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Intellectual Property Rights and Plant Variety Protection of Horticultural Crops: Evidence from Canada

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ABSTRACT

Total horticultural farm cash receipts were Can \$8.6 billion in Canada in 2014. Horticultural crops have dominated the Plant Breeders' Rights Office (PBRO) application submissions. In this paper we examine firstly the application pattern of plant breeders' rights (PBR) for horticultural crops following the enactment of the Canadian Plant Breeders' Rights Act (PBRA) in 1990. Secondly, we assess whether stronger intellectual property rights (IPR) are needed to boost plant variety development. Canadian Food Inspection Agency (CFIA) plant breeders' rights applications and grants data from 1992 to 2014 are employed to examine how PBR applications by public and private institutions have evolved in response to reduction in R&D funding for horticultural crop research by Canadian public institutions and changes to plant variety protection policy. We show that the bulk of PBR applications are for ornamental crops (followed by vegetables, and fruits) involving mostly 'rose' and 'pelargonium' and originate from European and U.S. corporations. Agriculture and Agri-Food (AAFC) accounted for 35% and 53% of the total apple and cherry applications, respectively. Since 2005, applications for ornamental varieties have declined suggesting the perception of a weak intellectual property protection environment. The PBR system allows farm-saved seed or propagating material use, while plant breeders can use germplasm material in new line breeding activities. Stronger IPR and royalty collection systems may promote greater private plant breeding and commercialization of new varieties for the heterogeneous Canadian horticultural crop industry.

Key words: Intellectual Property Rights, Plant Breeders' Rights, Horticultural Crops, UPOV

INTRODUCTION

To protect against the unauthorized use of germplasm material and create incentives for public and private plant breeders to develop new horticultural varieties requires the adoption of intellectual property rights (IPR) policies such as Plant Breeders' Rights (PBR). The combination of the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement in 1994 and the establishment of the International Union for the Protection of New Varieties of Plants (UPOV) in 1961 (International Convention for the Protection of New Varieties of Plants 2016) provided the impetus for countries around the world to adopt patents or *sui generis* systems, such as plant variety protection (PVP) regimes to protect plant varieties (Janis 2014). Canada enacted the Plant Breeders' Rights Act (PBRA) in 1990 based on the 1978 revision of the UPOV Convention to provide breeders with the rights to protect the breeding and commercial development of new plant varieties. The Act was amended and updated on February 27, 2015 to bring the PBRA into conformity with the 1991 revision of the UPOV Convention and to attract international genetics, encourage greater R&D investment in private plant breeding and harmonize Canada's plant protection regulations with those of major trading partners such as the United States (Canadian Food Inspection Agency 2015; Government of Canada 2016a). Jefferson et al. (2014) document some of the main differences between UPOV 78 and UPOV 91. While UPOV 91 expands the scope of PBR, it strengthens breeders' rights and allows farmers to use protected varieties for propagating purposes on their holdings (The Standing Senate Committee on Agriculture and Forestry 2014). Under the revised PBRA, Canadian PBR was extended from 18 to 25 years for varieties of fruit trees & vine (including rootstocks), 20 years for all other varieties of plants (excluding algae, bacteria, and fungi) and expands breeders' rights to include exclusive control over reproduction, exportation, importation, conditioning, and

stocking of propagation material of the protected plant variety (Canadian Food Inspection Agency 2015). The establishment of exclusive property rights also extends to harvested material including entire plants or parts of plants. Protection rights extended to harvested material is given only under certain conditions. For a plant breeder to be granted a PBR certificate, the variety has to be new, and distinct, uniform and stable (DUS) for a range of morphological characteristics when compared to the reference variety.

This paper analyzes (a) the applications for PBR for ornamental, vegetable, and fruit plant varieties received by Canadian Food Inspection Agency (CFIA) from public and private institutions and (b) to determine whether strengthened IPR or other innovative developmental approaches for crop varietal development are required to promote the domestic development of the Canadian horticulture industry. A recent study (Campi and Nuvolari 2015) based on a constructed Intellectual Property (IP) rating index indicates that Canada's PVP policies are not as strong as equivalent policies in the United States or Australia. The IP index score for Canada was 1.98 versus 3.71 for both the United States and Australia. The difference in the IP index score may be attributed in part to Canada not allowing patent protection for plants and the omission of 'essentially derived varieties' (EDV) from the 1990 PBRA. In the United States, ornamentals and fruits are the predominant plant types protected by plant patents since it affords protection for asexually propagated varieties with desirable attributes like color or smell in the case of flowers (Pardey et al. 2013). Australian government authorities, due to the PVP limitations of the farmer's privilege to save and grow seed of a protected variety and the breeders' exemptions where any breeder can use a protected variety to improve its genetic stock, have investigated the possibilities of expanding the scope of PBR to plant patents, trademarks and contracts to protect

enabling technologies in the horticultural industry such as promoters and markers (Sanderson and Hubicki 2009).

The enactment of PBR policies throughout the world was designed especially to stimulate private R&D investment in plant breeding and to foster the development of new varieties with improved traits of economic importance like disease and pest resistance. Not only IPR policies such as PBR can affect the incentives to invest in private R&D, but environmental and regulatory policies can correct market failure and strengthen the incentives for private companies to invest in and develop biological innovations to enhance agricultural productivity (Fuglie et al. 1996). To date several studies have looked at the effects of PVP policies on crop yield or number of varieties receiving PBR certificates in developed countries. Thomson (2015) found from analyzing wheat agronomic field-trial data that the Australian plant breeders' system suffered from low breeder varietal output stemming from a shift to royalty-funded plant breeding programs and inadequate variety release standards for new varieties. Diez (2002) found that PVP policies in Spain provided a positive incentive to increase R&D investment, especially in the private sector, because of greater opportunities for plant breeding companies to appropriate the benefits from research development efforts in multiple crops including hybrid corn¹. In the United States it was shown that there was no significant increase in wheat yield and R&D investment in wheat varietal development attributable to the 1970 U.S. Plant Variety Protection Act (PVPA) (Alston and Venner 2002). Plant Breeders' Rights has not been viewed as a major innovation driver in the Netherlands² particularly for vegetable varieties, but has served as a

¹ Applicants under the Spanish PVP have the exclusive commercial rights to produce or reproduce, offer for sale, sell, or import and export the protected material. While the Spanish PVP prohibits protected material from being used in further propagation activities, it provides an exception by allowing farmers to re-plant saved-seed from the previous crop.

² In the Netherlands, the holder of the right (breeder) can forbid others from reproducing, handling, offering for sale, selling, importing and exporting, or storing propagating material of the protected variety. The Netherlands

strategic tool to facilitate varietal protection against illegal sales and reproduction of intellectual proprietary technologies (Louwaars et al. 2009). Given the deficiencies (e.g., breeders' exemption) of the *sui generis* system under UPOV 78 for protecting plant varieties, Janis and Smith (2007) suggest that PVP regimes need to be modified in order to recognize that biotechnology and plant breeding methods have shifted over the years and fair competition rules are needed to respond to changes in technology. In the next section of this paper we describe the evolutionary development of PVP policies in Canada. This is followed by, a brief overview of public sector development of raspberry and strawberry by Agriculture and Agri-Food Canada (AAFC), a description of the data employed, and the changing trends in horticultural crop PBR applications, specified for country of origin, decade, and public and private institutions. In the fourth section we examine the changes in the Canadian horticulture industry over the years and analyze whether PBR and other policies such as trade have impacted the development of the domestic flower, fruit, and vegetable industry.

EVOLUTIONARY CHANGES IN PLANT VARIETAL RIGHTS IN CANADA

The Canadian PVP system has undergone substantive changes over the last one hundred years. The earliest development of plant variety protection policies, especially pertaining to crop variety inspection, testing, seed quality and regulation of trade, was the amended 1923 Canadian Seeds Act³ (Government of Canada 2016b) which required all varieties (e.g., seed potatoes) with the exception of ornamentals, vegetables, and fruits to be registered and licensed prior to

PBR system provides for a number of restrictions on the exclusive right of the breeder including the farmers' privilege and the breeder's exemption. For example, the Dutch PBR cannot protect or restrict genetic material from being used in the further development of new varieties.

³ Recent amendments to the Seeds Act occurred in 1985, 1988, 1994, 1997, 2005, 2012 and 2015. There were substantive changes to the Seeds Act as a result of passage of the Safe Food for Canadian Act (2012), which consolidated the authorities of many Acts related to food safety. The Agricultural Growth Act (2014) provided the authority for strengthening of Seeds Regulations and was responsible for changes to the PBRA bringing it in line with UPOV 91 standards (M. Forhan, Personal Communication, Variety Registration Office, Canadian Food Inspection Agency).

commercial sale (Agriculture and Agri-food Canada 2013). Agricultural field crops (e.g., wheat and canola) registered under the Seed Act were not only required to be physically different from a check or reference variety but they needed to demonstrate merit for selected agronomic characteristics like yield, disease and pest resistance.

Under the flexible Canadian Variety Registration system (VRS), the regulatory requirements for potato varieties are less stringent than the conditions for cereals or oilseeds. No merit⁴ requirement is necessary for potato varieties, as well as no field trials, nor recommending expert committees reviewing the field-trial data and recommending varieties for registration. As a result, there are less onerous regulatory requirements for potato, when compared to cereals and oilseeds. New potato applications are made directly to Variety Registration Office and are registered in eight weeks after applicants have provided detailed information on the new variety including the pedigree, breeding, description and photographs of various parts of the new variety (e.g., plant, leaf, flower, tuber) (M. Forhan, personal communication, Variety Registration Office, Canadian Food Inspection Agency, Ottawa, Ontario). As a condition for potato variety registration, application claims (e.g., resistance to golden and pale cyst nematode) made in the variety description form must provide scientific data to the CFIA to substantiate their claims.

While revision to the Canadian Seed Regulations⁵ has improved seed quality standards over the years by strengthening seed variety registration regulations for domestic and international markets, it limited plant breeders' access to varieties protected in foreign markets as

⁴ The new VRS allowed expert committees more flexibility in defining merit for their given crop. Merit is now defined as little as one or more criteria in the areas of agronomy, pathology, and grain quality, whereas previously it comprised of all three components (M. Forhan, Personal Communication, Variety Registration Office, Canadian Food Inspection Agency).

⁵ Recent Canadian seed regulations amendments are as follows: 1997/98- (corn and food grade soybeans exempted from registration); 2008 -(removal of the Kernel Visual Distinguishability criterion for market class wheat); 2009 -(flexible variety registration system introduced); 2011/12 -(Marketing Freedom for Grain Farmers Act passed); 2013/15 -(National review of the VRS conducted by AAFC) (M. Forhan, Personal Communication, Variety Registration Office, Canadian Food Inspection Agency).

well as breeders' having no exclusive rights to produce or commercialize new plant varieties (Galushko 2008). Canada's PBRA was enacted in 1990 during an era of declining public financial resources dedicated to agricultural research. Canadian government R&D spending as a percentage of gross value added in the agricultural sector decreased from 3% to 2% over the past 20-30 years compared to Australia and the United States where it increased from 1% to 2% over the same time period (The Standing Senate Committee on Agriculture and Forestry 2014). The intent of the PBRA was to foster greater private investment in plant breeding, provide greater access to foreign varieties and allow Canadian varieties to be protected in foreign markets (Canadian Food Inspection Agency 2015). Unlike the 1970 United States PVPA that protects sexually reproduced plants such as agricultural field crops (e.g., cereals, oilseeds, pulses), vegetables, tubers, and grasses (Koo et al. 2004; Strachan 2011), the Canadian PBRA protects plants that are reproduced both sexually and asexually. Under UPOV 91, Canadian breeders' rights are extended to royalty collection on harvested material and to EDV from protected varieties (Government of Canada 2016a; Canadian Seed Trade Association 2013). The "essentially derived" provision in UPOV 91 was designed to strengthen plant breeders' rights and limit the incidence of superficial changes in phenotypic traits or varietal imitation (Schmid 1985; Fuglie et al. 1996). The revised Canadian PBRA defines EDV as a variety predominantly derived from the initial variety and retains the essential characteristics that result from the genotype of the initial variety (Government of Canada 2016a). Lawson (2016) showed some of the challenges of establishing an EDV standard because the courts in different jurisdictions have weighed the plant characteristics evidence differently whether there are genotypic and phenotypic differences between the initial variety against a commonly accepted EDV. Based on the views of the International Association of Ornamental and Fruit Breeders, it was suggested

that, for vegetative reproduced ornamental and fruit varieties, the EDV standard requires the establishment of dependence for varieties which are phenotypically distinct and derived from the initial variety, while, for mutants and GMOs, as long as they are distinct and exhibit genetic conformity to the initial variety they ought to be considered EDVs (CIOPORA 2017)

Canada's revised PBRA protects farmer's rights to save and grow the seed of a protected variety for their personal consumption, while the previous legislation only permitted a farmer's use of farm-saved seed by not explicitly forbidding it (Government of Canada 2016a). UPOV 91 enshrines the farmer's privilege of producing seed for personal use in national legislation when compared to UPOV 78 (Jefferson et al. 2014). However, member countries under UPOV 91 have the option to include the farmers' privilege in their national legislation and deciding if they wish to impose any restrictions or conditions upon it. Some have argued that the farmers' exemption under UPOV 78 weakened private breeders' ability to appropriate their returns from R&D investment (Alston and Venner 2002). This is consistent with results reported by Srinivasan (2012) that PVP is a relatively weak form of protection in the United Kingdom since private companies are only able to appropriate a small proportion of their returns from R&D investment in the development of new varieties. While there has been some criticisms of the PVP system with its emphasis on observable phenotypic and morphological plant attributes and little consideration of the genotypic attributes developed by modern plant transformation methods (e.g., molecular markers), it continues to be used by countries like Australia since it has bolstered plant breeding funding and financing arrangements (Sanderson and Adams 2008).

The rapid development of the biotechnology industry associated with the genetic modification of plants with improved crop traits (e.g., herbicide resistance) has led many countries around the world to adopt or strengthen IPR policies. Horticultural crops in both the

United States and Australia are protected by both PBRs and plant patents (Sanderson and Hubicki 2009; Drew 2010). The Canadian Patent Act which entered into force in 1869 has been modified over the years and has shifted from a first-to-invent to a first-to-file system in 1989 (Vaver 2004). This is the same approach adopted by UPOV 91 for the application of PBRs. The Canadian Patent Act covers many technology fields (e.g., biotechnology) with the requirements for a patent to be granted including that the invention to be new, useful and nonobvious. This requirement is consistent with the World Intellectual Property Organization (WIPO) of the United Nations for the granting of any kind of IPR on a given invention. The Canadian Patent Act covers “lower life forms” and “higher life forms”. Lower life forms such as microorganisms are patentable in Canada (Abitibi Co., Re 1982) which provided the impetus for the development of microbial technologies employed in the forestry industry to reduce waste products from pulp mills. Though Canada’s Patent Act does not allow the patenting of higher life forms such as plants, the Canadian Supreme Court case, *Monsanto Canada Inc. v. Schmeiser* (Supreme Court Judgment 2004), upheld the decision that holders of plants with patented genes, plant cells and genetic processes are protected by the Canadian Patent Act (Koo et al. 2004; Siebrasse 2010). Unlike in Canada, agricultural crop developers in the United States can protect their varietal inventions either through a utility patent, a plant patent or a PVPA certificate in the case of horticultural crops such as potato.

PUBLIC SECTOR DEVELOPMENT OF RASPBERRY AND STRAWBERRY FRUIT

CROPS IN CANADA

Fruit crops such as berries are a diversified crop category and many are well adapted to Canada’s growing conditions, while they also are one of the fastest growing fruit market sector. The rapidly growing global demand for berries (Rusnak 2012; Knowles 2014) is fuelled in part by the

nutritional benefits about their health attributes provided by the relatively high phytochemical content. Over the years, the Canadian demand for berry fruit increased noticeably, with more than 84% of annual Canadian strawberry sales coming from imported berries (The Senate Standing Committee on Agriculture 2014).

Public sector plant breeding of a variety of berry crops, such as raspberry (*Rubus idaeus*) and strawberry (*Fragaria × ananassa*), has undergone substantive changes over the years. The focus of many breeding programs is to search for new berry crops suitable for specific climate conditions that would provide competitive advantage to growers. Unlike California, where private strawberry breeders (e.g., Driscoll) have been able to capture the value of their research through stronger intellectual property rights (e.g., plant patents), most of the publicly supported breeding programs in Canada are undertaken by public sector government institutions such as AAFC. It takes 10-15 years to develop a new raspberry or strawberry cultivar, and publicly-supported berry breeding programs in Canada have been in existence since the early 1930s. But due to government fiscal pressures, many of them such as AAFC, Ottawa; University of Guelph and Ontario Ministry of Agriculture and Food have been discontinued (Daubney 1990). Reduced public sector funding to federal government research centres and inadequate private plant breeding programs have contributed to changes in managing R&D funds for berry breeding. Since the mid-2000's, AAFC's berry breeding funding arrangements have emphasized industry-led science priorities and a market-research funded approach (e.g., Developing Innovative Agri-Products Initiative), where industry stakeholders are increasingly involved in the priority setting and the management of R&D funds.

The bulk of public sector breeding of raspberry and strawberry cultivars is now undertaken primarily by AAFC research centres in British Columbia (BC) and Nova Scotia.

Very few university breeding programs exist. A unique example is the University of Saskatchewan plant breeding program that focuses on berry crops such as blue honeysuckle or haskap (*Lonicera caerulea*). Berry breeding in BC started in the late 1940s with the release of three strawberry cultivars: 'Agassiz' in 1956, 'Cheam' in 1969, and 'Totem' in 1971 (Daubeney 1990). 'Totem' has found widespread acceptance in BC, the Pacific Northwest, and markets in the United Kingdom. Some of the early fresh market raspberry cultivars released in the 1970s included 'Skeena' and 'Chilcotin' (Daubeney 1986). The goal of the BC raspberry breeding program was to develop cultivars that have superior flavor, taste, and firmness, resistance to virus, root rot tolerance and are machine harvestable. Eight cultivars (e.g., 'Chilliwack') were released by the BC breeding program prior to the enactment of the PBRA in 1990, and several cultivars (e.g., 'Tulameen', 'Qualicum', 'Malahat', 'Kitsilano' and 'Cowichan') were released in the 1990s (Kempster et al. 2002). 'Tulameen' has become the standard for quality for raspberry production throughout the world. The success of the BC raspberry breeding program relied on germplasm exchanges from the United Kingdom (e.g., Scottish Crop Research Institute; East Malling Research Program). Raspberries are grown in BC, Ontario, Quebec, and Nova Scotia with 'Squamish' and 'Rudi' among five main cultivars planted in 2016 that originated from the BC breeding program. The three other popular cultivars are 'Meeker', 'Wakefield', and 'Chemainus'.

In contrast to BC, berry breeding in Nova Scotia began in 1949 with the release of multiple strawberry cultivars bred for growing conditions in Eastern and Central Canada and the northeastern United States (Daubeney 1990). The Nova Scotia breeding program relied on European cultivars as sources of germplasm material to enhance genetic diversity (Jamieson and Nickerson 1989). Strawberries are either short-day or day-neutral. There are five cultivars

sharing the top group of short-day berries. Except for an early season AAFC cultivar, 'Wendy', these cultivars are fairly old having been introduced in the 1980s and 1990s. With the shift in demand toward fresh strawberries, 'Totem', a processing mid-season cultivar, has fallen out of favor (Jamieson, 2011) and has been replaced by 'Puget Reliance', a Washington State short-day fresh market cultivar (about three percent of planted cultivars in Canada).

Short-day cultivars represent two groups distinguished by the location of production area in the southern or northern Canada. The first group, grown in southern areas, represents about 10-15% of short day cultivars and includes, in the ripening order, 'Annapolis', 'Wendy', 'Kent', 'Jewel', and 'Mira'. With the exception of the Cornell University developed cultivar 'Jewel', these cultivars were developed by AAFC. In group 2 (again in ripening order), 'Cavendish' a mid-season AAFC developed cultivar continues to be widely grown especially in northern areas, 'Cabot' is favored for its very large berries, and 'Valley Sunset' popularity rises because it is the very late season cultivar extending the production and marketing season (Jamieson, 2011).

The importance of day-neutral production in Canada is increasing. 'Albion' and 'Seascape' are the leading, equally popular UC Davis developed cultivars grown in Canada (Jamieson, 2011). Overall, the size of the strawberry production and the market for new varieties released by breeders is reflected in the annual quantity of sold plants. Annual sales are about 25 million short-day plants and 10-15 million day-neutral plants, respectively. Additionally, large numbers of Canadian plants have been shipped to Florida. The demand for cultivars grown in Florida influences the availability of cultivars in Canada. It appears that nurseries are not as interested in producing varieties of berries not protected by plant patents or PBRs, because of the perceived lower profit than from protected varieties (Jamieson, 2011).

DATA DESCRIPTIONS AND SOURCES

This study analyzed the Canadian Food Inspection Agency (CFIA) PBR application and grants data for horticultural (ornamentals, vegetables, and fruits) crops over the 1992-2014 period (de Wit 2015). The CFIA received a total of 6,913 horticulture crop PBR applications between January 1992 and December 2014. The PBR application data included several species of ornamentals, vegetables and fruits. The PBR application data recorded the year of application and the type of applicant (e.g., public institution or private firm). PBR application dates rather than grants dates are preferred for analysis of the innovative behavior of plant breeders (Pardey et al. 2012) because they provide a good measure of the performance of the PVP system and are not influenced by administrative lag times associated with data reported by grant date.

PBR APPLICATIONS FOR HORTICULTURAL CROPS BY COUNTRY OF ORIGIN

Horticulture crops dominate the Canadian PBR landscape, with ornamentals, vegetables and fruits credited for 84%, 10%, and 6%, respectively (Table 1). The number of cereal, oilseed, pulse, grass and other agricultural crops PBR applications respectively were 494, 868, 201, 20 and 14 over the same time period (de Wit 2015). The main cereal crops were wheat, barley and oat, while for oilseed they were canola, soybean and flax. The importance of PBRs for ornamentals is attributed to the diversity and large number of species produced, combined with the economic value of fairly small technology improvements and the vegetative reproduction method that makes the exact copying of flowers easy and valuable (Srinivasan 2005; Louwaars et al. 2009). The bulk of horticultural PBR applications were accounted for by major European countries (Switzerland, Netherlands, Germany, and Denmark) and the United States (Table 2). Canadian public institutions and private companies accounted for a smaller share (5%) of PBR

applications. In comparison, in the United States, agricultural field crops (e.g., cereals, oilseeds, pulse) and vegetables are major crops (83% and 13% of all PVPA applications) of the United States PVP system with 81% of the applicants being U.S. citizens or companies, while 9% were public institutions such as universities or government agencies (Strachan 2011).

Of the total PBR applications for ornamental plants, the top five species include rose (10.1%), pelargonium (9.9%), impatiens (9.3%), chrysanthemum (9.1%), and petunia (5.7%) (Table 3). It is evident that Canada is not a major player in the crop varietal development of ornamental crops accounting for 2% of applications. In the United States, where plant patents are used to protect horticultural crops more strongly than does Canada, 83% of plant patents were granted to ornamental species with the top flower species including rose (20%), chrysanthemum (11%), pelargonium or geranium (5%), and impatiens (4%) (Drew 2010).

With regard to PBR applications for vegetable varieties, most of them were granted for potato varieties (Table 4). Because Canada did not adopt PVP policies until the early 1990s, domestic producers were not able to access protected varieties from other jurisdictions prior to this period. The bulk of applications for potato were received from Europe (65%) and the United States (20%), while Canada accounts for 15 % (Table 4). In the 1960s Canadian public institutions like the University of Guelph were in the forefront in potato varietal development research with the development of a yellow-flesh potato called 'Yukon Gold' in 1966. While developers of this variety did not have access to IPR, this variety has found wide consumer acceptance in North American markets. Table 4 shows that there are fewer PBR filings by Canadian breeders' for non-potato vegetable crop species such as lettuce. The limited number of applications for non-potato vegetables is attributed to the fact that many commercial vegetable varieties (e.g., tomato, carrots, and cucumbers) are (i) hybrids where the seeds cannot be

reproduced successfully, and (ii) have a short economic life stretching over a few years only (Louwaars et al. 2009).

Apple and strawberry are the two main fruits that account, respectively, for 29% and 25% of the total fruit PBR applications (Table 4). The majority of apple and strawberry applications were filed by public and private institutions, respectively. Canadian plant breeders account for 48% and 27% of the total apple and strawberry applications. Of the 61 total Canadian apple applications, eight were by private individuals/companies. The low private sector role in apple breeding in Canada is consistent with a U.S. study that showed low private breeding efforts targeted at apple and pear varietal development is attributed to the high investment costs driven in part by the long juvenile time periods required for commercial fruit breeding (Stallmann and Schmid 1987). While the Canadian blueberry industry has grown significantly over the years, there are fewer applications by Canadian plant breeders. Between 2011 and 2015, blueberry (high bush and low bush) cultivated area increased by 5.7% from 70,811 ha in 2011 to 74,859 ha in 2015 (Agriculture and Agri-Food Canada 2017a). For cherry, Canadian applications account for 81%, while for pear and peach, they were 61% and 85%, respectively. The majority of Canadian cherry applications originated from the public sector (e.g., AAFC) fruit breeding program in British Columbia.

CHANGING TRENDS IN PBR APPLICATIONS FOR ORNAMENTALS, VEGETABLES AND FRUITS

Time Duration between filing of PBR Applications and receipt of Grants

The trends in the number of horticulture crops PBR applications from 1992 to 2014 are shown in Figure 1. Total applications for horticultural crops in Canada grew steadily from 151 in 1992 to 646 in 2005, but then declined to 242 in 2014. PBR grants for horticultural crops also increased

9-fold from 45 in 1993 to 392 in 2007, but subsequently declined to 233 in 2014. The time duration between filing an application and receipt of a grant (grant lags) has increased over the last 25 years from an average of 290 days in 1993 to 1207 days by 2014. In the United States, where the PVP system was adopted much earlier than in Canada, administrative delays in the granting of applications were responsible for grant lags averaging 500 days in the period 1977-1987 and increasing to 1,019 days between 2001 and 2005 (Pardey et al. 2012).

Canada's PBR testing system for the examination of new varieties and the grants of PBR certificates sets the responsibility with the applicant for ensuring that the comparative DUS trials are completed in a timely fashion. According to the CFIA (A. Parker, personal communication, PBR Office, Canadian Food Inspection Agency, Ottawa, Ontario), the length of time to establish DUS trials and collect the required information for the granting of the PBR is based on the crop species and can take between 2 to 5 years. For crops that require only one year of DUS testing, the applicant is given 2 years by the Plant Breeders' Rights Office (PBRO) from the time of application to have these trials established in Canada. In contrast, for fruit crops (e.g., apple) that require a longer time period to establish the variety trials to collect the necessary information, the applicant is given 5 years. Additionally, for foreign fruit tree species, the time period to have incoming propagating material meet the Canadian phytosanitary standards (e.g., virus free) can be quite lengthy.

Over the years, the PBRO has adopted administrative measures to shorten the time frame from application to grant of rights. For instance, the PBRO accepts foreign DUS test results for ornamental and horticultural crops from other UPOV member countries in lieu of conducting the trials in Canada (Canadian Food Inspection Agency 2016). Collaboration between international DUS Testing Offices is favourably accepted by the UPOV. These changes are applicable to

asexually propagated horticultural crops such as ornamentals, fruits and vegetables (excluding potato).

Trends in PBR Applications for Horticultural and Ornamental Varieties

In terms of application trends, European horticultural applications range from 90 in 1992 to 105 in 2014, while the United States range from 56 to 87 for the corresponding time period. Canadian applications vary from 4 in 1992 to 17 in 2014 (Figure 2). European applications for horticultural crops peaked in 2005 at 413 applications, while U.S. applications peaked in 2001 at 191. The peak in European horticultural crops PBR applications in 2005 stems from the number of ornamental applications since they account for the bulk of European horticultural crops applications (de Wit 2015). Europe has been historically recognized as the region of the world with a successful floriculture industry which provided American rose breeders with the opportunity to propagate European planting material during World War II (Moser and Rhode 2011).

A closer examination of the trend in PBR applications for selected ornamental crop species is provided by Figure 3. The two most important bedding and landscaping plants, pelargonium and impatiens, peaked, respectively, at 81 and 80 PBR applications in 2005. Rose variety applications increased nearly six-fold from 21 applications in 1992 to 123 applications in 1998, but declined significantly since 2004. It is unclear whether decreasing numbers of PBR applications for ornamental species post-2005 was due to market conditions or changing policy considerations. One plausible explanation may be attributed to global economic factors and the consolidation of the industry (A. Parker, personal communication, Canadian Food Inspection Agency, Ottawa, Ontario). The 2007/08 global financial crisis may also have affected the capacity of ornamental breeding companies to develop new crop varieties. The consolidation of

breeding companies witnessed in the late 1990's and early 2000's may have impacted competing lines offerings, which are often streamlined when new firms are acquired through a merger. Moreover, the lack of conformity of Canada's PBR policies with UPOV 91 may have affected foreign applications of new crop species because of the perceived weak intellectual property environment of UPOV 78.

Declining PBR applications for ornamental crops is not a trend unique to Canada, but has been observed as well in other developed countries. For example, in Australia a decline in nursery PVP applications after 2002 suggests that the reason may be attributed to changing climate conditions stemming from limited water availability (Sanderson and Adams, 2008).

Additionally, our descriptive data reveal foreign private companies are filing ornamentals applications in Canada for several hybrid varietal species (e.g., impatiens, petunia, verbena, and begonia). Impatiens hybrid species applications were filed by Ball Horticultural Company of the United States and Syngenta of Switzerland (Table 5). Petunia hybrid applications were filed by multiple companies including Suntory Flowers of Japan, and U.S. companies such as Ball Horticultural Company, Paul Ecke Ranch, and Goldsmith Seeds. Verbena hybrid applications were filed by Ball Horticultural Company, Suntory Flowers, Goldsmith Seeds and Syngenta, while begonia hybrid applications were filed by Suntory Flowers. While hybrid varieties are protected against illegal reproduction of seed by nurseries, they are not protected against imitation by plant variety protection (Srinivasan 2012). Janick (1998) suggests that horticulture hybridization is a successful breeding technique that allows breeders to control their products without the necessity of protecting their new inventions through plant patents or plant breeders' rights.

Trends in PBR Applications for Vegetable Varieties

PBR applications for potato and varieties registered by the CFIA Variety Registration Office are shown in Figure 4. The registered potato varieties averaged 11 per year over the 1990-2014 period. As mentioned before, potato varieties have to be seed certified and registered in Canada and satisfy a set of crop quality requirements (e.g., stress tolerances) before they are allowed to be commercially produced in Canada. The large number of public/private companies applying for PBRs for potato (27/year) is a reflection of the size of the potato industry in Canada with applications ranging from 79/year in 1992 to 59/year by 2014. As can be seen in Figure 4, Canadian PBR applicants averaged 4/year compared to 23/year for non-Canadian applicants. Of the 612 total applications for potato, Canadian applicants accounted for 14.7%, while United States, Netherlands and other European countries were credited for 19.6%, 35.8% and 28.8%, respectively. AAFC accounts for 60% of the Canadian potato applicants. These results are consistent with one of the aims of the PBRA to provide Canadian producers with greater access to foreign varieties (CFIA 2002). Additionally, the PBRA has benefited the domestic industry by fostering a number of international collaborations, such as partnerships between Dutch plant breeders and Canadian producers in the testing and development of potato varieties for adaptation to Canadian environmental conditions (Siebrasse 2010). The success of adapting foreign protected varieties to Canadian climate conditions is borne out over the years by Canada's increased export capacity and as a major producer of fresh, seed and processed potatoes. In 2014-2015, Canada's exports of potatoes and potato products were valued at Can \$1.36 billion, up 23.7% from 2010-2011 with most fresh exports destined principally to the United States (Agriculture and Agri-food Canada 2017b).

Trends in PBR Applications for Fruit Varieties

The top five fruits for which PBR applications were filed in Canada during 1992-2014 are shown in Figure 5. PBR applications for apple averaged 6/year and peaked at 17 applications per year in 2005, while applications for strawberry averaged 5 per year and peaked at 11 in 2009.

Blueberry PBRs peaked in 2012 at 10 applications and declined to 6 per year in 2014. The trends in filing PBRs applications for fruit crops reflect the sluggish growth pattern observed over the 2010-2015 period for cultivated fruit areas, which decreased by 1.5%, 2.7%, 19.5%, and 15.6% for apples, grapes strawberries, and raspberries, while cultivated areas for blueberries, cranberries and sweet cherries increased by 5.7%, 20.6% and 0.94%, respectively (Agriculture and Agri-food Canada 2017a). Unlike Canada, plant breeders in the United States have a range of IPR instruments to protect apple varieties, ranging from plant patents and trademarks for new apple varietal names. While PBRs in Canada can allow the owner of an apple variety to exclude others from merchandizing, importing or reproducing the protected propagating material, trademarks can be used by nurseries to differentiate their product associated with a set of attributes in the market place. One advantage that trademarks have over PBRs or plant patents is that they can be protected indefinitely, as long as the product is marketed and the trademark enforced (Tucker and Ross 2007). Trademark names in agriculture such as *Pink Lady* for apples have created value for agricultural products in the market place by bolstering consumer acceptance.

Despite having a long publicly funded plant breeding history in developing tree and small fruit, Canada continues to rely on fresh and processed fruit imports primarily from the United States. Fresh fruit imports were Can \$5.7 billion in 2015, up 12.9% from 2014 with part of the

value increases attributed to the lower value of the Canadian dollar. The top three fresh fruit imports were grapes, bananas and strawberries (Agriculture and Agri-Food Canada, 2017a).

PBR Applications for Horticultural Crops by Public Institutions and Private Companies

Applications filed by Canadian public institutions (e.g., AAFC and universities) for horticultural applications varied over the 1992-2014 period. AAFC, Canadian universities and U.S. universities, respectively, filed 182, 53, and 192 applications over the 1992-2014 period (Table 5).

AAFC has benefitted from filing PBR applications because they not only provide exclusive rights to breeders for protected varieties, but also provide a source of royalty revenues that helped partly support federal government plant breeding programs (Figure 6). Since 2000, AAFC has licensed roughly 700 cultivars (e.g., cereals, oilseeds, pulses, horticultural crops) representing over \$50 million in licensing revenues with wheat accounting for over \$17 million, followed by barley (\$5.5 million), oats (\$4.1 million), fruits (\$2.5 million) and ornamentals (\$1.8 million) (Management Solutions 2010). However, due to reduced government support for agricultural research over the years, royalty revenues especially for ornamental and vegetable crops have shrunk over the last few years. To strengthen federal government R&D investment spending, it is suggested that all royalty income generated by new AAFC crop discoveries ought to be added to AAFC research budget for further plant breeding research activities (The Standing Senate Committee on Agriculture and Forestry 2014). While it is recognized that royalty income has supported partly the development of new varieties, AAFC has earned such revenues primarily through nonexclusive licensing arrangements from varieties made freely available to the public. In the United States, at Cornell University, the combination of employing plant patents and nonexclusive licensing agreements for apples, cherries, raspberries, and strawberries

have improved the widespread dissemination of Cornell varieties, but have provided little incentives to develop the market for licensed varieties (Cahoon 2007).

Table 5 shows that the majority of PBR applications for ornamental varieties are granted to the top private companies. These accounted for 59% of the total ornamental applications. Companies like Syngenta of Switzerland, Ball Horticultural of the United States, Poulsen Roser of Denmark, Suntory Flowers of Japan, and Klemm Nils of Germany are the principal ornamental applicants. These companies were also the top companies that were granted plant patents for vegetatively propagated ornamental crop varieties in the United States (Pardey et al. 2013). Our results show chrysanthemum, pelargonium and impatiens are the major ornamental crop species filed by Syngenta, while impatiens and pelargonium are the principal ones filed by Ball Horticultural Company.

Concerning PBR applications for vegetables, most of them are for different potato varieties with multiple attributes including appearance, texture and usage. The main applicants for potato were European private firms, U.S. universities and private firms, and Canadian public government agencies such as AAFC (Table 5). The majority of European firms filing PBR applications for potato varieties are from the Netherlands, Ireland, Germany, and France. Of the major United States universities filing PBR applications for potato, Cornell University and University of Idaho are the principal ones, while the largest numbers of U.S. potato applications by private firms were received from Frito-Lay and Monsanto.

AAFC account for 112 (24.9%) of the total number of PBR applications for fruit species in the 1992-2014 period. Apple, strawberry, raspberry, and cherry applications accounted for 35%, 21%, 27%, and 53% of the relative totals of applications. American and Canadian universities account for 51 (11.4%) and 41 (9.1%) of the total PBR applications for fruit species,

respectively. Foreign applicants, including the U.S. private sector, account for the majority of PBR applications for strawberry varieties, while the bulk of PBR blueberry applications are granted to U.S. universities (e.g., Michigan State University) and private companies. PBR applications for fruit varieties were also filed by countries with relatively small breeding programs such as the New Zealand Horticulture Research Institute.

The University of California and private companies such as Driscoll Strawberry Associates are the main U.S. applicants for strawberry PBR's. The empirical analysis from this study indicated that a large share of fruit variety development such as apples, raspberry, strawberry and sweet cherry was undertaken by Canadian public research institutions rather than private companies. This was attributed to the limited economic opportunities from the sale of propagation material since they are planted on relatively small cultivated areas and incur high development costs to produce multiple varieties adapted to a wide range of environmental conditions (Alston and Pardey 2008).

HAS DEVELOPMENT OF THE HORTICULTURE INDUSTRY BEEN IMPACTED BY PLANT BREEDERS' RIGHTS POLICIES?

What have been the impact of PVP policies in stimulating investment and the development of the ornamentals, vegetables and fruits? Attributing the effects of the PBRA to new R&D investment in the horticultural industry is somewhat difficult since little R&D investment data is available for individual horticultural crops before and after the PBRA was enacted in 1990. What we attempt to present in this section is a descriptive assessment of the growth of the horticultural industry in Canada and how it has responded to alternative policies such as free trade agreements including NAFTA, Canadian-Costa Rica Free Trade Agreement and the Canadian-Colombian Free Trade Agreement. The main provisions of these Free Trade Agreements applicable to this

study is the intellectual property provisions provided for the protection of patents, copyrights, trade secrets, geographic indications, and plant breeders' rights.

As can be seen from Figure 7, floriculture, nursery, sod, and Christmas trees account for about one third of Canadian horticulture farm cash receipts and increased from Can \$914 million in 1990 to Can \$1,880 million in 2014. Vegetable and fruit (tree & small fruit) receipts, respectively, quadrupled and doubled over the same time period and reached Can \$2,515 million and Can \$857 million in 2014. The growth of greenhouse vegetables, in particular tomatoes, has been attributed to technological advancements in the adoption of hydroponics, computer temperature control systems, and biological control agents (Purdy 2005). The increased globalization has strengthened Canadian-U.S. agricultural trade and production of new ornamental, fruit and vegetable products. This is very evident in the ornamental industry where transformative changes in the floriculture sector have been attributed to increased floricultural product sales by mass merchandisers (e.g., Walmart) and increased Canadian imports from U.S. big-box stores located in major urban centers of Ontario (Reid et al. 2009).

The horticulture industry dominates the agriculture landscape in Ontario, BC and Quebec and is generally considered very labor intensive and varied in terms of the range of crops produced (Agriculture and Agri-Food Canada 2012). Of the total cultivated area (8,139,683 m²) dedicated to specialized greenhouse flower & plant production in Canada, Ontario, BC and Quebec accounted for 47%, 25%, and 14%, respectively (Agriculture and Agri-Food Canada 2014). Greenhouse floriculture is very diverse and specialized in the range of ornamental crop species grown in Canada. In 2015, the top four greenhouse flowers and plants produced were potted plants (Can \$786 million), bedding plants (Can \$277 million), cut flowers (Can \$147 million), and cuttings (Can\$51 million) (Statistics Canada 2017). The principal cut flower

species produced were tulips, gerberas, chrysanthemums, snapdragons and alstroemeria, while for potted plants they were geraniums, herbaceous perennials, tropical foliage and green plants, miniature roses, and petunias (Agriculture and Agri-Food Canada 2017c).

The Canadian horticultural industry has expanded significantly over the last twenty five years in response, principally, to growth in demand for ornamental products (Canadian Ornamental Horticulture Alliance 2013). The economic contribution of the ornamental sector to the Canadian economy has been estimated at Can \$7.5 billion coupled with the creation of 110,750 full-time positions (Deloitte 2009). Since the early 2000s, increases in disposable income has resulted in consumers spending roughly Can \$6.3 billion and Can \$1.8 billion, respectively, on ornamental products and landscape services (Deloitte 2009; Canadian Ornamental Horticulture Alliance 2013). The growth of medium sized nursery/garden center outlets and the expansion of large retailers such as Walmart has facilitated greater consumer spending on ornamental products.

How the establishment of Free Trade Agreements and the lowering of tariffs and non-tariff barriers impacted the Canadian horticultural industry can be partially gleaned from horticultural trade statistics on imports. While non-potato vegetable species accounted for few PBR applications, Canadian imports of field and greenhouse vegetables (e.g., lettuce, tomato, pepper, cauliflower, broccoli, cabbage, onion, and shallot) increased by 46% from \$ Can 2.3 billion in 2011 to Can \$3.4 billion in 2015 with most imports originating from the United States and Mexico (Agriculture and Agri-food Canada 2017d). Such a reliance on foreign markets for fresh vegetable supplies may be attributed partly to the seasonality of production in Canada and the limited R&D capacity to develop new vegetable varieties for the domestic farming community.

The combination of the boom in new home construction, demographic changes, and concerns for a greener environment have all contributed to the growth in demand for floriculture and nursery products (Bloskie 2004). Over the years Canada has been a net importer of ornamental products from the world with the majority of imports comprising bulbs, tubers and live plants. The United States, Colombia and the Netherlands are the top three ornamental product supplier countries. Figure 8 shows Canada's flower and bouquet bud imports from the world increased from Can \$49 million in 1990 to Can \$156 million in 2014. Flower imports like rose jumped from Can \$6 million in 1990 to Can \$71 million in 2014.

Horticultural product imports over the years appear to be driven primarily by demand influenced partly by the relatively weak value of the Canadian dollar, lowering of non-tariff trade barriers, and the seasonality of domestic production. While Canadian public research institutions have suffered budget cuts over the years, which have impeded their capacity to develop new crop innovations, Canada continues to rely on foreign horticulture imports to satisfy the demand of the domestic market.

CONCLUSION

Plant variety protection policies such as the PBRA were adopted by Canada in the 1990s to comply with international obligations and to provide patent-like protection for public and private plant breeding companies to develop new varieties for the Canadian industry. The PBRA has provided plant breeders with specific plant breeders' rights to compensate for their R&D efforts and allowed Canadian producers to access foreign planting material. Given the importance of horticulture crops in Canada's agricultural production landscape, it is not very evident whether PVP policies have influenced the development and adoption of new vegetable (non-potato) and ornamental products and as a consequence reduced the reliance on foreign imports. Our study

results show that most horticultural applications are granted to ornamental species and were filed by multinational European and U.S. private companies. Canadian potato PBR applications by public and private institutions account for 15% of total potato PBR filings with most of them accounted for by AAFC, while the bulk of applications were from the United States and Europe, notably the Netherlands. Although new Canadian apple, strawberry, raspberry and cherry varieties represent respectively about 48%, 27%, 27% and 81% of total PBR applications, blueberry varieties account for a relatively few Canadian applications. AAFC applications of apple, strawberry, raspberry and cherry were 35%, 21%, 27% and 53%, respectively.

This study argues that stronger forms of IPR and the development of alternative innovation processes such as open source approaches (e.g., University of California Public Intellectual Property Resource for Agriculture) are needed to hasten the commercial development of new horticultural products in the market place and spur companies to develop and merchandise new products. The conclusions are based on the examination of evidence from published studies that suggest that PBR is a relatively weak form of protection since Canadian public institutions and private companies find it difficult to appropriate the returns from their R&D investment. Our study shows that PBR applications in the horticulture sector over the last twenty five years, especially for ornamental crop varieties, have declined since 2005 which may be reflective of a weak intellectual property environment based on UPOV 78. Since horticultural crops are a heterogeneous group it would be prudent for government policy makers to consider stronger instruments of PVP to foster the domestic development of horticultural crops. The existing Canadian PBRA, which is a multipurpose plant variety protection regime for both sexually and asexually reproduced plants, may not be applicable to crop types such as ornamentals, where hybridization has allowed trade secrets to be used to protect and

commercialize varieties in the market place. Trademarks have been used in the U.S. fruit and ornamental industry as a marketing tool by breeders or propagators when selling propagated material and which can highlight plant attributes associated with commercial cultivars and to maximize premiums beyond the life of the plant patent (Drew 2010).

The Canadian PBRA may have fostered greater trade and served as a marketing tool for foreign companies to merchandise their new ornamental varieties in Canada rather than providing incentives for private companies to invest in plant breeding in the country. The recent updating of the PBRA (2015) and the extension of protection to harvested material as foreseen by UPOV 91 may provide a stronger intellectual property environment to attract foreign investment and speed the development of new varieties and plants. Strengthened IPR policies worth further exploration include plant patents which can protect ornamentals that are reproduced asexually. Derzko (1994) suggests that the reproductive characteristic of plants makes it challenging for new plants to satisfy the usefulness and non-obvious requirements of the Canadian Patent Act. Moreover, the UPOV provision to allow farmers to save seed and the difficulty of enforcing patent rights for plants against infringement can impede the patenting of crop innovations (Sanderson 2007). In the United States, competitive forces have pushed public institutions like universities towards plant patents and exclusive marketing arrangements for fruit innovations with strengthened royalty sharing agreements necessary to allow market returns to cover research costs (Stallmann and Schmid 1987). This approach may be necessary in Canada for tree fruit protection because of high development costs coupled with the long time required to develop and test new fruit varieties.

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Table 1. Horticulture Plant Breeders' Rights (PBR) application by crop group, 1992-2014

Crop	Frequency	Percent
Fruit	449	6.5
Ornamental	5,802	83.9
Vegetable	662	9.6
Total	6,913	100.0

Table 2. Horticulture PBR application by country of origin, 1992-2014

Country/region	Frequency	Percent
Canada	378	5.47
Japan	508	7.35
Major Europe ^a	3,200	46.29
Minor Europe ^b	313	4.53
New Zealand/Australia	228	3.30
USA	2,253	32.59
Other ^c	33	0.48
Total	6,913	100.00

^a Includes Switzerland, Netherlands, Germany, and Denmark.

^b Includes United Kingdom, Ireland, Austria, Belgium, France, Italy, Spain, Sweden, Hungary, Poland, Czech Republic, and Russian Federation.

^c Includes Israel, China, Republic of Korea, Argentina, Chile, Costa Rica, and Republic of South Africa.

Table 3. Accepted PBR applications for principal ornamentals by country of origin, 1992-2014.

Crop class	Canada	U.S.	Europe	Australia	New Zealand	Japan	Other countries	Total
Ornamentals								
Rose	19	92	472	-	1	-	-	584
Pelargonium	-	223	357	-	-	-	-	580
Impatiens	-	265	241	1	-	27	7	541
Chrysanthemum	10	260	259	-	-	-	1	530
Petunia	3	114	78	22	-	112	-	329
Calibrachoa	-	94	128	-	-	106	-	328
Verbena	-	108	111	-	-	38	-	257
Poinsettia	1	75	170	8	-	-	-	254
Osteospermum	-	28	104	-	-	25	-	157
Dahlia	-	33	71	-	-	-	-	104
Kalanchoe	-	19	82	-	-	-	-	101
Argyranthemum	-	8	28	53	-	-	-	89
Hydrangea	-	48	29	-	-	6	-	83
Nemesia	-	20	53	1	-	9	-	83
Diascia	-	26	36	7	-	6	-	75
Others	64	549	803	74	18	179	20	1707
Total	97	1962	3022	166	19	508	28	5802

Table 4. Accepted PBR applications for principal vegetables, and fruits by country of origin, 1992-2014.

Crop class	Canada	U.S.	Europe	Australia	New Zealand	Japan	Other countries	Total
Vegetables								
Potato	90	120	395	3	2	-	2	612
Lettuce	5	8	4	-	-	--	-	17
Tomato	-	4	5	-	-	-	-	9
Pepper	-	4	4	-	-	-	-	8
Cucumber	-	-	6	-	-	-	-	6
Others	2	7	1	-	-	-	-	10
Total	97	143	415	3	2	-	2	662
Fruits								
Apple	61	17	31	4	15	-	-	128
Strawberry	31	63	20	-	-	-	-	114
Blueberry	2	30	-	-	1	-	-	33
Raspberry	9	12	7	-	5	-	-	33
Cherry	26	-	6	-	-	--	-	32
Pear	14	-	5	-	2	-	2	23
Grapevine	10	4	1	-	-	-	-	15
Peach	11	-	-	-	2	-	-	13
Others	20	22	6	1	8	-	1	58
Total	184	148	76	5	33	-	3	449

1
2 **Table 5.** Top PBR applicants by horticulture crop class: ornamentals, vegetables and tree fruits.

Ornamentals			Vegetables			Tree fruits		
Applicant name	Number	Share (%)	Applicant name	Number	Share (%)	Applicant name	Number	Share (%)
Syngenta	951	16.4	HZPC Holland B.V.	94	14.2	Agriculture Canada ^a	112	24.9
Ball Horticultural Company	551	9.5	U.S. universities	79	11.9	U.S. universities	51	11.4
Poulsen Roser A/S	327	5.6	Agriculture Canada ^a	59	8.9	Driscoll Strawberry	50	11.1
Suntory Flowers Ltd	314	5.4	Agrico	38	5.7	Canadian universities	41	9.1
Klemm, Nils	303	5.2	Europlant Pflanzenzucht GmbH	32	4.8	New Zealand Horticulture Research & Food Institutes	26	5.8
Aris Horticulture, Inc.	245	4.2	Frito-Lay	23	3.5	Canadian private sector/individuals	25	5.6
Goldsmith Seeds Inc.	222	3.8	Saka Pflanzenzucht GmbH	22	3.3	Fall Creek Farms Inc.	10	2.2
Florfis AG	215	3.7	Irish Potato Marketing Ltd	22	3.3	Seminis Vegetable Seeds Inc.	3	0.7
Paul Ecke Ranch, Inc.	158	2.7	Germicopa SAS	22	3.3			
Spring Meadow Nursery, Inc.	157	2.7	Seminis Vegetable Seeds, Inc.	19	2.9			
All applicants	5802	100.0	All applicants	662	100.0	All applicants	449	100

3 ^a equivalent to Agriculture and Agri-Food Canada (AAFC)

Fig. 1. Horticulture crops plant breeders' rights (PBR) applications, grants and grant lag, 1992-2014.

Source: de Wit, M. 2015. Plant Breeders' Rights Office. Canadian Food Inspection Agency. Ottawa. Ontario

Fig. 2. Canada, United States, Europe, and Japan horticulture crops PBR applications, 1992-2014.

Source: de Wit, M. 2015. Plant Breeders' Rights Office. Canadian Food Inspection Agency. Ottawa. Ontario

Fig. 3. Ornamental PBR applications by the top five crop types, 1992-2014

Source: de Wit, M. 2015. Plant Breeders' Rights Office. Canadian Food Inspection Agency. Ottawa. Ontario

Fig. 4. Potato PBR applications and varieties registered, 1992-2014

Source: de Wit. M. 2015. Plant Breeders' Rights Office. Canadian Food Inspection Agency. Ottawa. Ontario

Fig. 5. The top five fruit PBR applications, 1992-2014

Source: de Wit, M. 2015. Plant Breeders' Rights Office. Canadian Food Inspection Agency. Ottawa. Ontario

Fig. 6. Agriculture and Agri-food Canada (AAFC) shares of royalty revenues by horticulture crop types.

Source: Bernadette, J. 2015. Tabulation Royalty Data Request. Financial Management Advisor for Science and Technology Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario

Fig. 7. Canada horticulture crops farm cash receipts by greenhouse & field vegetables, floriculture, nursery, sod & Christmas trees, potatoes, tree & small fruits, honey & maple products, 1990-2014.

Source: Statistics Canada. 2015.

Fig. 8. Canadian flowers and flower bouquets imports, 1990-2014

Note: Canada-Costa Rica Free Trade Agreement (FTA) and Canada-Colombia FTA came into effect on 2002 and 2011, respectively.

Source: Mukezangango, J. 2015. Agriculture and Agri-food Canada. Horticultural and Cross-Sectoral Division, Ottawa, Ontario.