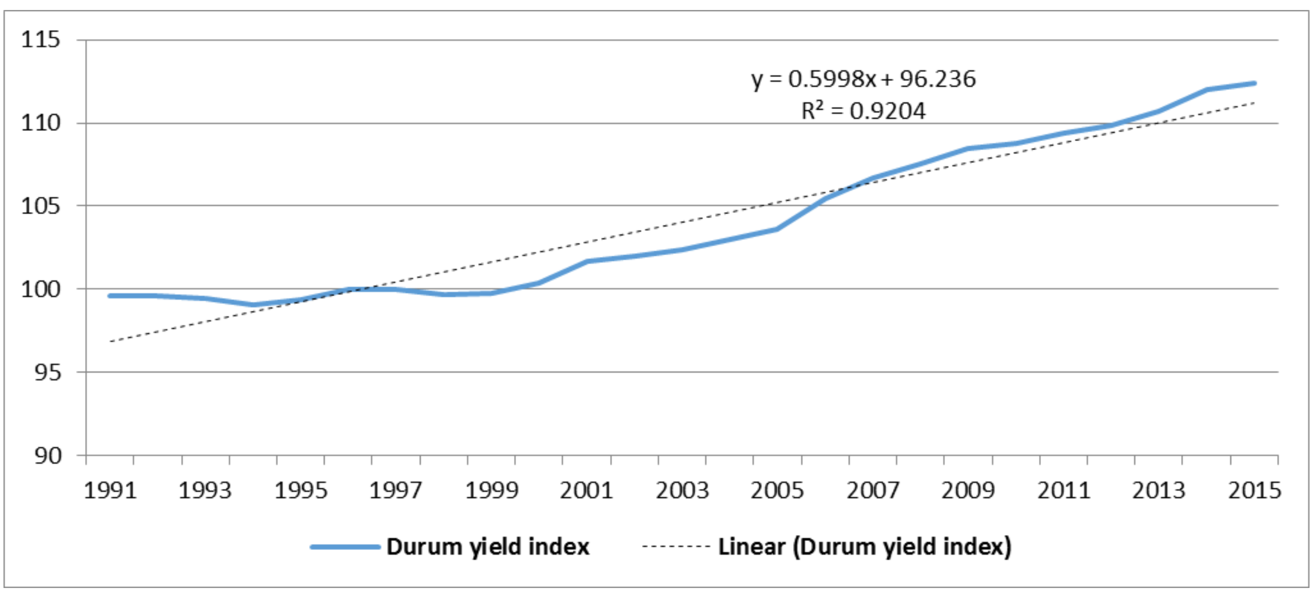
***Figure 3.9 Spring Wheat Yields - Acreage Weighted Sask. Performance Trial Trend***




## Durum

CDC Plenty was a durum variety that captured over 15% of Saskatchewan's durum acreage in 1994, with a yield index of 103.5, which contrasts with the 1991 check variety of AC Kyle (index of 100). In recent years CDC Verona has captured up to 18% of acreage, with a yield index of 112. Over the 1991 to 2015 time frame, the annual growth rate of performance trial yield for durum (after acreage weighting) is 0.50%, which compares to 0.86% for all prairie seeded acreage.

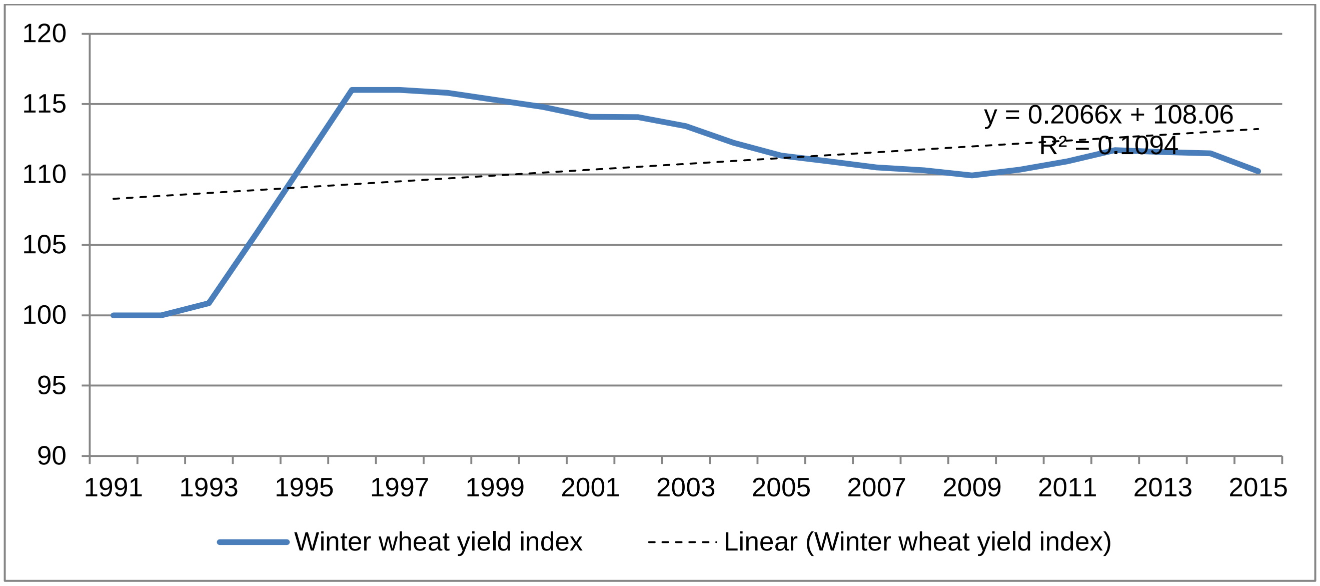
***Figure 3.10 Durum Yields - Acreage Weighted Saskatchewan Performance Trial Trend***



## Winter Wheat

The trend in yields for winter wheat is measured at 0.86% at the producer level across the prairies. The measured increased attributable to plant breeding is 0.45% per annum. In the 1994 to 2003 period, insured acreage in relation to total planting was very low and the insured acres in some years indicated only one variety – which is a likely explanation of why the data in Figure 3.11 increases sharply in the 1994 to 1996 period.

***Figure 3.11 Winter Wheat Yields - Acreage Weighted Sask. Performance Trial Trend***



# 4.0 Economic Benefit of CDC Plant Breeding Activities

In this Chapter the Benefit Cost Analysis (BCA) is used to measure the benefit-to-cost ratio (B/C) and the associated internal rate of return (IRR) on CDC spending on plant breeding. The analysis is first provided on a prairie wide basis followed by capturing only the benefits within Saskatchewan. A further section provides some sensitivity analysis of the results.

## 4.1 Measured Increases in Yields Attributed to Plant Breeding

Measured increases in yields attributed to plant breeding activities are provided in Table 4.1. These values are based on the following[21]:

- Variety performance trial data is assembled for each of the crop kinds for the three provinces;
- All variety yields are indexed in relation to the crop kind check variety that was in place for the first year of analysis;
- An annual yield index for each province is developed based on each variety's acreage share in each year (see Figure 3.9 above for an example using spring wheat);
- The compound growth rate over the applicable time period is computed[22], which are the values reported in Table 4.1

Using barley as an example, the measured annual increase in yield attributed to breeding is 0.46% per annum in Alberta, 0.39% in Saskatchewan and 0.55% in Manitoba. Across the three provinces, the acreage weighted average is 0.47%.

***Table 4.1 Annual Increase in Yields Attributable to Plant Breeding***

| Crop Kind | Manitoba | Saskatchewan | Alberta | Prairie Average |
|---|---|---|---|---|
| **Lentils** | | 0.74% | | 0.74% |
| **Field peas** | | 1.99% | 0.19% | 1.47% |
| **Dry beans** | 2.62% | 0.29% | 0.44% | 2.07% |
| **Chick peas** | | 0.65% | | 0.65% |
| **Canaryseed** | | 0.26% | | 0.26% |
| **Flax** | 0.10% | 0.48% | 0.22% | 0.39% |
| **Oats** | 0.90% | 0.39% | 0.34% | 0.47% |
| **Barley** | 0.46% | 0.39% | 0.55% | 0.47% |
| **Winter wheat** | 0.26% | 0.45% | 0.02% | 0.28% |
| **All spring** | 0.52% | 0.46% | 0.40% | 0.45% |
| **Durum** | | 0.50% | 0.72% | 0.54% |

Note: The time frame for Saskatchewan crop yield increase is from 1991 to 2015, unless crop insurance data is not available in the early years due to minimal acreage. For Alberta the time frame is from 2000 to 2015 and for Manitoba from 2000 to 2015.

The values for Saskatchewan are the values reported in the prior Chapter, with the values for Manitoba and Alberta measured using the same methodology. Annual increases in crop yields were not captured for all crops in the other two provinces when the crop's share was under 10% of

[21] The methodology used to measure the annual increase in crop yields due to plant breeding is summarized in Annex E.

[22] The growth rate is based on averaging the yield index values first two years (e.g., 1991 and 1992) and the last two years (2014 and 2015) to average out any possible extremes in beginning and ending point values.

all prairie acreage[23]. Table 4.2 reports the acreage share over the 1991 to 2015 period for the crop kinds. For example, Manitoba accounted for only 2% of lentil acreage, and Alberta 3%, with 96% of the acreage in Saskatchewan.

***Table 4.2 Provincial Share of Seeded Acreage, 1991 to 2015 average***

| Crop Kind | Manitoba | Saskatchewan | Alberta |
|---|---|---|---|
| Lentils | 2% | 96% | 3% |
| Field peas | 5% | 72% | 24% |
| Dry beans | 75% | 0% | 25% |
| Chick peas | 0% | 92% | 8% |
| Canary seed | 6% | 92% | 1% |
| Flax | 26% | 70% | 4% |
| Oats | 20% | 48% | 32% |
| Barley | 10% | 40% | 50% |
| Winter wheat | 38% | 40% | 23% |
| All spring | 17% | 53% | 30% |
| Durum | 1% | 84% | 15% |

The fourth column in Table 4.1 provides an acreage weighted average across the prairie region. For example, the annual yield increase attributed to durum is 0.54% on average, based on the Alberta and Saskatchewan acreage shares. In our analysis, this value, which is a weighting of a 1991 to 2015 average is not used, but rather the actual acreage share in each year is used to capture the annual impact of plant breeding for each crop kind.

The analysis is guided by data availability. In constructing the acreage weighted yield indexes, data is available from 1991 onward for Saskatchewan for crop insurance data and since 1975 for performance trial data. Since crop insurance data on acreage by variety is required to create a yield index capturing benefits at the producer level due to plant breeding the analysis starts in 1991 for Saskatchewan. In Manitoba, crop insurance data indicating acreages of varieties planted is available for most crop kinds[24] beginning in 1983 and performance trial data in 2007. For Alberta, performance trial data is available starting in 2000 and crop insurance data in 2000.

## 4.2 Prairie-Wide Net Benefit of CDC's Plant Breeding Activities

The benefits of CDC plant breeding are summarized by two measures – the internal rate of return (IRR) and the benefit-to-cost ratio (B/C). Table 4.3 reports on the IRR measurement and Table 4.4 below on the B/C ratio.

**Benefits Based on the 1991 to 2015 Period Using IRR**

Across the full CDC plant breeding program, the IRR is 13.9% when all CDC costs since 1971 are considered with benefits measured over the 1991 to 2015 period (see the first row in Table 4.3). This value of 13.9% equates the net present value of all benefits equal to the net present value of costs incurred by the CDC. The present value of CDC spending on plant breeding equals the measured benefits with a discount (interest) rate of 13.9%.

[23] In some case, for these crops with minimal acreage, provincial data does not exist on either performance trial yields or crop insurance acreage.
[24] The exception is dry beans where Manitoba crop insurance data is first made available in 2007. As well, for winter wheat limited acreage data was available prior to 2007.

***Table 4.3 Internal Rate of Return on CDC Plant Breeding by Crop Kind, With Benefits Starting in 1991***

| | Prairies to 2015 | | Prairies to 2030 | |
|---|---|---|---|---|
| **Crop kind** | **since 1971** | **since 1981** | **since 1971** | **since 1981** |
| **Spring wheat** | 14.5% | 21.9% | **15.1%** | 22.3% |
| **Winter wheat** | 7.1% | 11.0% | **7.6%** | 11.4% |
| **Durum** | 7.5% | 13.4% | **9.3%** | 14.9% |
| **Barley** | 15.5% | 28.4% | **15.7%** | 28.5% |
| **Oats** | 10.1% | 13.7% | **11.2%** | 14.6% |
| **Lentils** | 22.8% | 34.1% | **23.2%** | 34.3% |
| **Chickpeas** | 6.6% | 9.6% | **8.4%** | 11.4% |
| **Field (dry) peas** | 15.1% | 23.7% | **15.9%** | 24.4% |
| **Dry beans** | < 0% | < 0% | **-2.0%** | -1.7% |
| **Canary seed** | 22.4% | 22.4% | **22.6%** | 22.6% |
| **Flax** | 11.6% | 16.9% | **12.3%** | 17.5% |
| **Combined** | **13.9%** | **21.9%** | **14.6%** | **22.3%** |

Since benefits are being measured starting in 1991, the second column in Table 4.3 shows the IRR when CDC costs begin 10 years prior (in 1981). This time span is used to capture a potential lead time between beginning a plant breeding program and when varieties are released to growers. With fewer costs attributed to plant breeding, the IRR increases to 21.9% across the CDC's plant breeding program.

## Methodology Used to Attribute Plant Breeding Benefits to the CDC

The IRR measure is based on a methodology that first captures the benefit of plant breeding across western Canada that can be attributed to all breeding organizations, including the CDC. For any crop kind in each province, the benefits are measured using provincial data on production and yield, with a series of calculations that measures what yields, production and price would have been had the increase in yields attributable to plant breeding not occurred (this is the counterfactual). These calculations account for any potential price impact that higher output would have on prices received, and direct producer costs associated with plant breeding are accounted for, which is a producer levy that is used to fund variety development.

The benefit of plant breeding is measured as the increase in producer surplus (in inflation adjusted dollars), which can be considered as a margin above costs. This methodology is described in Annex E, with Annex F providing details on measuring changes in producer surplus.

Once the overall benefit of plant breeding is measured in a province, the next step is to allocate the benefits to plant breeding organizations. This was done by using CDC acreage share data. This acreage share is the total of all CDC's varieties that are planted in a year in relation to all reported variety acreage. This information is captured through provincial crop insurance data. For example, if CDC varieties have 42% of barley acreage in a given year, then 42% of the aggregate benefit measured for barley for that year is allocated to the CDC.

These benefits are then contrasted with the CDC's annual spending on plant breeding (see Annex B), with the resulting CDC's IRR in Table 4.3 measured using the formula described in Annex A.

## Extending Benefits to 2030 Using IRR

The third column in Table 4.3 provides the IRR when costs are considered between 1971 (at the start of CDC operations) with measured benefits extending out to 2030. A number of CDC varieties are planted in 2015 with significant acreage shares. The benefit of these varieties will continue for a number of years without any further spending by the CDC on plant breeding. To account for these future benefits, the benefits attributed to the CDC in 2015 were used as a baseline for benefits that would occur over the following 15 years – to 2030. The 2015 benefit measure was reduced by 10% in each subsequent year to portray the decline in CDC variety share, with the 10% decay rate reflecting growers substituting newly released varieties by other breeding organizations. This annual decay in CDC acreage share resulted in 2030 values being 20% of the 2015 value. These projected annual benefits assume 2015 values for the average price received and yield prevails.

Overall the IRR is 14.6% with benefits out to 2030. This column in Table 4.3 is shaded in light green to illustrate that this time period is the time period most preferred by the study authors, as it reflects all costs incurred by the CDC and captures future benefits based on known expenditures

There is some variance in the IRR between crop kinds, as shown in third column in Table 4.3. The measured IRR to CDC's spring wheat program is 15.1% over the 1971 to 2030 period, which is higher than the oats value of 11.2%, and lower than the IRR associated with lentils of 23.2%.

All of the crop kinds indicate a positive IRR aside from dry beans. With dry beans, the IRR is negative, meaning that the present value of benefits is less than the present value of costs incurred[25].

The overall CDC plant breeding program has an IRR of 14.6% when benefits are extend to 2030. This indicates that for every dollar invested by the CDC on plant breeding activities, a 14.6% return was achieved. When only considering CDC costs beginning in 1981, the overall IRR increases to 22.3%.

## Benefit Cost Ratios

The other benefit measure is the B/C ratio. The B/C ratio discounts future benefits and adjusts past benefits and expenditures to account for the time value of money (see Annex A) and place all values in a 2015 context. The first column in Table 4.4 shows the present value of net benefits (benefits after accounting for CDC costs), with overall net benefits being just over $4.0 billion (in 2015 dollars), with the largest benefit being $1.0 billion to lentil producers. These net benefits expand to $6.9 billion and $2.0 billion, respectively, when benefits are considered out to 2030.

The associated prairie wide B/C ratio for CDC plant breeding is 11.5 when all CDC costs since 1971 are considered and benefits are extended to 2030 (see the second last row in Table 4.4). This value of 11.5 indicates that across the CDC's plant breeding program, each dollar of plant breeding expenditures provided $11.50 of benefit across the three prairie provinces.

As with the IRR, the B/C varies across crop kinds. The largest B/C ratio is for lentils at 48.7 when all CDC are considered and benefits are captured out to 2030. The means that for every dollar invested in lentil plant breeding by the CDC, producers benefited by $48.70 dollars.

The B/C ratio for dry beans is less than one at 0.3 over the 1991 to 2015 period. This arises since the net present value of costs allocated to dry beans of $21.3 million (or $10.4 million in 2015 dollars) with the net present value of benefits less at $6.7 million ($5.4 million in 2015 dollars)[26].

[25] In the following section, the associated B/C ratio is less than one, meaning the stream of discounted benefits is less than the stream of discounted costs.

***Table 4.4 Benefit-Cost Ratios for CDC Plant Breeding by Crop Kind, With Benefits Starting in 1991 (discount rate of 3.5%)***

| Crop kind | Prairies (Benefits 1991 to 2015) | | | Prairies (Benefits 1991 to 2030) | | |
|---|---|---|---|---|---|---|
| | Present Value of Net Benefits | B/C Ratio - Cost (1971 to 2015) | B/C Ratio - Cost (1981 to 2015) | Present Value of Net Benefits | B/C Ratio - Cost (1971 to 2015) | B/C Ratio - Cost (1981 to 2015) |
| **Spring wheat** | $674.5 | 6.8 | 8.7 | $1,135.2 | **10.8** | 13.8 |
| **Winter wheat** | $74.2 | 2.1 | 3.1 | $96.5 | **2.5** | 3.6 |
| **Durum** | $65.6 | 1.8 | 2.4 | $190.7 | **3.3** | 4.4 |
| **Barley** | $824.6 | 8.7 | 12.7 | $1,155.0 | **11.8** | 17.1 |
| **Oats** | $79.1 | 2.5 | 3.0 | $142.7 | **3.8** | 4.5 |
| **Lentils** | $1,051.0 | 26.7 | 33.7 | $1,954.6 | **48.7** | 53.2 |
| **Chickpeas** | $12.5 | 1.5 | 1.8 | $32.1 | **2.3** | 2.7 |
| **Field (dry) peas** | $1,002.9 | 14.4 | 19.8 | $1,840.9 | **25.6** | 35.2 |
| **Dry beans** | -$14.6 | 0.3 | 0.4 | -$11.2 | **0.5** | 0.6 |
| **Canary seed** | $27.4 | 6.6 | 6.6 | $38.9 | **9.0** | 9.0 |
| **Flax** | $203.0 | 4.1 | 5.2 | $330.9 | **6.0** | 7.7 |
| **Combined** | **$4,000.2** | **7.1** | **9.3** | **$6,906.1** | **11.5** | **15.0** |

The B/C ratio is a measure of the present value of benefits over the present value of costs (based on the 3.5% discount rate). A low B/C ratio can occur for a variety of reasons, such as:

- when costs are incurred early in the 1971 to 2030 time period relative to the distribution of benefits;
- When the annual increase attributable to plant breeding is low (e.g., winter wheat with an annual increase of 0.28% compared to 0.45% for all spring wheats);
- When total acreage is small (e.g., chickpeas with just over 100,000 tonnes compared to 10 million tonnes for barley);
- When the CDC has a low acreage share in a crop kind (e.g., dry beans at 2% compared to 84% for flax).

***Table 4.5 Comparing Benefit Results, 1991 to 2015***

| Crop kind | IRR | B/C | Annual Yield Increase | CDC Acreage Share | Average Production (M. t.) |
|---|---|---|---|---|---|
| **Spring wheat** | 14.5% | 6.8 | 0.45% | 14% | 18.8 |
| **Winter wheat** | 7.1% | 2.1 | 0.28% | 85% | 0.7 |
| **Durum** | 7.5% | 1.8 | 0.54% | 8% | 4.6 |
| **Barley** | 15.5% | 8.7 | 0.47% | 38% | 10.1 |
| **Oats** | 10.1% | 2.5 | 0.47% | 16% | 2.9 |
| **Lentils** | 22.8% | 26.7 | 0.74% | 99% | 1.0 |
| **Chickpeas** | 6.6% | 1.5 | 0.65% | 62% | 0.1 |
| **Field (dry) peas** | 15.1% | 14.4 | 1.47% | 62% | 2.3 |
| **Dry beans** | < 0% | 0.3 | 2.07% | 2% | 0.1 |
| **Canary seed** | 22.4% | 6.6 | 0.26% | 79% | 0.2 |
| **Flax** | 11.6% | 4.1 | 0.39% | 84% | 0.8 |

[26] Dividing 6.8 by 14.9 results in a B/C value of 0.45.

Table 4.5 above provides a comparison of IRR, B/C, annual yield increases, the average CDC benefit share (based on CDC acreage share over the 1991 to 2015 period), and average production (also over the 1991 to 2015 period).

The economic impact of the CDC will, in all probability, increase when the following conditions apply:

- The number of acres devoted to a crop increases due to the release of new varieties (compare spring wheat to winter wheat tonnage in Table 4.5);
- Yields of CDC varieties perform above average and/or are high performers in the variety trials (compare lentils to chickpeas in Table 4.5);
- The acreage share of CDC varieties increases relative to other plant breeding institutions (e.g., compare canary seed to dry beans (in Table 4.5).

Using oats as an example, if the CDC market share doubles, from the reported 16%, then benefits also double, with the result that the B/C ratio of 2.5 in Table 4.5 increases from 2.5 to 5.0. If at the same time oat production also increases from 2.9 million tonnes to 4.35 million tonnes (a 50% increase), the B/C ratio would also increase in the same proportion (since the cost structure has no changed), resulting in a further increase from 5.0 to 7.5, with $7.50 in benefits for every dollar of CDC expenditures on oats.

## 4.3 Saskatchewan's Net Benefit of CDC's Plant Breeding Activities

While the benefits attributable to CDC plant breeding extends across western Canada, an interesting perspective is to consider only producer benefits realized in Saskatchewan, with a comparison to all CDC plant breeding costs. Table 4.6 shows the associated B/C ratios when comparing costs since 1971 to benefits until 2015 (first column) and benefits to 2030 (third column of data). As well, the second and fourth columns only consider costs incurred after 1981. In all cases, the net present value of benefits exceeds the net present value of costs with a 3.5% discount rate.

***Table 4.6 Benefit-Cost Ratios for CDC Plant Breeding by Crop Kind, With Benefits Starting in 1991 (discount rate of 3.5%) - Only Saskatchewan Benefits***

| | Saskatchewan | | | |
|---|---|---|---|---|
| **Crop kind** | **Cost (1971 to 2015), Benefits (1991 to 2015)** | **Cost (1981 to 2015), Benefits (1991 to 2015)** | **Cost (1971 to 2015), Benefits (1991 to 2030)** | **Cost (1981 to 2015), Benefits (1991 to 2030)** |
| **Spring wheat** | 3.2 | 4.1 | 5.1 | 6.5 |
| **Winter wheat** | 1.2 | 1.7 | 1.4 | 2.1 |
| **Durum** | 1.3 | 1.7 | 2.4 | 3.2 |
| **Barley** | 3.2 | 4.7 | 4.1 | 6.0 |
| **Oats** | 1.3 | 1.5 | 2.1 | 2.5 |
| **Lentils** | 26.7 | 29.1 | 48.7 | 53.2 |
| **Chickpeas** | 1.5 | 1.8 | 2.3 | 2.7 |
| **Field (dry) peas** | 14.5 | 20.0 | 25.8 | 35.5 |
| **Canary seed** | 6.6 | 6.6 | 9.0 | 9.0 |
| **Flax** | 3.9 | 5.1 | 5.8 | 7.4 |
| **Combined** | **5.3** | **6.9** | **8.9** | **11.6** |

Note: The B/C ratio for dry beans was not measured within Saskatchewan.

Using the 1971 to 2030 period, the lowest B/C is 1.4 for winter wheat ($1.40 of producer benefit for every dollar of expenditure on winter wheat breeding) and increases to 48.7 for lentils ($48.70 of producer benefit for every $1.00 of lentil variety development). When Saskatchewan accounts for most of prairie production, the B/C ratios are comparable, if not identical to those reported above for all of the three prairie provinces.

When considering the full CDC plant breeding program, for every dollar expended Saskatchewan producers benefit by $8.90 (using costs beginning in 1971 and benefits over the 1991 to 2030 period. By way of comparison, the benefits are $11.50 when the other two provinces are incorporated into the benefit stream (see Table 4.4).

For this same time period (1971 to 2015 for costs and 1991 to 2030 for benefits) the IRR is 13.2% for the full CDC program in Saskatchewan (see third column in Table 4.7), which compares to a 14.6% IRR when all three provinces are considered (see Table 4.3)

***Table 4.7 Internal Rate of Return on CDC Plant Breeding by Crop Kind, With Benefits Starting in 1991- Only Saskatchewan Benefits***

| Crop kind | Cost (1971 to 2015), Benefits (1991 to 2015) | Cost (1981 to 2015), Benefits (1991 to 2015) | Cost (1971 to 2015), Benefits (1991 to 2030) | Cost (1981 to 2015), Benefits (1991 to 2030) |
|---|---|---|---|---|
| **Spring wheat** | 11.2% | 17.4% | 12.0% | 17.9% |
| **Winter wheat** | 4.4% | 7.3% | 5.2% | 8.1% |
| **Durum** | 5.5% | 10.1% | 7.8% | 12.3% |
| **Barley** | 10.6% | 20.0% | 11.0% | 20.2% |
| **Oats** | 5.2% | 7.1% | 7.6% | 9.6% |
| **Lentils** | 22.8% | 34.1% | 23.2% | 34.3% |
| **Chickpeas** | 6.6% | 9.6% | 8.4% | 11.4% |
| **Field (dry) peas** | 15.1% | 23.8% | 15.9% | 24.4% |
| **Canary seed** | 22.4% | 22.4% | 22.6% | 22.6% |
| **Flax** | 11.4% | 16.7% | 12.1% | 17.2% |
| **Combined** | **12.3%** | **18.9%** | **13.2%** | **19.6%** |

## 4.4 Sensitivity Analysis

The above measures indicate a range in benefit based on the time period used to consider costs and benefits. For example, as shown in the last row in Table 4.3, the IRR ranges from 13.9% to 22.3% for the overall CDC plant breeding program, and the associated B/C ratio ranges from 7.1 to 15.0 (Table 4.4). That is, the measured benefits are sensitive to the time period used to measure benefits and costs.

**Including the Cost Reducing Impact of Disease Resistance**

The above measures of CDC performance are based on yield improvement in released CDC varieties. Another benefit of variety development is disease resistance in some crop kinds. In the case of peas, where annual yield gains are measured at 1.99% per annum in Saskatchewan, another benefit is resistance to powdery mildew. The CDC has released 25 field pea varieties that are resistant to powdery mildew, with these varieties grown on 84% of Saskatchewan's acreage in 2015. This attribute is cost saving with producers not needing to incur a $15/acre cost for applying a fungicide. On the 3.0 million acres of field peas in western Canada using a CDC powdery mildew resistant variety, this is an annual cost saving of $45 million (in 2015).

Including this cost saving attribute supplied by CDC varieties as a benefit increases the producer surplus by the amount of cost savings. The IRR for field peas increases from 15.9% to 17.1% and the B/C ratio increases from 25.6 to 34.6 when including costs since 1971 and benefits considered out to 2030.

Since 2010, producers of hard spring wheat have been able to plant midge tolerant wheat varieties, where the tolerant varieties eliminate the need to use insecticide as a control method. The CDC has released two midge tolerant varieties (CDC Utmost and CDC Titanium) each with a midge tolerant gene. In 2015 across the prairies 1.3 million acres, which is 9.1% of hard spring wheat acreage, was produced using one of these two CDC varieties (in Saskatchewan it was higher at 15% of acreage). With a $15/acre cost saving of not having to use an insecticide (and potential quality/yield improvement) a $19.6 million cost saving was realized by prairie producers in 2015. Since introduction, the cost saving in the Prairies is $57 million (in 2015 dollars).

In addition to yield gains, this cost saving attribute, which also minimizes the risk of a quality downgrade, increases the IRR from 15.1% to 15.4%, and the B/C ratio is now 12.4 (compared to 10.8). The benefit to producers attributable to CDC spring wheat variety development efforts is $12.40 for every dollar of expenditure (when including this midge tolerance benefit).

**Offset CDC Costs with US Royalty Income**

There are other considerations that may impact on the results. For example, the CDC received $1.72 million in royalty payments since 2007 from seed sales into the US (which is $1.82 million in 2015 dollars). These payments can be considered an offset to costs incurred to provide benefits to Canadian growers. This revenue stream is small in relation to both overall benefits (of $3.9 billion in 2015 dollars) between 1991 and 2015 and CDC costs since inception (of $347 million in 2015 dollars). This royalty stream is 0.5% of CDC expenditures, and has essentially no impact on the IRR measure or the B/C ratio.

**Expenditures on Plant Breeding versus Variety Development**

The B/C ratio and IRR presented above reflect CDC's costs associated with variety development. Variety development activities includes: (1) a pre-breeding activity, which is discovery research, (2) breeding, and (3) finishing. Plant breeding can be limited to the last two activities. A portion of CDC's annual spending is on pre-breeding activities (e.g., genomics, trait and marker development, germplasm screening), and in recent years approximately 40% of annual expenditures is on this pre-breeding activity. If this level of expenditure occurred since 2000, the B/C ratio (when considering benefits out to 2030) increases from 11.5 to 13.6, as a result of the attributed lower expenditure. Pre-breeding activities support plant breeding and the results achieved by producers, and this sensitivity analysis shows the higher measured return if pre-breeding activities are not considered.

**More Price Response with Higher Output**

With higher output due to successful plant breeding, prices received can decrease, with the amount of decrease related to the price responsiveness of demand. For example, a less elastic demand curve (more price response to a given change in volume) can result in a lower measure of benefits. This arises due to a lower amount of producer surplus with a lower price received on the expanded volumes.

In the case of lentils, an export demand elasticity of -1.5 versus -5.0 reduces the B/C ratio from 48.7 to 42.8 (using the 1971 to 2030 period). The excess demand elasticity for spring wheat is modelled at -50 (highly elastic and a price taker), and when the assumption is made that price is affected by the volume of exports (such as a -1.0 elasticity), then the IRR declines from 15.1% to 12.0% and B/C ratio declines from 10.8 to 5.7. These results do not change the fact that the CDC plant breeding program is highly beneficial to prairie agriculture.

**A Higher Discount Rate**

The discount rate used in the analysis is 3.5%, which has an impact on the B/C ratio measure, since the B/C value is based on net present value of costs and benefits. Increasing the discount rate will affect the discounted values of benefits and costs. In the case of spring wheat, a discount rate of 5.0% (versus 3.5%) reduces the B/C ratio of 10.8 to 8.1. With a 5% discount rate, the analysis indicates that every $1.00 on spring wheat varietal development has an $8.10 benefit realized by spring wheat producers. For the full CDC program the B/C ratio changes from 11.5 to 8.6. The IRR of 14.6% is not affected by the discount rate.

**Operating Cost of Lowest Cost Producer – Intercept of Supply Curve**

One assumption used to estimate producer surplus is that the supply curve intersects the price axis at 60% of price in the factual case. This implies that operating costs for the lowest cost producer is on average 60% of the price received. Lowest cost producers could have an operating cost structure that is 70% of the average price. If this were the case, the change in producer surplus due to plant breeding would be slightly lower. Using spring wheat as an example, the IRR decreases from 15.1% to 14.7% (when using the 1971 to 2030 time frames), and the B/C ratio changes from 10.8 to 10.0.

**Producer Levy Funding Varietal Development**

The results presented deduct the producer levy costs from the gains in producer surplus due to plant breeding. Another measure of CDC benefits is to exclude producer levy costs. Excluding producer levy costs increases the B/C ratio from 7.1 to 7.3 and the IRR from 13.9% to 14.2% for all CDC plant breeding (when considering all CDC costs since 1971 and benefits to 2015). When benefits are extended to 2030 the B/C ratio increases from 11.5 to 11.8 and the IRR from 14.5% to 14.9%.

**Considering only Pulse Crops**

The CDC has been an integral component of the expansion of pulse crop production in Saskatchewan, with 41% of CDC expenditures over the last 10 years focused on pulse crops. When considering only CDC pulse crop expenditures and benefits to pulse crop producers, the B/C ratio is 24.2 (compared to 11.5 across the complete CDC plant breeding program) and the IRR is 17.2% (compared to 14.6%). These results are due to (1) very high CDC market share in varieties grown and (2) the annual yield improvement for pulse crops provided by newly released CDC varieties.

This Chapter indicates that the CDC plant breeding program has been beneficial to Saskatchewan agriculture and to the crop sector across western Canada. The economic impact is larger than the increased returns realized by crop producers; there is also increased economic activity in the prairie region due to the higher productivity.

# 5.0 Perspectives on the Economic Impact of the CDC

In this Chapter additional perspectives are provided on the economic impact of the CDC plant breeding program on producers and on the economy in the prairie region.

## 5.1 Economic Contribution of CDC Varieties to the Agricultural Economy

Over the 1991 to 2015 period, gross output attributable to CDC plant breeding activities increased by $6.4 billion (in 2015 dollars)[27]. This increased output contributes to increased economic activity through the agricultural economy in western Canada. This $6.4 billion is a cumulative impact, beginning in 1991, and in 2014 agricultural output was $742 million higher based on the yield gains attributable to plant breeding at the CDC since 1991 (see first column in Table 5.1). Referring back to Figure 2.1, this $742 million is the height of the green area for 2014, and the $6.4 billion is the value of the green area from 1991 to 2015[28].

This $742 million value for 2014 can be viewed as a stock of benefits that has been built up since 1991[29]. Over the 1991 to 2014 period, this additional farm output resulted is an increase in gross output in the overall economy of the three prairie provinces of $1.5 billion, as shown in the third row in Table 5.1[30].

***Table 5.1 Impact of CDC Plant Breading on the Prairie Economy***

| Item | Units | Output Increase in 2014 (cumulative from 1991) | Average Annual Impact |
|---|---|---|---|
| **Additional Agricultural Output** | *$ million* | **$741.8** | **$32.3** |
| Gross Output Multiplier | *$/$* | 2.0 | 2.0 |
| **Additional Economic Upstream Activity** | *$ million* | **$1,483.6** | **$64.5** |
| Value Added Multiplier | *$/$* | 0.9 | 0.9 |
| **GDP (Value Added) on the Prairies** | *$ million* | **$667.6** | **$29.0** |
| Labour Share of Value Added | *%* | 40% | 40% |
| Wages and Salaries | *$ million* | $267.0 | $11.6 |
| Average FTE Wages and Salary | *$* | $45,000 | $45,000 |
| **FTE Employment Impact** | *FTE jobs* | **5,934** | **258** |

This gross output of $1.5 billion is the additional transactions (economic activity) that occurred in the prairie economy arising from the additional crop output and the associated upstream expenditures by crop producers, and is based on a gross output multiplier of 2.0[31]. This economic activity

[27] This is 33.5% of the $19.1 billion of additional output arising from new varieties supplied by all breeding organizations, with 33.5% representing the CDC share of measured benefits.
[28] The combined green and hatched red area in Figure 2.1 represents the $19.1 billion attributable to all breeding organizations.
[29] The value to 2014 is used since the value per acre in 2015 was significantly higher than trend values due to some above trend prices for some pulse crops. Using 2014 values versus 2015 values provides a more conservative impact estimate.
[30] These economic impacts (in this section) are conservative estimates since the economic activity associated with larger output in downstream sectors such as grain processing and grain handling is not accounted for.
[31] Background information on the methodology and on the economic multipliers can be found in various economic impact studies. One such report is "*The Economic Impact of Agriculture in Canada: A Three Dimensional Perspective*" prepared for the Canadian Agri-Food Policy Institute by Econometric Research Limited (May 2005). This study had gross output multipliers ranging from 1.96 to 2.39 for the three prairie

captures the direct, indirect and induced expenditures arising from crop farmers' expenditures on farm inputs and on household expenditures.

Since 1991, value added (which is essentially GDP) increased by an estimated $668 million, which is based on a value added multiplier of 0.9. Typically the value of increased output, as it circulated through the economy, is retained as value added by various economic entities (as payments to labour and capital)[32]. Wages and salaries paid to labour is typically the largest part of value added, and a labour share of 40% is used[33], which indicates that over the 1991 to 2014 period an additional $267 million (in 2015 dollars) was paid to labour throughout the prairie economy due to the CDC's impact on higher crop output. With an average full time equivalent (FTE) annual salary of $45,000 throughout the prairie economy this results in 5,934 FTE jobs added since 1991.

The data in the first column in Table 5.1 is a stock value (based on the contribution of plant breeding since 1991). Of equal interest is the annual increase in economic activity due to annual productivity gains attributed to the CDC's plant breeding program. This is shown in the last column of Table 5.1, where each year the CDC's plant breeding program contributes the following to the prairie economy (through additional expenditures made by crop producers):

- $32.3 million in additional farm output and expenditures by producers;
- $64.5 million in additional prairie wide economic activity (gross output);
- $29.0 million in additional GDP;
- $11.6 million in payments to labour as wages and salary; and
- Expansion in the labour force by 258 FTE jobs each year.

## 5.2 Impact of CDC Varieties on Producer Profitability

The above indicates the increase in overall economic output and impact on economic activity that is attributed to the CDC's variety development program. A second measure of CDC impact is on producer profitability, which is a subset of the above. Changes in producer profitability are the benefits measured in Chapter 4.0 – which is captured through increases in producer surplus[34].

Over the 1991 to 2015 period, across the three prairie provinces, an additional $3.8 billion in producer profits can be attributed to CDC's variety development program. The first column in Table 5.2 shows the cumulative increase in producer profitability by crop kind. The largest increase in producer profits occurs in field peas ($949 million); followed by lentils ($932 million), barley ($670 million) and then spring wheat ($616 million). This $3.8 billion is the benefits (in 2015 dollars) used to compute the IRR, and after discounting the B/C ratios shown in the prior section.

In 2014, the increase in producer profitability is estimated at $412 million, with this 2014 value capturing all of the yield gains since 1991 – this is a cumulative impact. The last column shows the annual increase of $17.9 million in producer profitability flowing from the CDC's offering of new varieties into the marketplace (based on the cumulative impact in 2014 show in the prior column).

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provinces. These multipliers are only for economic activity within the province, and when trade between provinces is considered the gross economic multiplier is larger. The Canada wide multiplier for agriculture was estimated at 2.63, which suggests that using a multiplier for the prairie region of 2.0 is conservative.

[32] The above referenced study has a valued added multiplier ranging from 0.80 to 0.91 (of GDP in relation to the initial expenditure or output increase) for the three prairie provinces, with a Canada wide value of 1.14. If a multiplier was derived for the prairie region it would have been higher than any of these provincial values due to trade between the three provinces.

[33] The above referenced study had labour income range between 37% and 44% of value added.

[34] How Producer Surplus is measured is discussed in Annex F.

***Table 5.2 Impact of CDC Plant Breading on the Producer Profitability***

| Crop Kind | Cumulative Annual Increase in Profitability (1991 to 2015) | Higher Profitability in 2014 (Cumulative from 1991) | Average Annual Impact (1991 to 2014) |
|---|---|---|---|
| | | *$ million* | |
| spring wheat | $616.4 | $70.2 | $3.1 |
| durum | $116.4 | $19.3 | $0.8 |
| winter wheat | $114.3 | $7.8 | $0.3 |
| barley | $670.3 | $42.5 | $1.8 |
| oats | $102.6 | $11.3 | $0.5 |
| lentils | $931.9 | $111.0 | $4.8 |
| chick peas | $31.9 | $4.1 | $0.2 |
| field peas | $949.1 | $121.3 | $5.3 |
| dry beans | $5.4 | $0.4 | $0.0 |
| canary seed | $24.7 | $1.6 | $0.1 |
| flax | $209.6 | $22.1 | $1.0 |
| **Total benefits** | **$3,772.7** | **$411.6** | **$17.9** |

Each year lentil producers in western Canada capture an additional $4.8 million in profits that can be attributed back to the CDC's variety development program (see the last column in Table 5.2). The per annum profit impact varies from a minimal impact with dry beans (due to low acreage and low CDC market share) to $5.3 million captured by field pea growers. Outside of pulse crops, the largest annual profit impact is with spring wheat ($3.1 million), followed by barley ($1.8 million) and then flax ($1.0 million).

This $17.9 million per year of additional producer profit is part of the $29.0 million in annual GDP impact on the prairies (see Table 5.1) due to the CDC's plant breeding program.

## 5.3 Economic Value of New Crop Kinds and Classes Provided by the CDC

CDC plant breeding activities have helped create new markets and opportunities for crop producers with pulse crops a leading example. As shown in Figures 2.7 to 2.11, CDC varieties account for between 90% and 100% of most pulse crop varieties planted in Saskatchewan. Across the prairies pulse crops have grown from 2.0 million acres in the 1991 to 1995 period to an average of 6.9 million acres in the 2011 to 2015 period – an increase of 4.9 million acres (see the last row in Table 5.3). Pulse crops account for 11% of prairie wide crop acreage over the last 5 years. The largest growth in pulse acreage is dry peas (2.2 million acres) and lentils (2.2 million acres) as illustrated in the fourth column in Table 5.3, followed by canary seed (277,000 acres) and then chick peas (153,900 acres).

While overall acreage increased by 3.95 million acres, the fourth column in Table 5.3 suggests that these additional acres planted to pulse crops replaced acres planted to wheat (a 7.6 million acre decrease) and barley (a 3.6 million acre decrease). The last column shows each crop kind's share in the 3.95 million acre increase, with lentils and dry peas each accounting for 55% of the increase and the wheat decrease being -194% of the increase and barley -90%.

***Table 5.3 Prairie Acreage Shifts by Crop Kind, 2011-2015 compared to 1991-95***

| Crop Kind | 1991 to 1995 Average Acres | 2011 to 2015 Average Acres | 2011 to 2015 Acreage Share | Acreage Change | Share of Acreage Change |
|---|---|---|---|---|---|
| | *acres* | *acres* | *%* | *acres* | *%* |
| Barley | 9,236,000 | 5,672,000 | 9% | -3,564,000 | -90% |
| Beans, dry | 67,853 | 139,200 | 0% | 71,347 | 2% |
| Canary seed | 0 | 277,000 | 0% | 277,000 | 7% |
| Canola | 10,382,181 | 20,171,000 | 33% | 9,788,819 | 248% |
| Chick peas | 0 | 153,900 | 0% | 153,900 | 4% |
| Corn for grain | 58,529 | 288,000 | 0% | 229,471 | 6% |
| Corn, fodder | 39,785 | 153,600 | 0% | 113,815 | 3% |
| Flaxseed | 1,405,617 | 1,168,400 | 2% | -237,217 | -6% |
| Lentils | 764,306 | 2,938,955 | 5% | 2,174,649 | 55% |
| Mixed grains | 124,000 | 19,400 | 0% | -104,600 | -3% |
| Mustard seed | 491,185 | 364,300 | 1% | -126,885 | -3% |
| Oats | 2,558,000 | 2,173,000 | 4% | -385,000 | -10% |
| Peas, dry | 1,180,058 | 3,368,400 | 6% | 2,188,342 | 55% |
| Rye | 367,800 | 204,400 | 0% | -163,400 | -4% |
| Soybeans | 0 | 1,148,000 | 2% | 1,148,000 | 29% |
| Sugar beets | 59,294 | 23,000 | 0% | -36,294 | -1% |
| Sunflower seed | 0 | 73,400 | 0% | 73,400 | 2% |
| Triticale | 24,540 | 30,000 | 0% | 5,460 | 0% |
| Wheat, all | 29,914,732 | 22,261,800 | 37% | -7,652,932 | -194% |
| **Total** | **56,673,881** | **60,627,755** | **100%** | **3,953,874** | **100%** |
| **Pulse crops** | **2,012,217** | **6,877,455** | **11%** | **4,865,238** | **123%** |

Source: Statistics Canada, CANSIM, Table 001-0017

The economic value of this acreage shift into pulse crops can be measured by comparing the per acre gross revenues and producer profitability (or producer surplus) of pulse crops to those same measures for wheat and barley. Table 5.4 provides an estimate of the higher annual prairie wide gross revenues and producer profitability use to expanded pulse acreage, with such acreage coming out of wheat and barley plantings.

The top portion of Table 5.4 uses the increased acreage (as reported in Table 5.3) for pulse crops in the 2011 to 2015 period and uses the average per acre gross revenues and per acre producer profitability (margin over costs) to derive prairie wide revenues and profitability. For example, the 2.2 million additional lentil acres generated $814 million in annual revenues and $163 million in producer profits. Aggregated across the five pulse crops, the additional revenues are $1.7 billion and producer profits are $337 million.

The next portion of Table 5.4 provides comparable information for the wheat and barley acres that these pulse crops replaced, with 68% of the acres coming out of wheat. The higher per acre producer surplus for pulse crops (e.g., $75/acre for lentils) compared to wheat ($59/acre) illustrates the economic incentive at the farm level for moving some acreage into pulse crops.

***Table 5.4 Annual Revenue and Producer Profitability Impact Due to More Pulse Acres***

| Item | Change in Acreage | Per Acre Gross Revenue | Annual Revenue Impact | Per Acre Profitability | Annual Profitability Impact |
|---|---|---|---|---|---|
| | *acres* | *$/acre* | *$ million* | *$/acre* | *$ million* |
| Lentils | 2,174,649 | $374 | $814.4 | $75 | $162.9 |
| Field Peas | 2,188,342 | $302 | $659.9 | $60 | $132.0 |
| Dry beans | 71,347 | $796 | $56.8 | $159 | $11.4 |
| Chick pea | 153,900 | $515 | $79.3 | $103 | $15.9 |
| Canary seed | 277,000 | $270 | $74.7 | $54 | $14.9 |
| **Total** | **4,865,238** | | **$1,685** | | **$337** |
| Wheat | -3,308,362 | $293 | -$969.5 | $59 | -$193.9 |
| Barley | -1,556,876 | $271 | -$422.6 | $54 | -$84.5 |
| **Total** | **-4,865,238** | | **-$1,392** | | **-$278** |
| **Net Change** | **0** | | **$293** | | **$59** |

The net change is an additional $293 million in farm output and with $59 million of additional producer surplus (last row In Table 5.4). This higher level of output has ramifications throughout the prairie economy. Table 5.5 shows the economic contribution of the additional $293 million in crop output. Using the same economic impact multipliers as in Table 5.1, the higher output increases GDP by $264 million and requires another 2,344 jobs to support the economic activity of $586 million.

***Table 5.5 Economic Impact of More Pulse Acres***

| Item | Units | Impact of Pulse Crop Expansion |
|---|---|---|
| | | *$ million* |
| Additional Agricultural Output | *$ million* | $293.0 |
| Gross Output Multiplier | *$/$* | 2.0 |
| Additional Economic Upstream Activity | *$ million* | $585.9 |
| Value Added Multiplier | *$/$* | 0.9 |
| GDP (Value Added) on the Prairies | *$ million* | $263.7 |
| Labour Share of Value Added | *%* | 40% |
| Wages and Salaries | *$ million* | $105.5 |
| Average FTE Wages and Salary | *$* | $45,000 |
| FTE Employment Impact | *#* | 2,344 |

It should be noted that the above impact is a cumulative impact, which means that the economy does not benefit by another 2,344 jobs each year. Rather, this is the net effect over the 2011 to 2015 period when compared to the 1991 to 1995 period. With this time span being over 20 years, an annual value is just under 100 jobs and higher GDP of $10 to $12 million per annum[35].

[35] These economic contribution values are not additional to those values reported in section 4.0 or prior tables in section 5.0. These values highlight the positive contribution of CDC plant breeding through expanded acres of crop kinds that previously not grown on many acres in western Canada.

## 5.4 Comparing CDC Performance to Other Public Breeding Institutions

The performance of the CDC is impressive with an IRR of at least 14.6% and B/C ratios of at least 11.5 ($11.50 in return for every dollar invested) when compared to other published results for public plant breeding organizations. These CDC results are based on taking a conservative approach on any required assumptions.

**Return to Public Plant Breeding in Brazil (Embrapa)**
Embrapa is a public research institution in Brazil, and a recent study by Pardey *et al* [36] measured the benefits of their breeding program for edible beans, upland rice and soybeans. The B/C ratios were 20 for upland rice, 7 for edible beans and 60 for soybeans[37]. The rather large B/C ratio for soybeans reflects in part the large acreage base of Brazilian soybeans. If the contribution of other research institutions is factored in for developing the variety the B/C for upland rice is 10, with a B/C of 5 for edible beans and a B/C of 54 for soybeans. By way of comparison, the range of B/C found for crop kinds released by the CDC averaged out at 11.5, with an upper value of 48.7 for lentils.

**International Rice Research Institute's Contribution to Rice Yield Improvement**
The International Rice Research Institute was established in 1960 and is an independent non-profit organization which conducts agricultural research and provides training. The Institute collaborates with national agricultural researchers in the countries where rice is grown. The study assessed the impact of yield improvement in rice varieties in the Philippines, Indonesia, and Vietnam from 1985 to 2009. Yield gains over this time period averaged 11.2 % in these countries. The economic benefits associated with the institute's work on higher yielding rice resulted in an average annual economic benefit of $(US) 1.46 billion. The IRR was estimated to be 28%. The estimated B/C ratio was 21.7 while the NPV was $(US) 97 billion[38].

**CIMMYT's Contribution to Wheat Breeding**
CIMMYT, an international non-profit organization, conducts research and training in wheat and corn in less developed countries. Its germplasm is used extensively by public and private wheat breeders. This coupled with high acreage shares for CIMMYT derived varieties produced an estimated average benefit over the 1988 to 2002 period of between $0.5 billion to $1.5 billion (in US funds) under the most conservative germplasm attribution assumption (CIMMYT cross rule) to $1.3 billion to $3.9 billion under the least conservative germplasm assumption (any ancestor rule). With annual expenditures of $(US) 9 million to $(US) 11 million, the estimated B/C ratio ranged from 50:1 to 390:1.[39]

**University of Michigan Bean Breeding Research Returns**
The returns to public sector spending on bean breeding research at the University of Michigan[40] was found to have a B/C ratio of 1.3 over a specific time period and decreased to less than 1.0 when a longer time period was considered[41]. This implies that every expenditure dollar generated up to

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[36] Pardey, P.G., Alston, J.M., Chan-Kang, C.,Magalhaes, E.C., Vosti, S.A., 2006. *"International and institutional R&D spillovers: Attribution of benefits among sources for Brazil's new crop varieties"*. Am. J. Agric. Econ. (2006) 88(1), 104–123..
[37] These results are based on the last cross rule.
[38] Brennan J and A Malabayabas, "*International Rice Research Institute's Contribution to Rice Varietal Yield Improvement in South-East Asia*", Australian Centre for International Agricultural Research, 2011.
[39] Lantican M, H Dubin and M Morris, "*Impacts of International Wheat Breeding Research in the Developing World 1988 to 2002*", CIMMYT.
[40] Mywish K. Harediaa, Richard Bernsten, Catherine Ragasac, "*Returns to public sector plant breeding in the presence of spill-ins and private goods: the case of bean research in Michigan*" Agricultural Economics 41 (2010) pp: 425-442.
[41] This B/C ratio is based on the last cross rule, which is the approach used in this CDC study. If a geometric rule is considered, the B/C ratio increases to 4.6.

$1.30 in benefits. These B/C ratios are low for two reasons. One being the acreage base to which the plant breeding efforts apply, which decreased from 500,000 acres in the early 1980's to just over 200,000 acres in more recent times within Michigan. This acreage base limits the amount of benefit that can be captured. Secondly, the benefit calculation is only limited to Michigan production and does not account for benefits (the spillover effect) of Michigan State varieties planted in other growing regions.

## Benefits of the Soybean Breeding Program at the University of Guelph

A major paper by MBA students at the University of Guelph[42] assessed the benefits of the soybean breeding program in the Plant Science department over the 1980 to 1998 period. This study used yield gains observed through province wide results and the share of University of Guelph varieties based on certified acreage seed acreage, and then adjusted the benefits by 50% to account for the contribution of agronomics to yield gains. The net present value attributed to the soybean breeding program was $711 million over the period and a B/C ratio of 48.6.

## Review of University of Alberta Canola Breeding Program

A report was prepared in 2005 for the Alberta Crop Industry Development Fund[43] which reviewed the canola breeding program, with the authors noting that the University of Alberta indicated that the canola breeding program contributed $276 million to the Alberta economy. The report provided an estimate of annual impact if certain breeding objectives were achieved, such as yield enhancement, higher oil content, higher protein content and disease resistance. This report did not include benefit measures such as the B/C ratio or a return on the investment.

## Impact of Barley Breeding by Alberta's Field Crop Development Centre (FCDC)

This study estimated the economic return to investment in the FCDC's feed barley program by the Government of Alberta over the period 1973 to 2001. The program was three pronged: improve crop yield, improve silage yield, and improve disease resistance. The estimated IRR was 27%.[44]

## Saskatchewan's Agricultural Development Fund Investment in Crop Genetics

A 2005 review of Saskatchewan's Agricultural Development Fund (ADF) spending on crop genetic R&D by Scott et al[45] found that every dollar invested by ADF returned $3.43 in producer surplus (with an IRR of 17.8%) and $4.95 in combined producer and consumer surplus.[46]

## Return on Saskatchewan Pulse Growers Investment in Plant Breeding

Gray et al[47] examined the returns to the research funded by the Saskatchewan Pulse Growers through producer levies from 1984 to 2008. The IRR to producer expenditures was calculated to be approximately 40%. The B/C ratio for producers from genetic improvement research was 27.8 for the 1984 to 2024 period.

[42] Yvas, Sima and Wendy Zhang, "*Benefits of the Soybean Breeding Program at the University of Guelph from 1971 to 2001*", a major paper presented to the MBA Agribusiness Committee of the University of Guelph, (August 2002)

[43] BrassicaXCorp. Ltd and S.J. Campbell Investments Ltd, "*A Review and Assessment of the Canola Breeding Program at the University of Alberta*" (October 2005).

[44] Nagy J, "*Economic Returns to Feed Barley Yield Increasing and Disease Resistance Research at the Alberta Field Crop Development Centre*", Canadian Journal of Agricultural Economics, 2003.

[45] Scott T, H Furtan, A Guzel, and R Gray, "*Returns to Research, Agriculture Development Fund, Expenditures on Crop Genetics*", University of Saskatchewan, 2005.

[46] Gray R and S Malla, "*The Rate of Return to Agricultural Research in Canada*", CAIRN Policy Brief, October 2007.

[47] Gray R, C Nagy, V Galushko, and S Weseen, "*Returns to Pulse Crop Research & Development and the Management of Intellectual Property Rights*", December 2008.

## 5.5 Leveraging Investments in the CDC's and Economic Impact

The economic impact reported in section 4.0 shows that for every dollar invested in CDC variety development efforts, there are $11.50 in benefits realized by crop producers, and a 14.6% internal rate of return. Funding to the CDC comes from a variety of sources, including producer organizations, government and private companies. Leveraging of CDC funding by third parties provides significant benefits across the prairie economy. For example, if a producer organization contributes $1.0 million per annum over a five year period, and these funds are matched by one or two other parties, then the economic contribution of CDC's activities will be much larger.

The first column in Table 5.6 summarizes the economic impact associated with $1 million in CDC spending. With a B/C ratio of 11.5, producer benefits (as measured by producer surplus) are $11.5 million. Actual output is higher, by a factor of 1.69, which is based on the ratio of additional crop output associated with CDC plant breeding of $6.4 billion over the enhanced producer surplus of $3.7 billion. This farm output of $19.5 million results in additional economy wide gross output of $39 million, based on the 2.0 gross output multiplier. GDP increases by $17.6 million, based on the value added multiplier of 0.9, and payments to labour are $7.0 million (based on labour income being 40% of GDP). FTE employment increases by 156 person-years (based on higher output).

***Table 5.6 Economy Wide Impact of Investing in Plant Breeding at the CDC***

| Item | Units | No Matching | Matched by Co-Funders | Tripled by Co-Funders | 3 X Leverage Impact |
|---|---|---|---|---|---|
| CDC Expenditures | *$ million* | $1.00 | $2.00 | $3.00 | $2.0 |
| Benefit-to-Cost Ratio | *$/$* | 11.5 | 11.5 | 11.5 | |
| Producer Benefits | *$ million* | $11.5 | $23.1 | $34.6 | $23.1 |
| Increased Output per $ of Benefit | *$/$* | 1.69 | 1.69 | 1.69 | |
| Value of Additional Farm Output | *$ million* | $19.5 | $39.0 | $58.6 | $39.0 |
| Value of Gross Output | *$ million* | $39.0 | $78.1 | $117.1 | $78.1 |
| GDP Impact | *$ million* | $17.6 | $35.1 | $52.7 | $35.1 |
| Wages and Salaries | *$ million* | $7.0 | $14.1 | $21.1 | $14.1 |
| FTE Employment | *FTE jobs* | 156 | 312 | 468 | 312 |

The next column in Table 5.6 provides values when this $1 million is matched by a co-funder, such as another producer organization or a government granting agency. The third column shows values for when the other organizations leverage the initial $1 million to $3 million. The last column shows the impact of leveraging the $1 million into $3 million, with 312 jobs provided in western Canada and $35 million in additional GDP. The impact is not an annual impact; rather the impact is associated with the spending profile and occurs over a number of years.

Of interest, if government provided the additional $2 million, then all government tax take over a number of years would be in the range of $7.5 million – this is based on total taxes to all levels of government being approximately 9% to 10% of the economic activity in the economy[48]. Federal tax revenues are approximately 5% of gross output (economic activity), indicating that a $2 million investment in the CDC will generate at least $3.5 million in additional federal tax revenues; thereby suggesting that the federal government investment would bring in more tax dollars than invested in CDC plant breeding. This result arises from the productivity enhancing impact of variety development activities undertaken by the CDC.

[48] See the above footnote and the Econometric Research Limited report, "Agriculture in Canada"

# Annex A – Benefit Cost Analysis

Benefit cost analysis (BCA) is an approach where the benefits of a certain initiative, or change, are compared to the costs associated with that initiative or change. There is no standard approach; however there are a few principles that should be followed in any BCA.

### Some Basic Principles of Benefit Cost Analysis

There are a few basic **principles** that should be applied in BCA and those which may be applicable to an economic impact assessment of the CDC are discussed below[49].

The focus of BCA is on the ***impact of achieving an objective***, which requires that the ***objective needs to be clearly articulated***. In many CBA the objective is associated with future projects, such as building a bridge. In the case of the CDC the objective is clear, which is the economic impact of the CDC plant breeding program from inception in 1971 to the present.

Most BCA typically ***compare a few options that can be used to achieve the stated objectives***. This occurs when the BCA addresses future benefits and costs of projects. With the CDC, the focus is on expenditures and benefits that have occurred since inception. The counterfactual – of no CDC – is used to measure the impact of the CDC.

An ***adequate description of the current situation and current operating environment*** is required. Knowledge of the operating environment ensures that the counterfactual can be adequately incorporated.

The ***operating environment associated with each option*** needs to be clearly described. This is an important requirement when comparing options of how to achieve an end. In the case of assessing performance of CDC plant breeding there are no options to address, aside from the counterfactual.

The analysis should be based on ***incremental change*** from the existing situation, which becomes the baseline for analysis. The change from the current situation is the absence of the CDC, which is the counterfactual of no CDC.

Typically a range ***of costs and benefits need to be considered*** which result from the change of no CDC. Plant breeding programs can impact on input suppliers, grain producers, grain companies and users of grain. In this project, the focus is on grain and special crop producers in western Canada, with the benefits being the higher yields resulting from adoption of CDC varieties. As well, ***secondary benefits and costs may be important***. An example can be the secondary benefit of more overall economic activity in a province due to higher volumes of crop products being grown and marketed processed.

The ***benefits associated with each option should be compared to the costs of each option*** to allow for an assessment of which option, if any, is most preferred to the current situation. In this project we are comparing the costs incurred by the CDC to the benefits captured by producers using CDC released varieties.

[49] For interested readers, an often referred to book in the areas of cost benefit analysis associated with agricultural development is Gittinger, J. Price, *"Economic Analysis of Agricultural Projects*", Economic Development Institute, The World Bank, 1984. This book is written for analysis of development projects; however, a number of the concepts and illustrations apply to most analyses.

***Benefits can include additional returns, increases in production, quality improvements, and reduced costs***, while ***costs can include incremental increases in costs and a reduction in gross returns***. The benefits being captured with plant breeding is the increase in producer surplus due to higher yields, which are compared to the costs incurred at the CDC.

Benefits and costs should be measured in the ***same units of measurement***, typically using a monetary value. This allows for a direct comparison between all benefits with all associated costs. To the degree possible, a ***monetary value should be assigned to all non-monetary benefits and costs***. For this project all costs and benefits are captured in nominal values based on the year the costs (benefits) were incurred (realized). These nominal values are inflation adjusted to constant dollars (e.g., 2015 dollars).

Not all benefits and costs are tangible and measurable. There are some ***costs and benefits that are intangible and difficult, if not impossible, to quantify***. An example of such a benefit can be potentially more investment in seed development in Canada due to the spillovers associated with CDC plant breeding activities. In cases where the cost or benefit cannot be quantified, the benefit or cost should be identified and described.

The time value of money should be considered when benefits and costs occur in separate time periods. This implies that ***benefits and costs must be accounted for in each time period*** (typically a year), with appropriate discounting of future costs and benefits to assess the ***present value of costs and benefits***. This is referred to as the ***net present value (NPV)***[50]. This is particularly important in investment projects, where costs are typically incurred at the beginning with benefits accruing in the future. With plant breeding costs associated with a released variety are incurred over a seven to ten year period and the benefits accrue over a subsequent period that can last over 20 years. This project does not assess the BCA of any specific variety, but rather the overall CDC plant breeding program.

The annual net benefit is divided by an ***appropriate discount factor*** (this can be based on the cost of capital) to calculate the present value of the net benefit (benefits minus costs) for any year. The sum of these present values is the net present value (NPV).

***Costs and benefits to various stakeholders should remain identifiable*** to allow for an indication of advantages and disadvantages to various groups and stakeholders associated with a change. There are many participants along the supply chain, from plant breeding organizations, seed companies, producers, marketers, food processors and consumers. In this project our only focus is on costs incurred by the CDC and the benefits realized by producers. Benefits to users and consumers are not considered for this analysis.

***Avoid double counting*** of benefits or costs. An example of double counting can be increased sales revenues to producers due to a new variety and enhanced exports of the commodity. The net incremental impact must be considered in the analysis.

When ***uncertainty*** exists concerning a future outcome, this can be accounted for by placing probabilities on potential outcomes and then computing the ***expected value*** of the associated costs and benefits[51] (i.e., ***the expected net present value (ENPV***). For this project, a large part of the

[50] The NPV is the sum of annual values of the present value of benefits and costs, or the sum of the discounted value of net benefit in each year. In any year the discounted value is the annual net benefit divided by the applicable discount factor.
[51] This is computed by attaching probabilities to a range of plausible outcomes and then determining the expected value. (See also Annex I).

benefits realized over the 1991 to 2015 period and future benefits are subject to a decay factor to account for the assumption of no new variety releases after 2015.

In some cases, ***sensitivity analysis*** can be conducted to see how future outcome are affected by changes in assumptions on certain key parameters. These assumptions must be realistic and supported by industry. In this project, our sensitivity analysis is to compare benefits that end in 2015 to an outcome where existing CDC varieties continue to be used to 2030.

In situations when the incidence of costs and benefits is invariant with respect to time (benefits and costs are the same in each year (before or after inflation adjustment), then the ***analysis can be collapsed into a single year analysis***. This is due to the fact that the NPV will be a scalar of the net benefits in any year.

***There is no standard approach*** for each benefit cost analysis, however ***industry insight and input is required*** for a meaningful analysis. As noted in a Treasury Board[52] guide on cost benefit analysis, "*There is no 'cookbook' for benefit-cost analysis. Each analysis is different and demands careful and innovative thought. It is helpful, however, to have a standard sequence of steps to follow. This provides consistency from one analysis to another, which is useful to both the analysts doing the study and the managers reading the report.*
*Obviously, the ... "steps cannot be performed by the analyst in isolation and will require consultations with the decision-maker and others, the gathering of a wide variety of information, and the use of a number of analytical techniques. It is important that, as the analyst proceeds, the decision-maker is kept in touch with the form of the analysis and the assumptions being made".*
*- Treasury Board, Benefit-Cost Analysis Guide, 1976"*

### Calculating Benefit Cost Ratios and Internal Rate of Return

The following is an example to illustrate how a benefit-cost ratio (B/C) is calculated as well as the internal rate of return (IRR). The second column in Table A1 illustrates potential annual costs of a hypothetical plant breeding program over the 1995 to 2015 period. These costs are inflation adjusted and are represented as costs in 2015 dollars. The third column shows annual benefits to producers attributable to varieties released by the breeding organization. The fourth column shows annual net benefits, which are negative in the earlier period due to the breeding organization incurring costs and not having any varieties released into the marketplace. The sum of net benefits over the 1995 to 2015 timeframe is $1.1 billion.

These annual net benefits allow for computation of the IRR. The IRR is the discount rate (or interest rate) which results in a zero net present value. In other words, the discount rate in which the annual flow of costs is equivalent to the annual flow of benefits over the applicable time period. The IRR in this example is 82%. This discount rate of 82% results in the present value of the expenditures equaling the present value of the benefits over time.

To compute a B/C ratio, a discount rate of 3.5% is used (see the resulting annual discount factor in column five) to estimate the present value (PV) of these inflation adjusted costs (in column six) and the PV of benefits (column seven). The PV of costs and benefits is computed by dividing the inflation adjusted value (in columns 2 and 3) by the discount factor.

The discount factor accounts for the time value of money, and in any year using a discount rate "r" the discount factor is as follows (with a value of 0.6 in 2000):

Discount factor = $(1+r)^{\wedge\ (\text{year-2015})}$

[52] Treasury Board Secretariat, <u>*Benefit Cost Analysis Guide*</u>, DRAFT July 1998

***Table A1 Calculating the IRR and Benefit-Cost Ratio: An Example***

| Year | Costs | Benefits | Net Benefits | Discount factor (w/ 3.5% discount rate | Discounted Costs | Discounted Benefits | Discounted Net Benefits |
|---|---|---|---|---|---|---|---|
| | *$ million (2015 dollars)* | | | | *$ million (discounted 2015 dollars)* | | |
| 1995 | $0.5 | $0.0 | -$0.5 | 0.50 | $1.0 | $0.0 | -$1.0 |
| 1996 | $0.7 | $0.0 | -$0.7 | 0.52 | $1.3 | $0.0 | -$1.3 |
| 1997 | $1.0 | $0.5 | -$0.5 | 0.54 | $1.9 | $0.9 | -$0.9 |
| 1998 | $1.2 | $0.8 | -$0.4 | 0.56 | $2.2 | $1.4 | -$0.7 |
| 1999 | $1.5 | $2.0 | $0.5 | 0.58 | $2.6 | $3.5 | $0.9 |
| 2000 | $4.0 | $6.0 | $2.0 | 0.60 | $6.7 | $10.1 | $3.4 |
| 2001 | $6.0 | $10.0 | $4.0 | 0.62 | $9.7 | $16.2 | $6.5 |
| 2002 | $8.0 | $18.0 | $10.0 | 0.64 | $12.5 | $28.2 | $15.6 |
| 2003 | $10.0 | $28.0 | $18.0 | 0.66 | $15.1 | $42.3 | $27.2 |
| 2004 | $12.0 | $50.0 | $38.0 | 0.68 | $17.5 | $73.0 | $55.5 |
| 2005 | $14.0 | $78.0 | $64.0 | 0.71 | $19.7 | $110.0 | $90.3 |
| 2006 | $15.0 | $85.0 | $70.0 | 0.73 | $20.4 | $115.8 | $95.4 |
| 2007 | $16.0 | $92.0 | $76.0 | 0.76 | $21.1 | $121.1 | $100.1 |
| 2008 | $17.0 | $95.0 | $78.0 | 0.79 | $21.6 | $120.9 | $99.2 |
| 2009 | $18.0 | $105.0 | $87.0 | 0.81 | $22.1 | $129.1 | $106.9 |
| 2010 | $19.0 | $112.0 | $93.0 | 0.84 | $22.6 | $133.0 | $110.5 |
| 2011 | $20.0 | $115.0 | $95.0 | 0.87 | $23.0 | $132.0 | $109.0 |
| 2012 | $21.0 | $130.0 | $109.0 | 0.90 | $23.3 | $144.1 | $120.9 |
| 2013 | $21.5 | $145.0 | $123.5 | 0.93 | $23.0 | $155.3 | $132.3 |
| 2014 | $22.0 | $147.0 | $125.0 | 0.97 | $22.8 | $152.1 | $129.4 |
| 2015 | $22.5 | $155.0 | $132.5 | 1.00 | $22.5 | $155.0 | $132.5 |
| **Totals** | **$250.9** | **$1,374.3** | **$1,123.4** | | **$312.6** | **$1,644.1** | **$1,331.5** |
| **IRR** | | | **82%** | | | | |
| **PV Costs** | | | | | **$312.6** | | |
| **PV Benefits** | | | | | | **$1,644.1** | |
| **Benefit Cost Ratio** | | | | | | **5.3** | |
| **NPV** | | | | | | | **$1,331.5** |

The resulting PV of costs is $313 million, while the PV of benefits is $1,644 million. The net present value (NPV) is PV of benefits minus PV of costs, which is $1.3 billion over the 1995 to 2015 time period[53].

The ratio of the PV of benefits over the PV of costs is the benefit-cost ratio, or

B/C = PV Benefits/PV of Cost

In this example, the B/C is 5.3, which means that for every million dollars invested there are $5.3 million dollars in benefits. When the B/C ratio is 1.0, this implies the NPV =0 due to PV of benefits being equal to the PV of costs.

[53] This NPV equals zero when the discount factor is 82%.

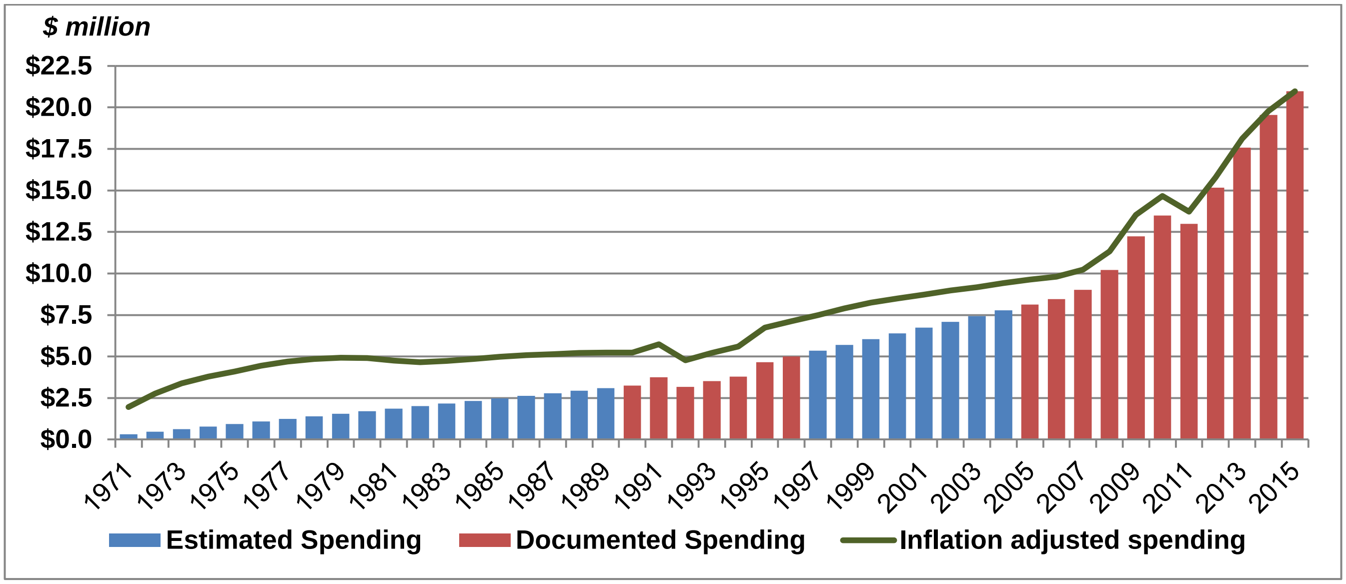
# Annex B – Annual Expenditures by the CDC on Plant Breeding

The CDC has transformed from a plant breeding entity with a $324,000 budget in 1971 to an organization in 2015 with 9 breeders and 2 pathologists and annual expenditures of $20 million.

## CDC Expenditures on Plant Breeding

Over the 45 year period CDC expenditures are estimated to total $257 million, which translates into $348 million in constant 2015 dollars. Figure 2.2 of this report is reproduced below as (Figure B1) which shows the progression in CDC spending on plant breeding in nominal and in real (2015) dollars.

***Figure B1 CDC Expenditures on Plant Breeding, 1971 to 2015***




Over the prior 11 years (FY 2005/06 to 2015/16) total CDC spending on plant breeding was $154 million in constant 2015 dollars ( $145.2 million of nominal dollars), which accounts for 44% of CDC expenditures over the 45 years since inception. Very accurate data on spending by crop kind is available over this eleven year period; the distribution of expenditures by crop kind over this period is provided in chapter 2.0 in Figure 2.3.

## Estimated CDC Plant Breeding and Research Expenditures by Crop Kind

Prior to 2005, accurate information was not obtained on plant breeding by crop kind, aside from some expenditure data reported in the 1990 to 1996 Annual Reports for some of the cop kinds. A methodology was used to estimate spending by crop kind which relied on information supplied on the number of CDC plant breeders in each year and the focus of these breeders. For example, in a year when there were 7 plant breeders and 1 breeder focused on flax, then flax is allocated 14.3% (1÷7) of the annual expenditures. As well, over the 1996 to 2004 period the distribution of spending was a spline of the plant breeder focus and the three year average over the 2005 to 2007 period; with a 90:10 weighting of the three year average and the breeder focus in 2004 which reduced to a 10% weight of the 2005 to 2007 average and 90% on the breeder focus in 1996.

The resulting distribution of CDC spending on plant breeding is illustrated in Figure B2, with spring wheat accounting for 17% of the inflation adjusted spending.

***Figure B2 Distribution of Estimated CDC Expenditures on Plant Breeding by Crop Kind, (2015 dollars), 1971 to 2015***

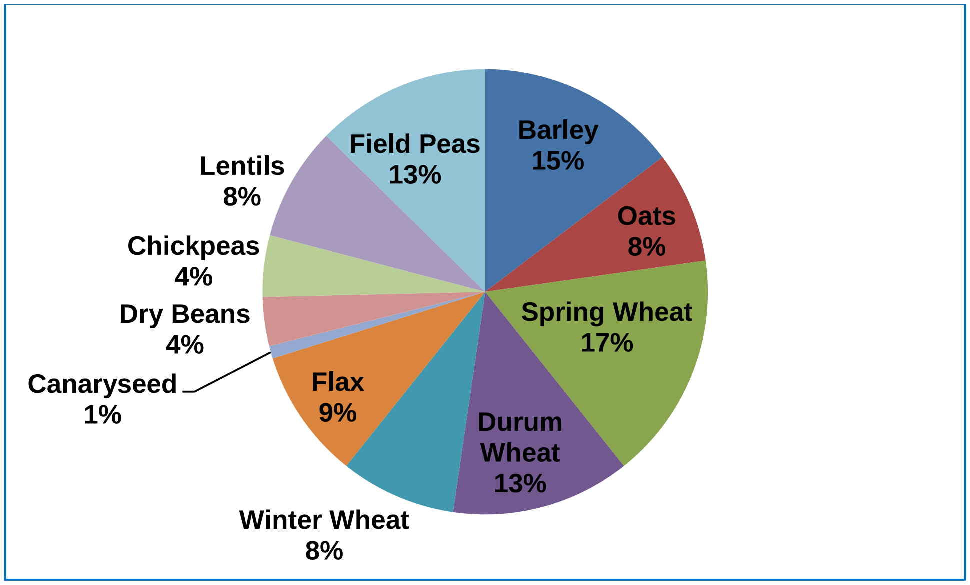



Table B1 shows the nominal and inflation adjusted funds expended by crop kind over the 45 year period. In 2015 dollars the highest spending was on spring wheat at $57.5 million (17% of the total), followed by barley at $51 million. The fewest funds were spent on canary seed, with the first canary seed variety released in 1983.

***Table B1 Estimated CDC Expenditures on Plant Breeding by Crop Kind, (2015 dollars), 1971 to 2015***

| Crop Kind | Nominal Dollars | 2015 Dollars |
|---|---|---|
| Barley | $34.8 | $51.0 |
| Oats | $21.2 | $28.2 |
| Spring Wheat | $40.7 | $57.5 |
| Durum Wheat | $34.1 | $45.3 |
| Winter Wheat | $18.6 | $29.2 |
| Flax | $23.2 | $32.9 |
| Canaryseed | $2.6 | $3.2 |
| Dry Beans | $9.6 | $12.4 |
| Chickpeas | $12.8 | $15.5 |
| Lentils | $24.8 | $28.7 |
| Field Peas | $34.6 | $44.0 |
| **CDC Total** | **$257.1** | **$347.8** |

These spending levels will be used to calculate the benefit-to-cost ratio and the internal rate of return (IRR) associated with CDC plant breeding activities.

## Royalties Captured by the CDC

The CDC has also captured royalties on its varieties, with some royalty revenues arising from CDC varieties sold into the US market, such as northern tier states with growing conditions similar to those on the prairies. Over the 1982 to 2015 period, the CDC has earned $26.8 million in royalty revenues, for an average of $788,000 per annum (in nominal dollars). Table B2 shows the distribution of these funds by crop kind (and selected classes for wheat). Across all wheat classes, a total of $8 million in royalties was collected by the CDC over this time frame, which accounts for 30% of all royalties captured since 1982.

***Table B2 Royalties Captured by CDC on CDC Varieties, 1982 to 2015***

| Crop Kind | Royalties | Distribution |
|---|---|---|
| Barley, Feed | $1,909,215 | 7.1% |
| Barley, Malt | $3,565,960 | 13.3% |
| Canaryseed | $125,478 | 0.5% |
| Chickpea | $278,125 | 1.0% |
| Fababean | $6,920 | 0.0% |
| Flax | $2,002,225 | 7.5% |
| Lentil | $1,952,398 | 7.3% |
| Oats | $1,295,336 | 4.8% |
| Field Peas | $877,047 | 3.3% |
| Wheat, Winter | $2,025,993 | 7.6% |
| Wheat, Spring | $5,065,566 | 18.9% |
| Wheat, Durum | $907,483 | 3.4% |
| Wheat, Spelt | $11,198 | 0.0% |
| Others, no longer identified | $6,760,207 | 25.2% |
| **Total** | **$26,783,726** | **100.0%** |

A portion of the $26.8 million in royalties collected by the CDC is shared with selected funding partners (e.g., the WGRF, private companies). For example, in the 2015 crop year the CDC collected $2.88 million in royalties and distributed just under $0.4 million to these selected funding partners. The remaining funds are used to support CDC breeding programs, with a portion (35%) allocated across all breeding programs, with the remainder accessible to each plant breeder in proportion to the royalties received for the crop kind.

The majority of these royalties are from CDC varieties grown within western Canada, with just over $1.7 million in royalty income on seed sales into the US market over the 2007 to 2015 time frame, which is 6.3% of all royalty income.

Table B3 summarizes the royalty income captured outside of Canada, by crop kind over the 2007 to 2015 period. All of the CDC's chickpea royalties are from the US and 93% of field pea royalty income is from the US market.

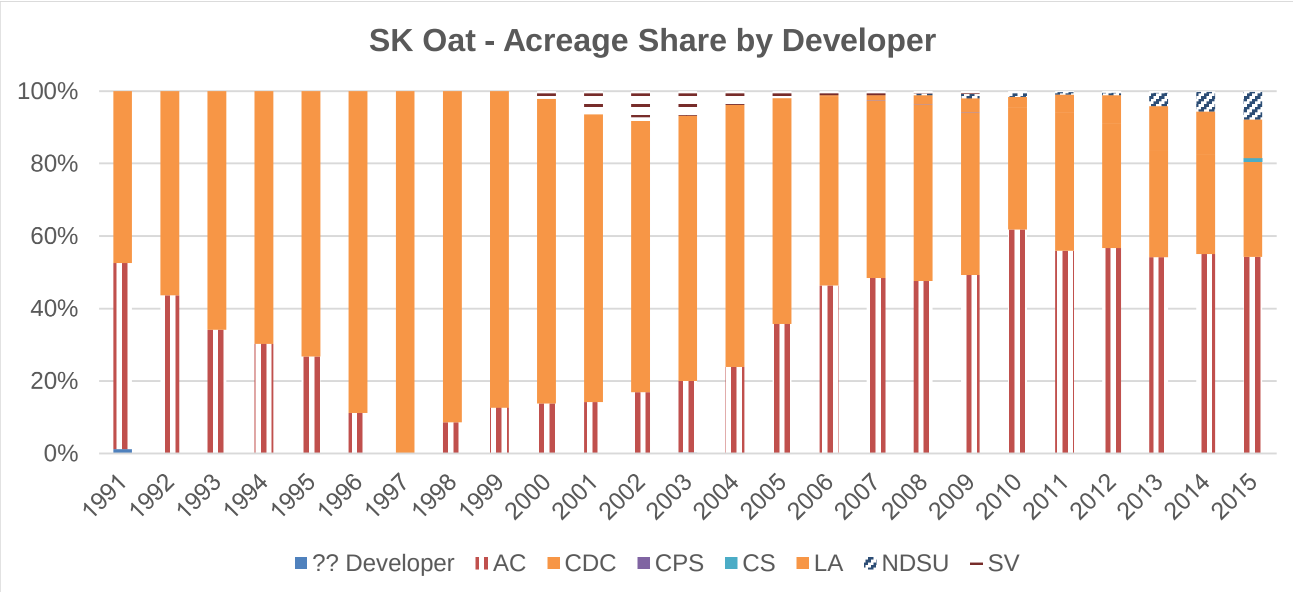
***Table B3 CDC Royalties in CDC Variety Sales into the US Market, 2007 to 2015***

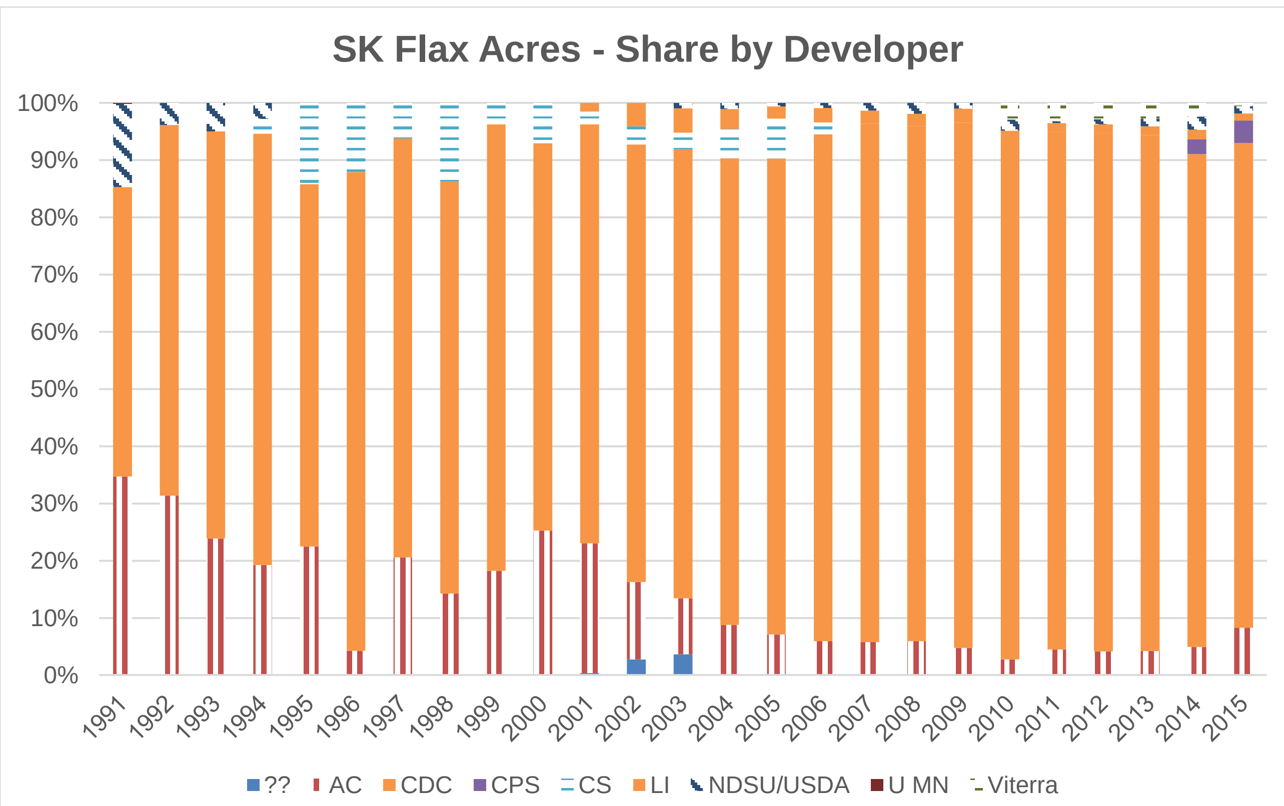
| Year | Crop Kind | | | | | | Totals |
|---|---|---|---|---|---|---|---|
| | Feed barley | Malt barley | Chick-pea | Lentil | Field Pea | Winter wheat | |
| **2007** | $4,660 | $11,597 | | $3,078 | $155,406 | $42,986 | **$217,727** |
| **2008** | | $36,002 | $1,836 | $13,950 | $94,329 | | **$146,117** |
| **2009** | | $538 | $7,337 | $12,335 | $139,664 | $20,777 | **$180,651** |
| **2010** | | $60 | $5,580 | $32,799 | $121,477 | | **$159,916** |
| **2011** | | $93 | $20,428 | $4,528 | $45,216 | $48,199 | **$118,464** |
| **2012** | | $11,823 | $109,789 | $101,008 | | $11,288 | **$233,908** |
| **2013** | | $8,267 | $47,761 | $34,429 | | | **$90,457** |
| **2014** | | $126,329 | $53,517 | $20,712 | $261,224 | $5,917 | **$467,699** |
| **2015** | | $17,338 | $31,877 | $51,421 | | | **$100,636** |
| **Total** | **$4,660** | **$212,047** | **$278,125** | **$274,260** | **$817,316** | **$129,167** | **$1,715,575** |

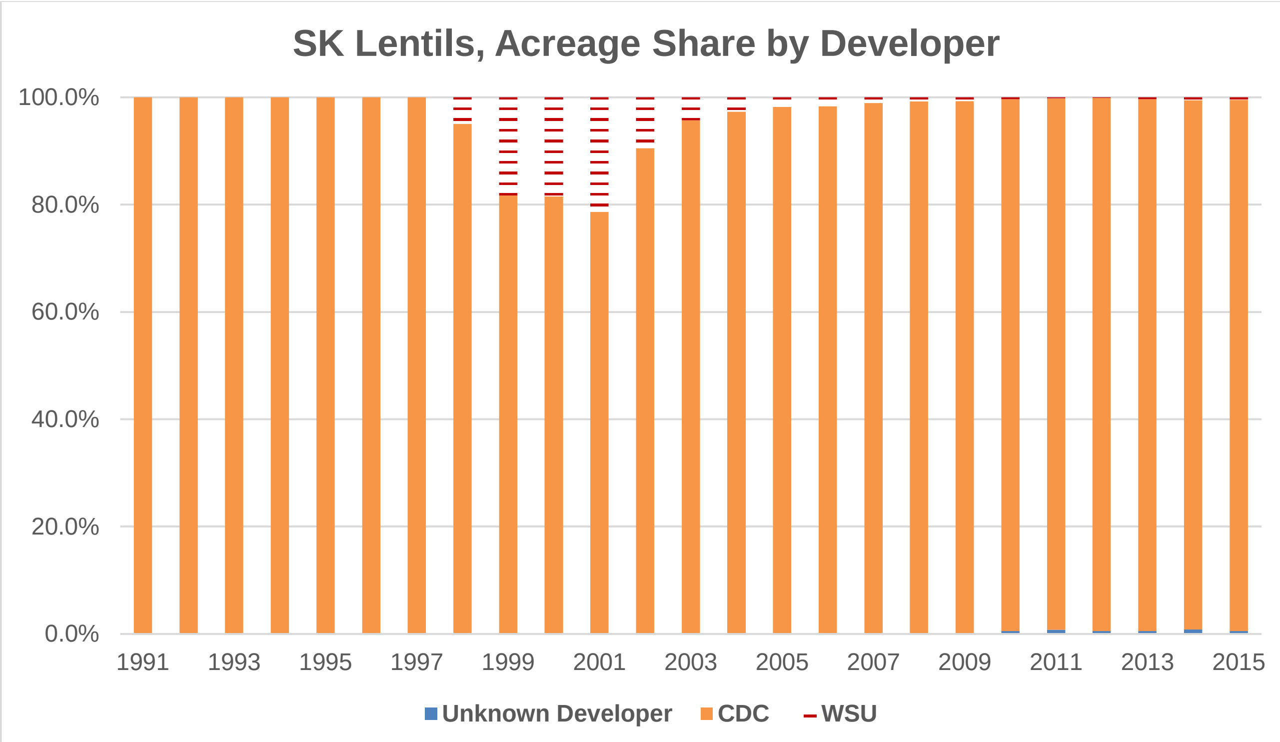
This non-Canadian royalty income will be deducted from CDC expenditures by crop kind to have the net cost incurred by the CDC on CDC plant breeding benefiting the crops sector in western Canada. That is the above royalty income can be viewed as offsetting costs incurred to develop varieties for prairie agriculture.

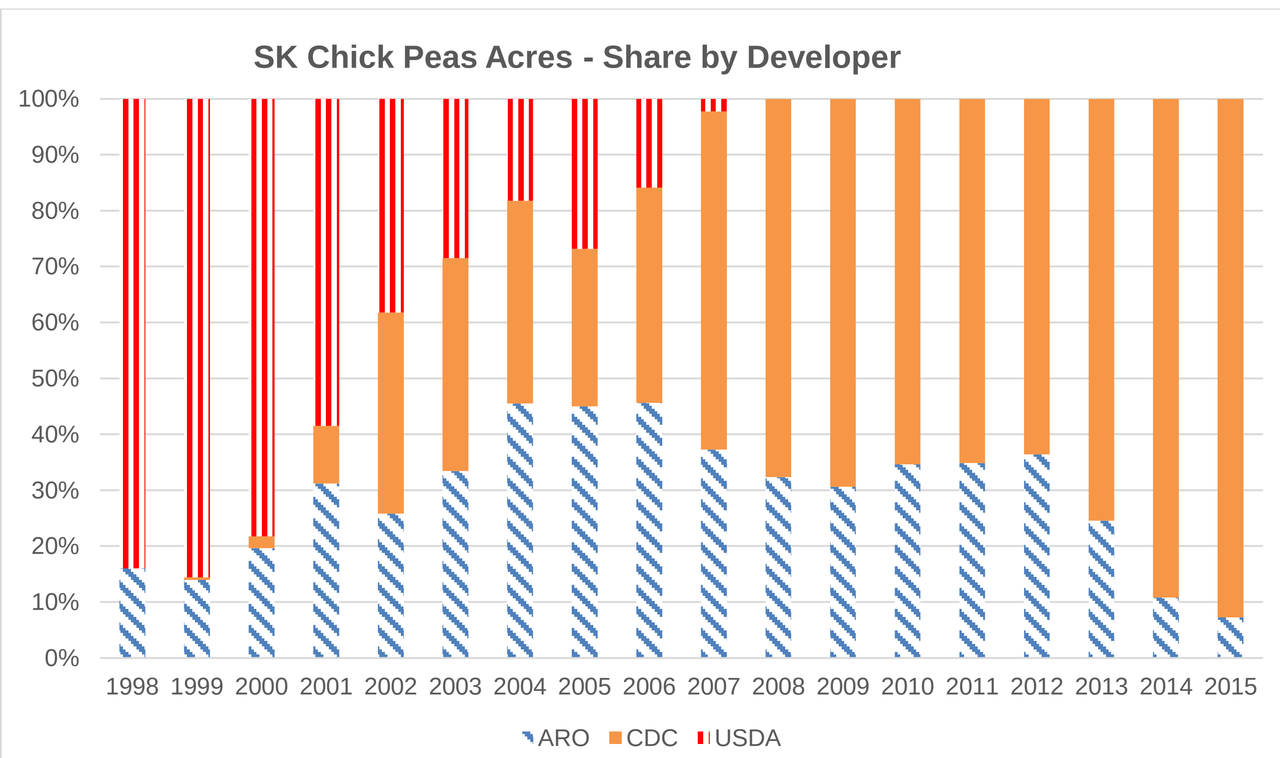
# Annex C – Acreage Share by Product Developer

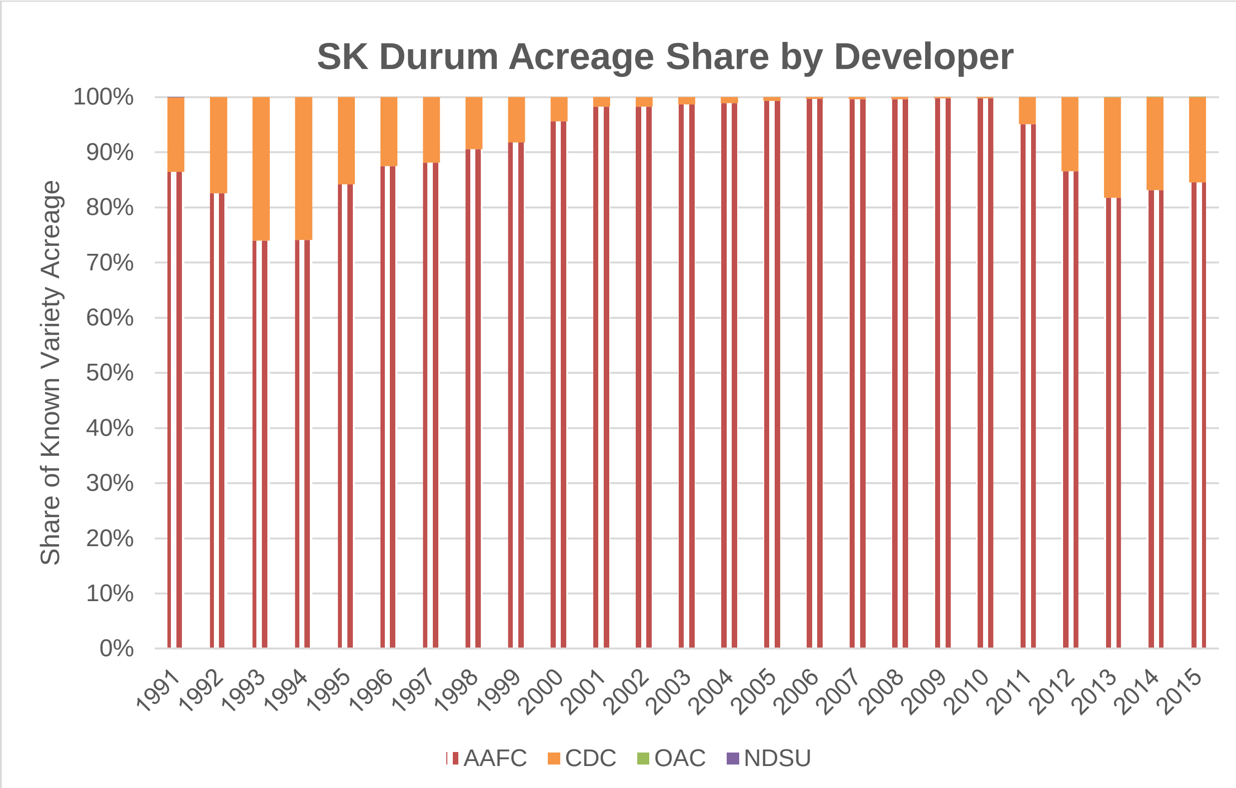
In this Annex the acreage share by product developer is graphically illustrated for Saskatchewan acreage. This data is based on crop insurance data. In some crop kinds the CDC has a significant market share, such as in flax, lentils, chickpeas, barley and winter wheat. A crop kind where CDC has low market share is durum.




SK Lentils, Acreage Share by Developer
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Unknown Developer
CDC
WSU


SK Chick Peas Acres - Share by Developer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
ARO
CDC
USDA


SK Durum Acreage Share by Developer
Share of Known Variety Acreage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
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2005
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2007
2008
2009
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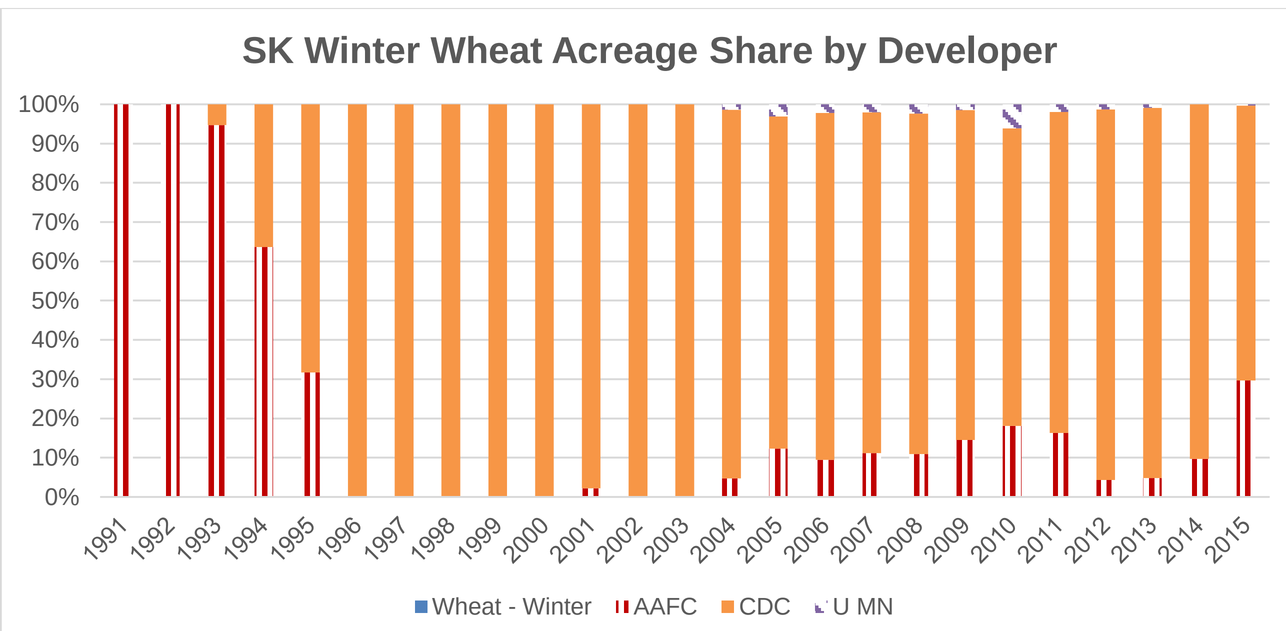
2012
2013
2014
2015
AAFC
CDC
OAC
NDSU


SK Winter Wheat Acreage Share by Developer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
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2013
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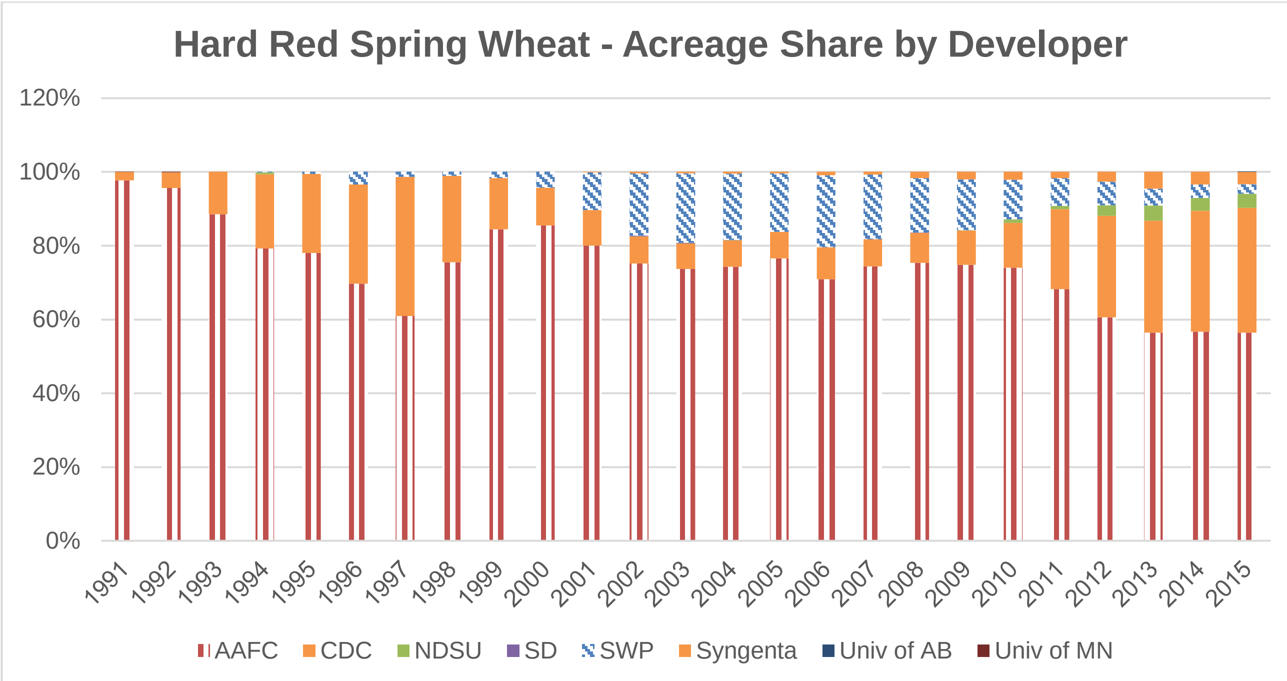
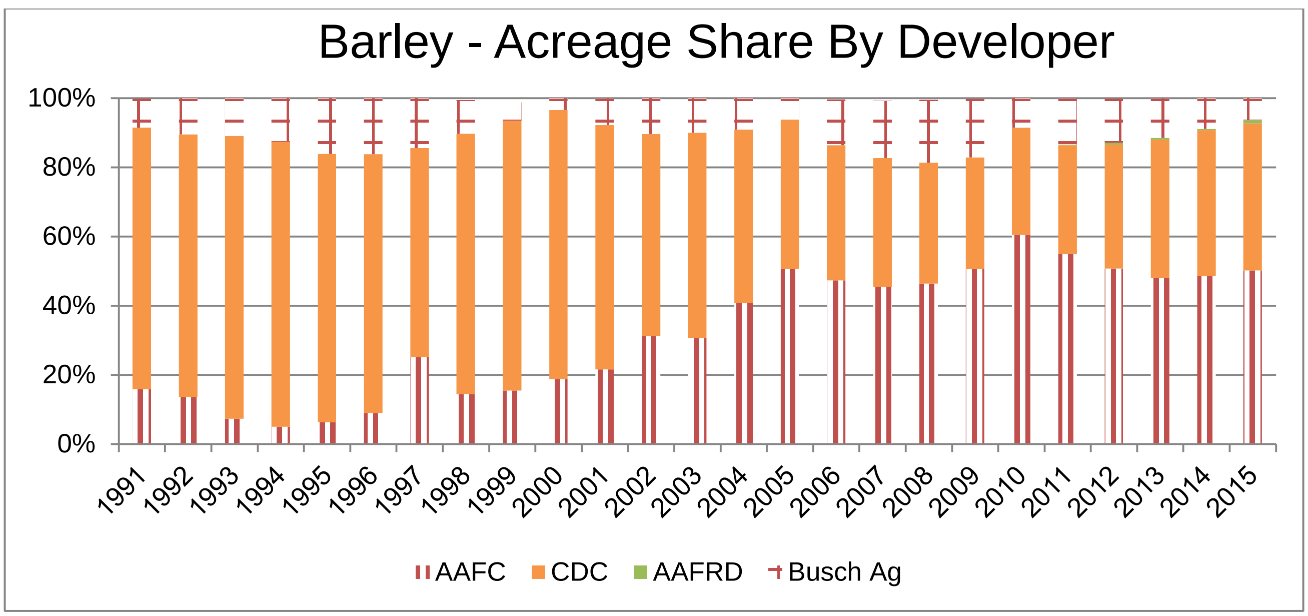
2015
Wheat - Winter
AAFC
CDC
U MN


Hard Red Spring Wheat - Acreage Share by Developer
120%
100%
80%
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
AAFC
CDC
NDSU
SD
SWP
Syngenta
Univ of AB
Univ of MN


Barley - Acreage Share By Developer
100%
80%
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
AAFC
CDC
AAFRD
Busch Ag

# Annex D – Assumptions and Data Sources

## Assumptions

The following are ***assumptions used to estimate the benefits of plant breeding attributable to the CDC***:

1. The factual begins with measuring the benefits of all plant breeding activities in western Canada, with the associated counterfactual based on no plant breeding activities over the time period considered;
2. The benefit of the CDC is based on first measuring the impact of all plant breeding efforts and then allocating a share of the overall plant breeding benefits to the CDC based on market share of CDC varieties planted;
3. The factual is the measured percentage increase in yields based on performance trial data and the counterfactual is the measured yield in the base year of analysis (and no increase in yields attributable to variety development; however, in the counterfactual yields can increase due to improved agronomics, etc.);
4. The share of overall benefits of plant breeding that are attributable to the CDC plant breeding activities are proportional to the CDC's acreage share (based on CDC varieties seeded);
5. The net impact of spillovers are considered to be small, with spill-ins into the CDC from other institutions of genetic material and knowhow equal to spill outs from the CDC to other breeders;
6. Acreage share of CDC varieties as captured by crop insurance data (with most crop kinds having insured acres equal to or exceeding 70% of seeded acres) are highly representative of the acreage shares of CDC varieties for all seeded acres of a crop kind;
7. Producer surplus measures the benefit of plant breeding;
8. Higher yields attributable to plant breeding do not require higher levels of other inputs, with any higher level of inputs captured prior to observing the yield associated with the check varieties;
9. Improved disease resistance of varieties is captured through the associated impact on yields;
10. For crops where Canada is a major supplier into the export market, the increase in exportable supply due to plant breeding and its impact on prices received need to be accounted for;
11. Producer surplus is the higher gross revenue that are not offset by higher input costs;
12. The last year a variety was in a performance trial is and its yield relative to a check variety is most indicative of its yield potential, with the last entry being an accumulation of results from current year and prior year performance trials;
13. For the period 1991 to 1999 when CDC variety share is not available for Alberta and Manitoba, the share is imputed based on increasing the CDC share from 0% in 1991 (in equal increments) to the share measured for 2000;
14. The benefit cost analysis for the period ending in 2030 only captures additional benefits based on the CDC varieties in the market in 2015. These varieties are assumed to have a 10% annual decay (market share and benefits drops by 10% each year after 2016) and the future benefits based on 2015 values are discounted using a discount rate of 3.5%. (This underestimates the benefits for recently released varieties because they are not fully adopted);
15. The overall CDC program is being assessed and accounting for the time period between CDC expenditures and benefits attributable to individual CDC varieties is not required;
16. Royalty revenues captured by the CDC on CDC varieties used outside of Canada can offset costs incurred to develop varieties for producers in western Canada.

## Data Sources Used to Measure Yield increases Attributable to Plant Breeding

A number of data sources are used to measure the benefit of plant breeding for a crop kind. Yields by variety are captured using variety performance trail data for each of the provinces. In Saskatchewan, the "SaskSeed Guide" is produced by the Saskatchewan Variety Performance Group and the Saskatchewan Advisory Council on Grain Crops. Representatives are from the following groups: Saskatchewan Ministry of Agriculture, seed companies, Saskatchewan Seed Growers Association, producer organizations, AAFC, Crop Development Centre, University of

Saskatchewan, and Saskatchewan Crop Insurance Corporation.[54] Data is available from 1991 onward.

Variety trials in Manitoba are coordinated by the Manitoba Crop Variety Evaluation Team which has members from the following organizations: Manitoba Seed Growers Association, Canada Seed Trade Association, Manitoba Pulse Growers Association, University of Manitoba, Manitoba Agriculture, Food & Rural Initiatives, and AAFC. The results are published in "Seed Manitoba". Financial support is provided by Manitoba Agriculture, Food and Rural Development, Manitoba Cooperator, Manitoba Seed Growers Association, producer organizations, and seed companies[55].

In Alberta, the Alberta/British Columbia Grain Advisory Committee and Alberta Agriculture and Forestry coordinates the Alberta Regional Variety Testing program for cereals and oilseeds. The Alberta Regional Variety Testing program for pulses is coordinated by the Alberta Pulse Growers Commission and Alberta Agriculture and Forestry. Testing in Alberta is funded by Alberta Agriculture and Forestry, the Alberta Seed Growers' Association, Alberta Seed Processors, Alberta Pulse Growers Commission, AAFC, and seed companies. [56] Variety performance results are published in the "Alberta Seed Guide".[57]

Acreage shares by variety are estimated using seeded acres by crop variety as published by each of the provincial crop insurance agencies: the Saskatchewan Crop Insurance Corporation, the Manitoba Agricultural Services Corporation, and the Agricultural Financial Services Corporation in Alberta. For most crop kinds, over 70% of seeded acreage is insured and our methodology is based on these insured acres being representative of all acreage planted by the many varieties for each crop kind. This variety specific acreage allows us to create an acreage weighted index of crop yields (based on varieties planted).

[54] http://www.saskseed.ca/images/varieties2016.pdf
[55] http://www.seedmb.ca/about/
[56] http://seed.ab.ca/variety-trials/cereals/
[57] http://seed.ab.ca/variety-trials/cereals/

# Annex E –Estimating Yield increases and Benefits to Producers

The following are the various sequential steps taken to estimate the yield increases and the resulting benefits to producers due to CDC plant breeding and release of spring wheat varieties into the western Canada market place.

### Starting Date for Yield Increase Analysis

1. The starting date is 1991, based on data availability on crop acreage by variety using crop insurance data and variety performance trial data. For Saskatchewan, both are available starting in 1991. For Manitoba, the earliest that performance trial data could be assembled was 2007 and crop insurance data starting in 2000 was used. For Alberta, performance trial and crop insurance data beginning in 2000 was made available for this project.

### Determining Significant Varieties to Estimate Yearly Yield Indexes

2. The performance trial check varieties for the time period under consideration were determined for the relevant time period crop insurance data is available. In the case of spring wheat in Saskatchewan this includes Katepwa, AC Barrie and Carberry in Saskatchewan.
3. The crop insurance data which shows acreage by variety is reviewed to pick out (1) the check varieties, (2) varieties that had at least a 3% acreage share in one year, From this data set, CDC varieties are identified;

### The Yield Index and Scalar Adjustment for Years with New Check Varieties

4. For each province (of Alberta, Manitoba and Saskatchewan) an acreage weighted yield index is calculated for each year based on variety specific yields as captured through performance trial data and variety acreage shares as captured through crop insurance data. This calculation creates an annual series of yield indexes (e.g., see Figure 3.1);
5. In each province a provincial agronomic specialist was used to help determine which performance trial district is used which will create a consistent yield index series over the applicable time period, such as area 1 and 2 for spring wheat in Saskatchewan. In Alberta and Manitoba provincial averages were used.
6. The check variety in the beginning year has an assigned index of 100 for the complete time period;
7. When a new check variety is introduced a scalar adjustment factor is developed, which is the ratio of the new check variety index (of 100) over the index of the old check variety in the last year an index is provided for the former check variety. For Saskatchewan this is 1.0417 for indexing variety yields in the 2000 to 2014 period when AC Barrie replaced Katepwa, and 1.108156 (1.0417 x 1.0638) for indexing yields in 2015 when Carberry replaced AC Barrie;

### Developing an Annual Yield Index

8. Using the varieties selected above the most recent yield index and the year for each variety is captured from the performance trial data;
9. In Saskatchewan, in the case of spring wheat, for varieties with the last yield index in 1999 or earlier the published index is used for all years – for varieties with the last published yield index in the 2000 to 2014 period, the published yield index is adjusted using the scalar noted above (or 1.0417) and used for all of the years, and for varieties with a published yield index in 2015 the value is adjusted upwards by (1.108156) and used for all of the years. The result is a vector of yields by variety. A comparable methodology was used in the other two provinces.
10. Crop insurance acreage data for the significant varieties is used to develop an annual variety acreage share;
11. The yield index by variety is multiplied by its yearly acreage share in each province, which is then summed across the varieties to obtain a variety acreage weighted provincial yield index (e.g., with a value of 109.5 in 2010);

12. The annual increase in yields in the factual case is the annual percentage year over year growth in the acreage weighted yield index. The annual increase is based on averaging the yield index for the first two years (e.g., 1991 and 1992) and the last two years (2014 and 2015) to minimize the potential impact of extreme beginning and ending data points, with the annual increase calculated using the compound growth formula. This is labeled as labeled as $K^{SK}$ for Saskatchewan, $K^{AB}$ for Alberta and $K^{MN}$ for Manitoba;
13. The counterfactual is represented by the acreage weighted yield index for the first year of analysis; in other words the annual percentage increase attributed to plant breeding does not occur.
14. The prairie wide yield index ($K^{PR}$) for any year is the weighted average across the provinces, based on total acreage in each year for spring wheat in each province. The value of $K^{PR}$ in any year is the % increase in the supply offering (i.e., the shift in the supply curve - % $\Delta$ S);

### Estimating any Price Impact Due to a Larger Supply Offering

15. For each year, prices as captured by AAFC, along with the aggregate production ($Q_0$ at the provincial and prairie wide level) as reported by Statistics Canada is used, and a value of production (VOP) is calculated;
16. The potential price impact of additional supply due to prairie wide $K^{PR}$ (or % $\Delta$ S) is calculated using the formula % $\triangle$Ps = %$\triangle$S/[Ed – Es], where the values of Ed and Es are -50 and 0.5 for spring wheat, for example. The price impact with the supply shift in any year is estimated using $P_0$ *(1+% $\triangle$Ps) = $P_1$. This price impact applies at the provincial level and at the prairie wide level.

### Determining the Change in Producer Surplus

17. Compute the associated yearly producer surplus due to plant breeding, which is the yield gain (K) multiplied by the average yield for the year, which is then multiplied by the crop year average price for the crop kind and accounts for the acreage for the year (with these values on yield, acreage, and price as reported by Statistics Canada[58]). Annex F has additional detail on the methodology used to calculate producer surplus to account for adjustments such as any impact of higher volumes on prices received. This producer surplus can be calculated on a provincial basis as required, such as in the case of Saskatchewan.
18. The producer surplus for each year in the factual case is determined based on having the supply curve intercept at 60% of $P_0$ with the producer surplus ($PS_0$) measured as [ 0.4 x $P_0$ x $Q_0$/2];
19. The producer surplus for each year in the counterfactual case is determined based on having the supply curve intercept at 60% of $P_0$ adjusted for the %$\triangle$S with the producer surplus $PS_1$ measured as [ ($P_1$ – {(1- %$\triangle$S) x 0.4 x $P_0$)} x $Q_1$/2];
20. The increase in producer surplus in any year due to plant breeding in all breeding organizations is the difference between $PS_0$ and $PS_1$, defined as $\Delta$ PS for each year
21. This change in producer surplus, which is the benefit to producers of plant breeding is calculated at the provincial level or at the Prairie wide level;

### Attributing Benefits to the CDC

22. The variety acreage share information is used to develop an annual aggregated CDC acreage share within each province;
23. The annual benefits due to plant breeding by the CDC (CDC Benefits) is estimated by taking the CDC acreage share in each year (based on crop insurance data) and multiplying this CDC share by the annual change in producer surplus. This computation is conducted at the provincial level and summed to capture the prairie wide level CDC impact;

[58] If Statistics Canada does not report price, yield or acreage, values as reported by each provincial government will be used.

### Transforming Nominal Values into Current (2015) Values

24. The annual CDC Benefits (at the provincial and at the prairie wide level) are in nominal dollars and are adjusted into constant 2015 dollar values using the CPI for Canada. These inflation adjusted CDC Benefits are used in a subsequent calculation to estimate the internal rate of return (IRR);

### Correcting for the Time Value of Money to Compute Benefit-Cost Ratios

25. The inflation adjusted CDC Benefits are modified to reflect the time value of money using a discount rate of 3.5%, with 2015 as the reference point. A 2005 CDC Benefit will be $(1.035)^{10}$ (or 1.4106) larger than the inflation adjusted value. The formula of $(1.035)^{(2015-\text{ actual year})}$ results in project benefits beyond 2015 being discounted such as in 2020 the discount factor is 0.8420. This same discount value will apply to CDC annual expenditures to estimate the benefit cost ratio.

### Benefit cost analysis for the period ending in 2015

26. The above annual benefits are expressed in constant dollars (e.g., 2015 dollars) using an CPI inflation adjustment;
27. Annual CDC expenditures are captured by crop kind; and for years where expenditures are only at an aggregate basis, allocate expenditures to crop kinds based on the crop kind focus of the CDC plant breeders in each of those years;
28. Nominal expenditure dollars are inflation adjusted (constant dollars) using the same inflation indices as employed for inflation adjusting benefits;
29. Benefits and costs which can occur in different time periods (costs incurred for a variety during development and finishing and benefits realized by producers can occur 10 to 20 years after these costs are incurred) are adjusted by a discount rate (at 3.5%) to reflect the time value of money.
30. A benefit cost ratio is computed for each crop kind using data from the applicable starting date to 2015, with the benefits being the sum of annual (inflation adjusted benefits) and the costs being the sum of annual expenditures;
31. An internal rate of return (IRR) is calculated, where the value of expenditure equals the value of benefits;

### Benefit cost analysis for the period ending in 2030

32. For each crop 2015 benefits are used for 2016 with inflation adjusted benefits reduced per annum after 2016 (to 2013) with lower benefits reflecting a 10% reduction in CDC acreage share;
33. Future benefits are discounted using a discount rate to reflect the time value of money;

### Economic value of new markets based on new crop kinds and classes released by the CDC

34. The economic value of new crop kinds and/or classes based on release of CDC varieties is based on the increase in producer surplus created by these varieties. The additional producer surplus is based on measures of crop acreage that declined as crop acreage for these new crop kinds (or classes increased). The producer surplus of, for example, fewer barley acres that were switched into pulse crop acres is compared to the producer surplus of the pulse crop acreage.

## Spill-ins and Spill-outs in Western Canada

As noted by Pardey et al[59], there are cases when the germplasm provided by another institution is considered and some of the benefit provided by that institution is attributed back to that institution (e.g., AAFC or another university) – the "spill-in".

Spillovers occur in plant breeding, where for example, germplasm developed by the CDC is shared with other organizations which results in the other organization using the CDC genetics as parent to a new variety. This spillover we can refer to as a spill-out. Similarly, a CDC variety could be based have parentage of genetics received from another breeding organization on the prairies such as AAFC. This is an example of a spill-in.

Attribution of benefits to the CDC can be based on a few rules, which are:

1. CDC cross rule, which allows for full (100%) attribution for any variety which CDC has released;
2. CDC cross (rule # 1) and/or CDC parent rule for any variety planted in western Canada, which gives a 50% attribution weight to a CDC parent (and 100% to a CDC cross);
3. Geometric rule which assigns declining weights based on whether the CDC variety is a CDC cross, a CDC parent, or a CDC grandparent;
4. CDC ancestor rule that gives full attribution to any variety that has some CDC variety parentage].

Employing only the CDC cross rule (rule # 1) requires only information on CDC released varieties. Using rule # 1 (CDC cross) does not directly account for spillovers – whether as spill-ins supporting CDC genetics or spill-outs to other varieties of CDC genetics. This assumes spill-ins are comparable to spill-outs.

Rule # 2 requires information on parentage of CDC and non-CDC varieties planted – namely whether a CDC variety (non-CDC variety) is a parent and associated acreage and yield of the non-CDC variety (CDC variety). Rule # 3 (geometric weighting based on lineage) requires significant information on all varieties planted in western Canada. Comparable information is required for rule # 4 (CDC ancestory). Rules 2, 3, and 4 are not used given the current project scope.

For this project, all benefits of a variety that the CDC released are attributed to the CDC. Using this rule (CDC cross rule) does not require a large data search on the genetic material in a CDC variety for such spill-ins. It also precludes any spillovers which would occur if the CDC's genetic material was used to produce non-CDC varieties by AAFC, other universities, and private seed companies.

[59] See for example Pardey, P.G., Alston, J.M., Chan-Kang, C.,Magalhaes, E.C., Vosti, S.A., 2006. *"International and institutional R&D spillovers: Attribution of benefits among sources for Brazil's new crop varieties"*. Am. J. Agric. Econ. (2006) 88(1), 104–123 where the benefits of plant breeding were attribute to Embrapa. This approach was also used for Michigan State university bean breeding program in Mywish K. Marediaa, Richard Bernsten, Catherine Ragasac, "*Returns to public sector plant breeding in the presence of spill-ins and private goods: the case of bean research in Michigan*" Agricultural Economics 41 (2010) pp: 425–442

## Comparisons of Methodology

In this report our methodology for assessing benefits follows an approach used by Marediaa *et al* and Pardey *et al* [60], where the overall benefit of plant breeding in a sector or crop kind is first assessed, and then a portion of overall benefit is attributed to a breeding institution based on the acreage share of varieties released by that institution.

This approach is not exactly the same as the one used on pulses in western Canada or on varietal development funded by the WGRF. In these latter assessments, the overall approach does not begin with the benefit of all breeding programs, but rather measures the impact of varieties released by a program and/or funded by an external organization. The yield enhancement of this program is measured in relation to the overall sector (or crop kind output); where for example the counterfactual is the lower output volume, due to lower yields, attributable to certain varieties not being released into the market place.

While the general approach is not the same, both approaches are valid and provide evidence on the economic impact of plant breeding programs.

[60] See for example Pardey, P.G., Alston, J.M., Chan-Kang, C.,Magalhaes, E.C., Vosti, S.A., 2006. *"International and institutional R&D spillovers: Attribution of benefits among sources for Brazil's new crop varieties"*. Am. J. Agric. Econ. (2006) 88(1), 104–123 where the benefits of plant breeding were attribute to Embrapa. This approach was also used for Michigan State university bean breeding program in Mywish K. Marediaa, Richard Bernsten, Catherine Ragasac, "*Returns to public sector plant breeding in the presence of spill-ins and private goods: the case of bean research in Michigan*" Agricultural Economics 41 (2010) pp: 425–442

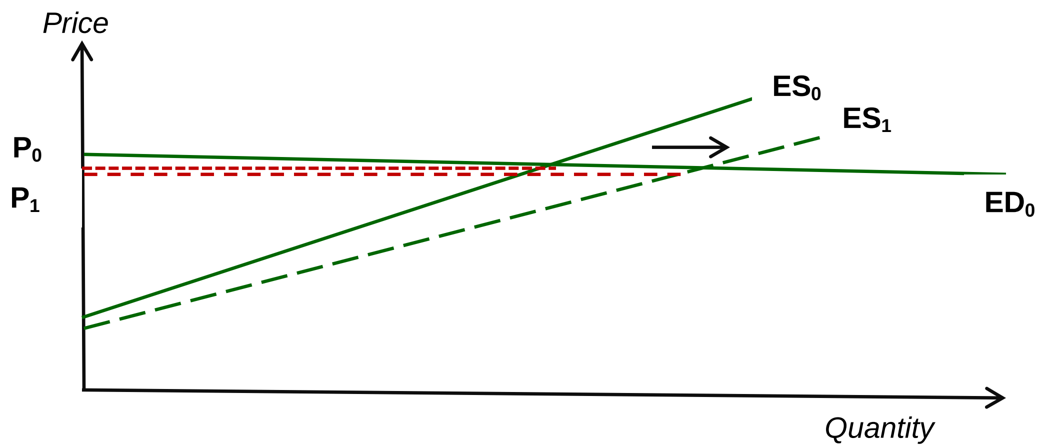
# Annex F – Increases in Supply and Impact on Producer Surplus

## Additional Supply May Have an Impact on Prices Received

For some crop kinds, an increase in Canadian supply can have an impact on price received (e.g., in the case of durum) and for other crop kinds (e.g., chick peas and feed barley) an increase in supply will likely have no material impact on prices received. The price impact depends on the nature of the demand curve facing the sector, with a highly elastic demand resulting in a negligible price impact when supply increases (as associated with improved varieties). A highly elastic demand means that as more volume is consumed price there is a minimal price impact[61].

Figure F1 is an example of a highly elastic demand curve. With a highly elastic export demand there is a minimal price impact with an increase in exportable supplies - from **$ES_0$** to **$ES_1$**. With a highly elastic demand curve facing Canadian exports the price impact is very small with a price change from **$P_0$** to **$P_1$**.

***Figure F1 Price Impact with an Increase in Supply – with a Highly Elastic Demand***



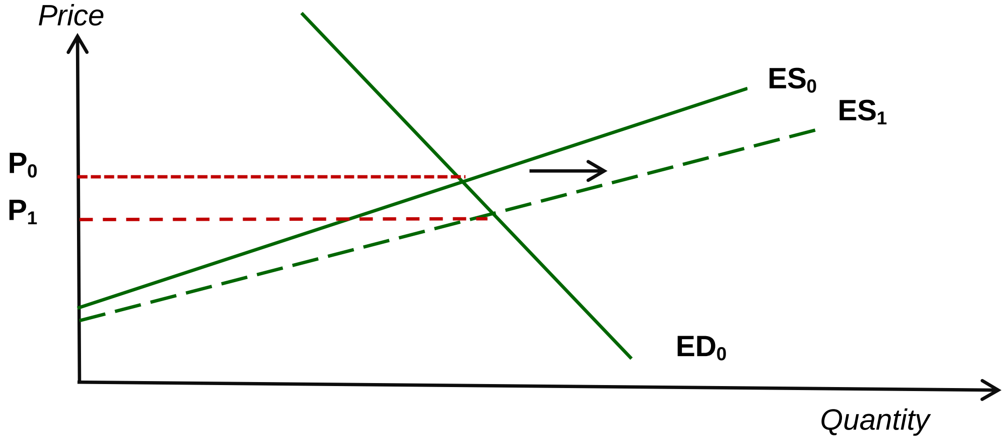

A highly elastic demand curve facing Canadian supply offering into the export market occurs when Canadian exports are a small share of overall world supplies. This occurs in the case of barley, for example, where Canada's exports are less than 1% of global barley production. In such a situation Canada as an exporter faces a highly elastic export demand, as illustrated in Figure F1,

In other crop kinds, Canada's exports are a larger share of global production, such as in the case of durum, with the export demand facing Canadian exports being more price responsive. This means that price will decrease as more supply is provided into the global marketplace. Figure F2 illustrates an excess demand for Canadian exports that is not highly elastic.

With an increase in exportable supplies - from **$ES_0$** to **$ES_1$** in Figure F2 the price change from **$P_0$** to **$P_1$** is much larger due to the nature of the export demand curve facing Canada. For example, if the export demand has an elasticity of -2.0, then with a 10% increase in supply price decreases by 5%.

[61] The elasticity of demand is defined as the % change in quantity for a given % change in price. A highly elastic demand curve can have a value of -40 for example, meaning that a 1% change in price is associated with a 40% change in quantity demanded – in other words a nearly horizontal demand curve. When the % change in quantity is less than the % change in price (elasticity of less than -1.0) demand is considered to be inelastic.

***Figure F2 Price Impact with an Increase in Supply – when Demand is not Highly Elastic***




With a shift in supply (i.e., moving from $\mathbf{ES_0}$ to $\mathbf{ES_1}$ as illustrated above), the formula to measure the impact on producer price, such as the percentage change in price (% △Ps) due to a percentage shift in supply (% △S), is[62]:

- % △Ps = %△S/[Ed – Es];

where;

- %△S is the percentage shift in the supply curve;
- Ed is the elasticity of demand, which is a % change in Q for a given % change in price; and
- Es is the elasticity of supply.

Table F1 shows the resulting price impact for a 1% increase in supply (shift in supply curves) for selected supply and demand elasticities. For example, with an export demand being highly elastic, such as -40 and export supply elasticity of 0.5[63], a 1% shift in the supply offering lowers price by only -.025%. With a crop valued at $200/tonne, this is 5 cents of price impact. If plant breeding had a 15% impact over a number of years, the price effect is 74 cents.

***Table F1 Percentage Change in Price for a 1% Shift in Supply for Selected Supply and Demand Elasticities***

| Supply Elasticity | Demand Elasticity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **-0.50** | **-0.75** | **-1.00** | **-2.5** | **-5.0** | **-10.0** | **-20.0** | **-40.0** | **-1000.0** |
| **0.01** | -1.9608 | -1.3158 | -0.9901 | -0.3984 | -0.1996 | -0.0999 | -0.0500 | -0.0250 | -0.0010 |
| **0.25** | -1.3333 | -1.0000 | -0.8000 | -0.3636 | -0.1905 | -0.0976 | -0.0494 | -0.0248 | -0.0010 |
| **0.50** | -1.0000 | -0.8000 | -0.6667 | -0.3333 | -0.1818 | -0.0952 | -0.0488 | **-0.0247** | -0.0010 |
| **0.75** | -0.8000 | -0.6667 | -0.5714 | -0.3077 | -0.1739 | -0.0930 | -0.0482 | -0.0245 | -0.0010 |
| **1.0** | -0.6667 | -0.5714 | -0.5000 | -0.2857 | -0.1667 | -0.0909 | -0.0476 | -0.0244 | -0.0010 |
| **1.5** | -0.5000 | -0.4444 | -0.4000 | -0.2500 | -0.1538 | -0.0870 | -0.0465 | -0.0241 | -0.0010 |
| **2.0** | -0.4000 | -0.3636 | -0.3333 | -0.2222 | -0.1429 | -0.0833 | -0.0455 | -0.0238 | -0.0010 |

[62] A handy reference is: Gardner, Bruce "*The Economics of Agricultural Policies",* MacMillan Publishing, 1987. The approach used here is similar; the focus in the book is on using this approach to assess the impact of various government policies on commodity markets.

[63] With export supply being the producer supply curve minus the domestic demand curve at various price levels, the elasticity of export supply can be above 0.5, such as 1.0 when the supply elasticity is 0.3 to 0.5.

## Determining the Elasticity of the Export Demand Curve Facing Canada

The export demand elasticity facing Canada can be highly elastic since this export demand elasticity is the summation of all excess demand in global trade (from a Canadian perspective). Excess demand is defined as the quantity demanded minus the quantity supplied, at given price levels. The elasticity of excess demand curve facing Canada "$EED_C$" (or the export demand facing Canada) can be represented as follows:

- $EED_C = \sum_i \{(Qd_i/X_C)^* Ed_i - (Qs_i/X_C)^* Es_i\}$

Where;

- $Qd_i$ is the demand for the product in country "i" at a given price level;
- $X_C$ is the exportable supply offered by Canada;
- $Ed_i$ is the elasticity of demand for the product in country "i";
- $Qs_i$ is the supply offered for the product in country "i" at a given price level; and
- $Es_i$ is the elasticity of supply for the product in country "i";

Using wheat as an example, Canada shipped out 24 million tonnes of wheat exports in 2014/15, with just over 700 million tonnes of global consumption. Canadian exports are 3.4% of global consumption (24/700). If all countries have the same demand and supply elasticities (such as Ed = -0.7 and Es = 0.8), then the elasticity of the export demand facing Canada (**$EED_C$**) is -42.9 (based on);

- [(700/24)*-0.7] – [{(700-24)/24* 0.8}] = - 42.9

Referring back to Table F1 a 10% increase in supply offering by Canada would have a price impact of 0.25%, or 50 cents/tonne, when Canada's supply elasticity is 0.5.

FAPRI[64] provides estimates of own-price elasticities for wheat and barley, with the average of the demand elasticity across all countries and food and feed use is -.23 and the supply elasticity for the major suppliers being on average 0.21. In this case using the above formula the export demand facing Canada for wheat is less elastic with a value of -12.6. Using a value of -10 (for the export demand facing Canada) as shown in the above table the price response is in the 0.9% to 1% range with a 10% increase in Canadian wheat export supply, or $2/tonne.

The above illustration indicates that for major grains, plant breeding programs as they increase crop yields can have a small impact on price received by producers.

Table F1 indicates that when Canada faces a highly elastic export demand curve, then the resulting price impact associated with higher production volumes is minimal. This can occur in the case of wheat, where the excess demand curve can range from -15 to -40. This is not necessarily the case for crops such as durum, oats, lentils, and field peas, where Canada is much larger global supplier.

The above formula used to determine the elasticity of the export demand facing Canada (**$EED_C$**) is directly related to the ratio of global production to Canadian exports. The higher this value (or the lower the value of Canadian exports in relation to global production), the more elastic is the export demand curve. Table F2 uses the most recent data supplied by FAO and other organizations to illustrate the importance of Canadian exports as a share of global production (the resulting implication on the excess demand facing Canada is provided in Table F3 on a following page). As shown in the fourth column (of Table F2), Canadian oat exports accounted for 6.0% of global

[64] Food and Agricultural Policy Research Institute (FAPRI), http://www.fapri.iastate.edu/, Iowa State University, Ames, Iowa.

production and 6.4% of supply in the rest of the world (ROW Supply)[65]. In the case of lentils (canary seed), Canada accounts for 23.7% (67.5%) of global production[66].

***Table F2 Canadian Crop Exports in Relation to Global Production, 2013***

| Crop | Global Production | Canadian Export | ROW Supply | Canadian Exports/ Global Production | Global Production/ Canadian Exports | Canadian Exports/ ROW Supply | ROW Supply/ Canadian Exports |
|---|---|---|---|---|---|---|---|
| | *1,000 tonnes* | *1,000 tonnes* | *1,000 tonnes* | % | | % | |
| **Fababeans** | 4,178 | 12 | 4,165 | 0.3% | 334.8 | 0.3% | 333.8 |
| **Chick peas** | 13,306 | 54 | 13,252 | 0.4% | 247.2 | 0.4% | 246.2 |
| **Barley** | 143,600 | 1,267 | 142,333 | 0.9% | 113.4 | 0.9% | 112.4 |
| **Dry beans** | 23,697 | 294 | 23,402 | 1.2% | 80.5 | 1.3% | 79.5 |
| **Wheat** | 711,142 | 19,808 | 691,334 | 2.8% | 35.9 | 2.9% | 34.9 |
| **Oats** | 23,881 | 1,440 | 22,441 | 6.0% | 16.6 | 6.4% | 15.6 |
| **Durum** | 35,225 | 4,726 | 30,499 | 13.4% | 7.5 | 15.5% | 6.5 |
| **Lentils** | 2,299 | 545 | 1,754 | 23.7% | 4.2 | 31.1% | 3.2 |
| **Flax** | 11,450 | 2,833 | 8,617 | 24.7% | 4.0 | 32.9% | 3.0 |
| **Dry peas** | 5,303 | 1,806 | 3,497 | 34.1% | 2.9 | 51.7% | 1.9 |
| **Canary seed** | 230 | 155 | 75 | 67.5% | 1.5 | 208.2% | 0.5 |

Source FAO (http://faostat3.fao.org/download/Q/QC/E), AAFC (Canada: Grains and Oilseeds Supply and Disposition) and http://www.internationalpasta.org/resources/IPO%20BOARD%202013/2%20Chris%20Gillen .pdf

## Export Demand Elasticities and Price Impacts

The ratio of global production to Canadian exports (such as 113.4 for barley) and ROW production over Canadian exports can be used to provide an indication of the elasticity of the export demand facing Canada by crop kind. To do so, one assumption is required, which is that elasticity of internal demand and supply in the major importing and exporting countries (as captured by FAO data) are comparable, such as -0.5 for **Ed** and 0.5 for **Es** in each of the countries. Using this assumption of similar elasticities of internal supply and demand in all other countries, the formula:

- $\mathbf{EED_C} = \sum_i \{(\mathbf{Qd_i/X_C})^* \mathbf{Ed_i} - (\mathbf{Qs_i/X_C})^* \mathbf{Es_i}\}$ becomes
- $\mathbf{EED_C = Ed} \; ^*\sum_i \mathbf{Qd_i/X_C - Es} \; ^* \sum_i \mathbf{Qs_i/X_C}$

With $\sum_I$ $\mathbf{Qd_i}$ equivalent to global production and $\sum_I$ $\mathbf{Qs_i}$ is equivalent to ROW (rest of world) production.

Table F3 indicates the elasticity of the export demand ($\mathbf{EED_C}$) facing Canada when an elasticity of demand at -1.0 and -0.2 and an elasticity of supply at 1.0 and 0.2 in each of the countries are assumed. The lower end of -0.2 and 0.2 are based on the demand and supply elasticities noted by FAPRI for wheat and barley.

For example, with chick peas, where Canadian exports are only 0.4% of global production, with elasticities of demand and supply at -1.0 and 1.0 (in each of the importing and exporting countries), the elasticity of the export demand facing Canada is -493, which is highly elastic (essentially a

[65] ROW supply is the label used for the measurement of global production less Canadian exports.
[66] The fifth and last columns in Table F2 are the ratios $\sum_i$ $\{(\mathbf{Qd_i/X_C})$ and $\sum_i$ $(\mathbf{Qs_i/X_C})$ used in the **EED** formula shown on the previous page.

horizontal demand curve (refer back to Figure F1). This results in no price impact (i.e., 0.0%) when Canada's supply offering increases by 10%, as shown in the second last column in Table F3).

The supply and demand elasticities of -1.0 and 1.0 in other countries are designed to account for longer run supply and demand conditions where there is substitutability between grains as ingredients. For example, wheat can substitute for durum in the manufacture of some pasta products.

In the case of oats, with exports a 6.0% of global production, the export demand can range from -6.4 (elasticities of -0.2 and 0.2) to -32.21 (elasticities of -1.0 and 1.0), which result in a -1.4 to -0.3% price impact with a 10% increase in supply[67].

***Table F3 Price Impact Associated with a 10% Increase in Supply by Crop Kind***

| Crop | Canadian Exports/ Global Production | Export Demand Elasticity with ROW Elasticities of -1.0 and 1.0 | Export Demand Elasticity with ROW Elasticities of -0.2 and .2 | Price Impact with 10% Supply Increase and ROW Elasticities of -1.0 and 1.0 | Price Impact with 10% Supply Increase and ROW Elasticities of -0.2 and .2 |
|---|---|---|---|---|---|
| | % | | | % | % |
| **Faba beans** | 0.3% | -668.5 | -133.7 | 0.0% | -0.1% |
| **Chick peas** | 0.4% | -493.5 | -98.7 | 0.0% | -0.1% |
| **Barley** | 0.9% | -225.7 | -45.1 | 0.0% | -0.2% |
| **Dry beans** | 1.2% | -160.0 | -32.0 | -0.1% | -0.3% |
| **Wheat** | 2.8% | -70.8 | -14.2 | -0.1% | -0.7% |
| **Oats** | 6.0% | -32.2 | -6.4 | -0.3% | -1.4% |
| **Durum** | 13.4% | -13.9 | -2.8 | -0.7% | -3.0% |
| **Lentils** | 23.7% | -7.4 | -1.5 | -1.2% | -5.0% |
| **Flax** | 24.7% | -7.1 | -1.4 | -1.2% | -5.2% |
| **Dry peas** | 34.1% | -4.9 | -1.0 | -1.7% | -6.8% |
| **Canary seed** | 67.5% | -2.0 | -0.4 | -3.4% | -11.2% |

In the case of durum, a 10% increase in supply based on improved varieties can have a 0.7% to 3.0% price reduction, which becomes significant, arising from an export demand elasticity of -2.8 to -13.9. The analysis also indicates that with lentils (flax) as Canadian supply increases by 10%, a price impact between 1.2% and 5.0% (1.2% to 5.2%) can be expected.

[67] The annual impact on price of an increase in supply due to higher output can be estimated using the selected supply and demand elasticities and the formula noted above {% △Ps = %△S/[Ed – Es]}. The Canadian export supply elasticity is assumed to be 1.0 and 0.5 when ROW elasticities are 0.5 and -0.5.

## Canada's Export Demand and Export Supply Elasticities

Table F3 indicates that the elasticity and resulting price impact of additional supply can vary based on assumptions made on supply and demand elasticities in major importing and exporting countries. For this project, the elasticities as shown in Table F4 are used for this study. The table also shows the price impact associated with the assumed exportable supply and export demand elasticities. For example, in the case of lentils, with an export supply elasticity of 1.5 and export demand elasticity of -5.0, a 10% supply increase results in a 1.5% price decrease.

***Table F4 Supply Elasticities and Excess Demand Elasticities Used for Analysis and Price Impact with a 10% Supply Shift***

| Crop | Crop Export Supply Elasticity | Excess Demand Elasticity | Price Impact with a 10% Increase in Supply |
|---|---|---|---|
| **Faba beans** | 1.5 | -100 | -0.1% |
| **Chickpeas** | 1.5 | -100 | -0.1% |
| **Barley** | 0.5 | -50 | -0.2% |
| **Dry beans** | 1.5 | -50 | -0.2% |
| **Wheat** | 0.5 | -50 | -0.2% |
| **Oats** | 1.0 | -30 | -0.3% |
| **Durum** | 0.5 | -10 | -1.0% |
| **Lentils** | 1.5 | -5 | -1.5% |
| **Flax** | 1.5 | -5 | -1.5% |
| **Dry peas** | 1.5 | -4 | -1.8% |
| **Canary seed** | 1.5 | -2 | -2.9% |

The supply elasticities used are 0.5 for the major grains of wheat and barley, and 1.0 for oats. The other crops are more price responsive (with a 1.5 supply elasticity) due to their lower acreages and the additional acreage that can be attracted with an increase in price. Clark and Klein[68] estimated the wheat supply elasticity at 0.13 in the short run which increased to 0.51 over the longer run, and Ulrich et al[69] had a supply elasticity of 0.7 for barley. Clark and Klein found the flax supply elasticity to be at least 1.6

On the export demand side, Ulrich et al had a demand elasticity of -10 for barley and Zettner et al estimated the export demand elasticity for wheat to range between -4.6 and -7.1 (using data over the 1975 to 1979 period).

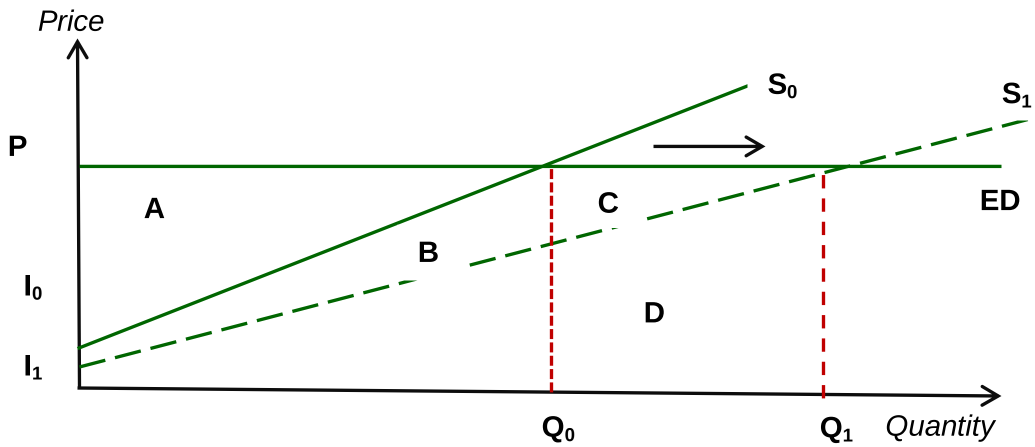
Our analysis will conduct some sensitivity analysis on producer benefits through varying the elasticities, particularly on the export demand side.

[68] Clark and Klein , ----
[69] Ulrich et al ----

## Increase in Production Due to Plant Breeding and Producer Surplus

An increase in output due to plant breeding can be viewed as an outward shift in the supply curve for a specific crop kind, such as barley. This is represented in Figure F3, where the supply curve shifts out from $\mathbf{S_0}$ to $\mathbf{S_1}$, with production increasing from $\mathbf{Q_0}$ to $\mathbf{Q_1}$. The increase in the value of production (with minimal price impact due to more supply) is **P** x ($\mathbf{Q_1} - \mathbf{Q_0}$), which is area **C** plus area **D** in Figure F3.

***Figure F3 Change in Producer Surplus with an Increase in Supply and Highly Elastic Demand***




The economics profession uses a measure called "Producer Surplus" which measures the welfare realized by producers when they sell a product. It is the difference between the amount (in dollars) a producer is willing to supply a product for and the amount received when selling the good in the market. In Figure F3, with the supply curve $\mathbf{S_0}$, the producer surplus is area **A.** This is the area above the supply curve at a given market price, with the supply curve representing what sellers are willing to offer their product into the market at various levels of supply (quantity offered). The willingness to offer can be approximated by the marginal cost of suppliers.

With an increase in output due to plant breeding and improved genetics available to producers, the outward shift of the supply curve results in an increase in producer surplus of area **B** plus area **C** (with producer surplus now being area A + B + C). The producer surplus can be calculated by measuring the area **P**, $\mathbf{Q_1}$, $\mathbf{I_1}$.

When demand is not highly elastic (i.e., the demand curve facing Canadian exports is no longer horizontal), the change in producer surplus due to an outward shift in the supply curve needs to account for the price response associated with the higher supply offering. This is illustrated in Figure F4. With an outward shift in the supply curve resulting in a lower price ($\mathbf{P_1}$), producer surplus changes from $\mathbf{P_0}$, $\mathbf{Q_0}$, $\mathbf{I_0}$ to $\mathbf{P_1}$, $\mathbf{Q_1}$, $\mathbf{I_1}$, and the gain in producer surplus is calculated as $\{[(\mathbf{P_1}-\mathbf{I_1})* \mathbf{Q_1}/2] - [(\mathbf{P_0}-\mathbf{I_0})* \mathbf{Q_0}/2]\}$

***Figure F4*** ***Change in Producer Surplus with an Increase in Supply and Demand is not Highly Elastic***

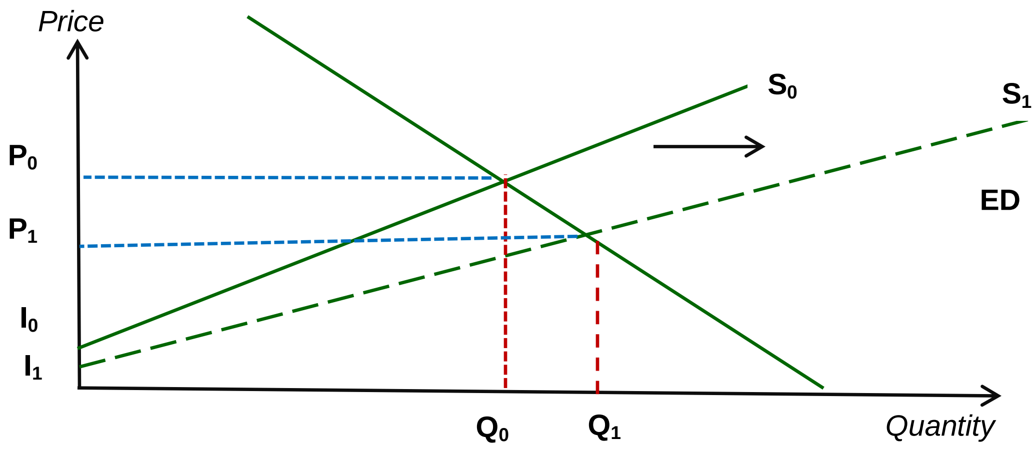



Table F5 provides an example of the change in producer surplus when accounting for the elasticity of export demand. The first four rows in Table F5 are when the demand elasticity is -1.0. The first row is for the initial situation (with $\mathbf{P_0}$ = $200, $\mathbf{Q_0}$ = 100,000 units, and $\mathbf{I_0}$ = $120/unit. The value of production (VOP) is $20 million, and the producer surplus is $4 million (based on $\mathbf{P_0}$-$\mathbf{I_0}$)* $\mathbf{Q_0}$/2).

***Table F5*** ***Change in Producer Surplus with a 10% Supply Increase with Various Export Demand Elasticities***

| Item | Price | Quantity Demanded | Value of Production (VOP) | Supply Intercept (I) | Producer Surplus |
|---|---|---|---|---|---|
| **Export Demand Elasticity of -1.0, ES = 0.5** | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 |
| 10% shift in supply (1) | $186.67 | 106,667 | $19,911,111 | $108 | $4,195,556 |
| Percentage change | -6.7% | 6.7% | -0.4% | -10% | 4.9% |
| Absolute change | -$13.33 | 6,667 | -$88,889 | | $195,556 |
| **Export Demand Elasticity of -3.0, ES = 0.5** | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 |
| 10% shift in supply (1) | $194.29 | 108,571 | $21,093,878 | $108 | $4,684,082 |
| Percentage change | -2.9% | 8.6% | 5.5% | -10% | 17.1% |
| Absolute change | -$5.71 | 8,571 | $1,093,878 | | $684,082 |
| **Export Demand Elasticity of -40.0, ES = 0.5** | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 |
| 10% shift in supply (1) | $199.51 | 109,877 | $21,921,049 | $108 | $5,027,191 |
| Percentage change | -0.2% | 9.9% | 9.6% | -10% | 25.7% |
| Absolute change | -$0.49 | 9,877 | $1,921,049 | | $1,027,191 |
| **Highly Elastic Export Demand, ES = 0.5** | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 |
| 10% shift in supply (1) | $199.80 | 109,950 | $21,968,169 | $108 | $5,046,771 |
| Percentage change | -0.1% | 10.0% | 9.8% | -10% | 26.2% |
| Absolute change | -$0.20 | 9,950 | $1,968,169 | | $1,046,771 |

The supply curve, as noted above, is the willingness to produce and offer product at various price levels. The willingness to produce and offer is related to the cost of production, with the $120 reflecting the marginal costs of the least cost producer. In other words, the least cost producer has an operating cost of $120/unit, and is capturing a 40% margin ($80/$200), which is the producer surplus. At $\mathbf{Q_0}$ in Figure F4, the highest cost producer has essentially no producer surplus. The overall producer surplus of $4 million is 20% of the overall VOP.

With a 10% increase in supply each producer can supply 10% more product (due to improved varieties) with the same cost structure, which is why the supply curve shifts to the right by 10% (see the second row in Table F5). As well, each producer could produce the same amount as before with 10% less cost, which results in the supply intercept decreasing by 10%, with $\mathbf{I_1}$ = $108. The outward shift in supply causes a price reduction of 6.7% with $\mathbf{P_1}$**,** = $186.67. With a demand elasticity of -1.0, the actual quantity demand increases by 6.7%, with $\mathbf{Q_1}$ = 106,667 units. The VOP shrinks slightly by -0.4%; however due to the supply curve shift, producer surplus increases by 4.9%. This impact is as characterized in Figure F4.

With an export demand of -40, the outwards shift of the supply curve only has a .0.2% price impact (see third section in Table F5), which results in a 9.9% increase in the amount demand in the export market. As a result the VOP increases by 9.6%; however producer surplus increases by 25.7% as a result of a minimal price effect (arising from the export demand elasticity). The increase in producer surplus of $1.03 million is 54% of the increase in the value of production of $1.92 million. This outcome is as represented in Figure F3.

In our analysis we will assume that the lowest cost producer (or production at the intercept) has a cost structure that is 60% of the market price. If the initial supply intercept was at $150 (versus $120), the increase in producer surplus would be 2% more with an $\mathbf{EED_C}$ of -40. A supply intercept of $80, which reflects a much lower cost structure for the most efficient producer results in a 2% less producer surplus increase with a 10% supply shift. This range in impact suggests that the assumption made on the value of the intercept, within this range, will not have a large impact on the overall benefits being estimated. It can be noted that when an assumption is made that the supply curve intercept is at a $0 price (cost structure), and then the increase in producer surplus is 6% less.

## Accounting for Producer Funding of Varietal Development and Producer Surplus

Producers in western Canada contribute to varietal development through check-offs and levies, with a portion of the funds received supporting variety development. These levies are costs to producers and in our analysis we conduct a sensitivity analysis by accounting for the levy cost incurred by producers. With a 1% levy, for example, the incidence of cost between producers and consumers is a function of market structures – namely the supply and demand elasticities. When demand is highly elastic, the levy cost is essentially incurred by producer, when viewed against the counterfactual of no levy. In particular, the net incidence on producers can be determined by the formula:

- $\mathbf{- EED_C \div (Es_C - EED_C)}$

Where;

- $\mathbf{EED_C}$ is the elasticity of export demand facing Canada; and
- $\mathbf{Es_C}$ is the elasticity of Canada's supply at the producer level.

Table E6 is used to illustrate the levy impact on producers (see the third column), when a value of 99% for barley indicates that 99% of the levy amount is a producer cost, while in the case of dry peas, due to the demand curve not being horizontal, the producer community absorbs 73% of the levy. (Check do oats have a levy? And what about flax – check the annual reports).

The fourth column in Table F6 provides the overall levy rate by crop kind, with the barley and wheat levies of $0.50/tonne and $0.30 tonne (WGRF rates) expressed as a percent of average prices. The second last column shows the levy rate actually incurred by producers after accounting for the incidence analysis (using supply and demand elasticities). The last column shows the implied producer cost, based on the levy rate incurred by producers, and using average commodity prices.

***Table F6 Supply Elasticities and Excess Demand Elasticities Used for Analysis and Producer Price Impact When Accounting for Producer Levies***

| Crop | Crop Export Supply Elasticity | Excess Demand Elasticity | Levy Impact on Producers | Levy Rate - Percent of Value | Levy Rate Producer Incurred | Producer cost $/t |
|---|---|---|---|---|---|---|
| Faba beans | 1.5 | -100 | 99% | 1.0% | 1.0% | $0.00 |
| Chickpeas | 1.5 | -100 | 99% | 1.0% | 1.0% | $3.94 |
| Barley | 0.5 | -50 | 99% | 0.4% | 0.4% | $0.50 |
| Dry beans | 1.5 | -50 | 97% | 1.0% | 1.0% | $5.58 |
| Wheat | 0.5 | -50 | 99% | 0.2% | 0.1% | $0.30 |
| Oats | 1.0 | -30 | 97% | | | |
| Durum | 0.5 | -10 | 95% | 0.1% | 0.1% | $0.29 |
| Lentils | 1.5 | -5 | 77% | 1.0% | 0.8% | $3.08 |
| Flax | 1.5 | -5 | 77% | 1.0% | 0.8% | $2.58 |
| Dry peas | 1.5 | -4 | 73% | 1.0% | 0.7% | $1.45 |
| Canary seed | 1.5 | -2 | 57% | 1.0% | 0.6% | $2.26 |

For variety development, the amount incurred by producers is less than above since all of the levy proceeds are not used for variety development. Variety development can account for 20% of the funds received.

With an assumption that 20% of a 1% levy rate is directed towards plant breeding, the impact on producer surplus as shown in Table F5 is as follows in Table F7. The aggregate levy cost incurred by producers is deducted from the Producer Surplus (PS). For example, when the elasticity of the export demand is -3.0, then the producer incidence of 0.2% of $194.29/t is 33 cents, which is 85% of the full 0.2% value (of 38.8 cents). This reduces produce surplus by $36,161 and the percentage increase in producer surplus is now 16.2%, versus 17.1%.

Including the producer incidence of levies and check-offs used for variety development is included as a sensitivity analysis. The exact portion of producer levies that are directed to variety development is not known (by the study authors). Based on the best information compiled for this project (on the portion of the levy applicable to plant breeding), the amount of levy allocated to variety development used in this project is $0.25/tonne for wheat and durum, $0.20/t for oats and barley, $0.50/t for flax, $0.85/t for field peas, $1.50/t for lentils, chick peas and canary seed, and $2.00/t for dry beans.

***Table F7 Change in Producer Surplus with a 10% Supply Increase with Various Export Demand Elasticities and Accounting for Levy Cost Incurred by Producers***

| Item | Price | Quantity Demanded | Value of Production (VOP) | Supply Intercept (I) | Producer Surplus | Levy Cost at 0.2% of Value | Aggregate Levy Cost | Producer Surplus |
|---|---|---|---|---|---|---|---|---|
| **Export Demand Elasticity of -1.0, ES = 0.5** | | | | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 | | | $4,000,000 |
| 10% shift in supply (1) | $186.67 | 106,667 | $19,911,111 | $108 | $4,195,556 | $0.25 | $26,548 | $4,169,007 |
| Percentage change | -6.7% | 6.7% | -0.4% | -10% | 4.9% | | | 4.2% |
| Absolute change | -$13.33 | 6,667 | -$88,889 | | $195,556 | | | $169,007 |
| **Export Demand Elasticity of -3.0,ES = 0.5** | | | | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 | | | $4,000,000 |
| 10% shift in supply (1) | $194.29 | 108,571 | $21,093,878 | $108 | $4,684,082 | $0.33 | $36,161 | $4,647,921 |
| Percentage change | -2.9% | 8.6% | 5.5% | -10% | 17.1% | | | 16.2% |
| Absolute change | -$5.71 | 8,571 | $1,093,878 | | $684,082 | | | $647,921 |
| **Export Demand Elasticity of -40.0, ES = 0.5** | | | | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 | | | $4,000,000 |
| 10% shift in supply (1) | $199.51 | 109,877 | $21,921,049 | $108 | $5,027,191 | $0.39 | $43,301 | $4,983,890 |
| Percentage change | -0.2% | 9.9% | 9.6% | -10% | 25.7% | | | 24.6% |
| Absolute change | -$0.49 | 9,877 | $1,921,049 | | $1,027,191 | | | $983,890 |
| **Highly Elastic Export Demand, ES = 0.5** | | | | | | | | |
| Initial Situation (0) | $200.00 | 100,000 | $20,000,000 | $120 | $4,000,000 | | | $4,000,000 |
| 10% shift in supply (1) | $199.80 | 109,950 | $21,968,169 | $108 | $5,046,771 | $0.40 | $43,718 | $5,003,053 |
| Percentage change | -0.1% | 10.0% | 9.8% | -10% | 26.2% | | | 25.1% |
| Absolute change | -$0.20 | 9,950 | $1,968,169 | | $1,046,771 | | | $1,003,053 |