AGRONOMIC AND DEMOGRAPHIC ASSESSMENT OF FIELDS AND FARMERS INVOLVED IN A PESTICIDE FREE PRODUCTION (PFP) PILOT PROJECT IN MANITOBA

BY

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ABSTRACT

Nazarko, Orla M. M. Sc. University of Manitoba, August 2002. Agronomic and Demographic Assessment of Fields and Farmers Involved in a Pesticide Free Production (PFP) Pilot Project in Manitoba. Major Professor: Dr. Rene Van Acker

Limited adoption of existing strategies for pesticide use reduction led to the development of Pesticide Free Production (PFP). This alternative crop production system was developed by Manitoba farmers, researchers, and extension workers in 1999. PFP is intended to be a flexible, straightforward framework for reducing pesticide use that will appeal to a broad range of Manitoba farmers. The guidelines prohibit the use of in-crop pesticide use, seed treatments, and prior use of residual pesticides. However, a pre-emergent application of a non-residual pesticide such as glyphosate is permitted, as is synthetic fertilizer use. The agronomic and demographic characteristics of fields and farmers involved in a PFP pilot project were characterized.

Seventy-one farmers volunteered 120 fields for inclusion in the project. Fields and farmers were categorized into one of three groups, based on whether or not PFP certification was achieved. If certification was achieved, fields and farmers were further categorized based on whether or not the field or farm was in transition to organic production. Eleven crops were included in the project, primarily spring and winter cereals and flax (*Linum usitatissimum* L.). Overall, 68% of fields and 83% of the land base volunteered was certifiable as PFP, with higher levels of certification in spring cereals and lower levels in canola (*Brassica napus* L. and *B. rapa* L.) and winter wheat (*Triticum aestivum* L.). Over 2300 ha were certifiable as PFP. The primary reason for farmer interest in PFP was to reduce input costs. Farmers without certifiable fields tended to be more interested in marketing opportunities than farmers with certifiable fields. Participants volunteered from virtually all agricultural regions of Manitoba. However, there were proportionally more participating fields from regions that typically have higher levels of cattle and forage production, and reduced or zero-tillage. Yields were not significantly different among groups. Yields of certifiable PFP crops were 90% and 84% of the long-term yield average in fields not in transition to organic and fields in transition to organic, respectively. Weed densities in certifiable fields were 110 plants m^{-2} and 112 plants m^{-2} in fields not in transition to organic and fields in transition to

organic, respectively, and were not significantly different among groups. Weed densities in certifiable fields were considered to be relatively light on the basis of comparison with pre- and post-spray weed densities for this region, and participating farmers' indication of the severity of weed pressure. Farmers indicated high satisfaction with the outcome of certifiable PFP. Residual weed populations were not an issue for the majority of farmers, and few indicated that they expected to increase future pesticide use as a result of producing a certifiable PFP crop.

Management practices most commonly indicated for use in PFP were crop rotation with forages, increased seeding rates, and delayed seeding. Certifiable PFP tended to be more common among farmers who demonstrated active preparation for a reduced-pesticide year. As herbicide use decreased among groups, an increase in the use of tillage was evident. Results indicate that soil conservation practices may be more frequently implemented in cropping systems utilizing PFP than those in transition to organic production.

In general, farmers participating in the project, particularly those not in transition to organic, were typical of Manitoba for most demographic variables, including farm income, farm and field size, age, and off-farm employment. One exception was that all participant groups had higher levels of education than a random sample of Manitoba farmers. The regional distribution of participants, crop choice for PFP, and farmers' decisions to retain relatively small and weed-free fields for certifiable PFP demonstrated a tendency for PFP to be implemented in relatively low-risk situations. However, in the context of typical Manitoba farm operations, PFP was implemented on relatively large fields and farms, indicating the potential for its implementation on a commercial scale.

The finding that farmers implementing PFP can be considered mainstream is a critical one, as it suggests that there is the ability of PFP or other intermediate strategies to be implemented by a large segment of the farm population in Manitoba. In this way, PFP has the potential to have a significant impact by providing a framework for pesticide use reduction.

FOREWARD

This thesis has been written in manuscript style. The manuscripts were prepared in accordance with the style requirements of the Canadian Journal of Plant Science.

GENERAL INTRODUCTION

Pesticide use in Western Canada is extensive, despite growing awareness of its associated problems. Concerns regarding the use of pesticides include the effect of pesticides on non-target organisms (Carson, 1962), increasing pesticide resistance (Beckie et al., 1999), pesticide residues in groundwater (Pantone, 1992), and crop losses due to pesticide drift (Pimentel et al., 1993b). The simplified cropping systems made possible by pesticide use are vulnerable to disasters like pesticide resistance and extreme weather (den Hond et al., 1999). In addition to the environmental and health concerns related to pesticide use, they represent a significant cost to farmers (8% of total farm costs in Manitoba; Manitoba Agricultural Review, 2000). This is particularly important in the face of stagnant net farm incomes and rising input costs (Manitoba Agricultural Review, 2000). In fact, the financial situation of many Western Canadian farmers is one of crisis (Boyens, 2001).

In response to these concerns, various initiatives exist to reduce pesticide use. These include government-funded strategies such as Ontario's Food Systems 2002 (Hamill et al., 1994), grassroots initiatives such as organic farming, frameworks arising out of academic debate (e.g. Integrated Pest Management (IPM)), and consumer-driven approaches such as the labeling of food produced with reduced amounts of pesticides (Kane et al., 2000).

Existing strategies for reducing pesticide use in Manitoba have suffered from limited adoption. While the membership of the largest organic producers' organization in Manitoba is increasing by approximately 13% per year, membership accounts for only 2% of Manitoba's farm population, and the area in organic production comprises only 0.1% of field crop acreage in Manitoba (Unpublished data, Organic Producers Association of Manitoba). The transition process from conventional to organic production can be challenging for producers because of financial and social pressures, as well as the requirement to learn fundamentally different management practices (Durham, 1999).

Several authors have called for more flexible frameworks for reduced pesticide use (Swanton and Weise, 1991; Stenholm and Wagonner, 1990; Morris and Winter, 1999); however, such concepts have not been widely implemented (Sutherland, 2000).

The limited of adoption of Integrated Pest Management (IPM) or Integrated Weed Management (IWM) is due in part to farmers' perception that it is complicated and difficult to implement (Bultena, 1995). Some authors (e.g. Buhler et al., 2000) blame current economic conditions and policies for low adoption of IPM. These conditions often result in larger operations and decision-making based on short-term profit motivations, and as such conflict with the longer-term perspective required by IPM.

Studies of the agronomic characteristics of fields and farms practicing low-input agriculture address a range of production systems, from organic agriculture to various frameworks for reduced inputs (e.g. IPM). Several studies have found that organic yields can, in some cases, be reduced from conventional yields for some crops (Lockeretz et al., 1981; Stanhill, 1990).

In Western Canada, weeds dictate many crop production practices (Wyse, 1994), and herbicides represent over 70% of total pesticides used in Canada (Hamill et al., 1994). As a result, weed control is likely to be the major to pesticide use reduction in Western Canada. Weed densities and communities have been found to be different in organic versus conventional fields (Leeson et al., 1999; Entz et al., 2001).

Reducing herbicide use has led to concern about escalating weed populations and yield reduction in future years (Czapar et al., 1997; Bellinder et al., 1994); others have found this to be a manageable issue (Buhler, 1999b). However, little is known about this issue. The impact of residual weed populations in future crops varies, and its seriousness is likely related to management of the cropping system (Légerè et al., 1996).

A broad range of mechanical and cropping-systems based methods of weed control are used in organic production (Bond and Grundy, 2000; Frick, 2000). Biologically robust cropping systems that are less susceptible to weed proliferation and interference may allow for reduction in herbicide use (Van Acker et al., 2000). For example, crop rotation is often beneficial in allowing for reduced inputs (Liebman and Dyck, 1993). Forages are often cited as being particularly beneficial (e.g. Schoofs and Entz, 2000). Some crops (Lawson, 1994) and regions (Constance et al., 1995) may be particularly appropriate for reduced-input systems.

In addition to the agronomic considerations associated with reduced pesticide use, demographic and attitudinal characteristics of farmers may be important in determining the adoption or success of such strategies. According to the traditional theory of technology adoption, the adoption of new technologies in agriculture is related to demographic characteristics and has often been found to occur initially among farmers who are younger, better educated, operate larger farms, and own rather than rent land (Bultena and Hoiberg, 1983). However, 'environmental innovations' in agriculture (such as IPM) are considered to be fundamentally different from traditional agricultural technologies (Vanclay and Lawrence, 1994; Saltiel et al., 1994; Black, 2000; de Buck et al., 2001). Environmental innovations differ from traditional technological innovations in that they are complex packages of methods, and they are not universally applicable (different practices are appropriate for different farms). In addition, the benefits of such practices do not necessarily accrue to the adopter themselves, but rather to society as a whole (for example, practices that prevent groundwater contamination) (Saltiel et al., 1994). Therefore, traditional theories of technology adoption may not adequately describe the adoption of environmental innovations. In particular, different demographic and attitudinal variables may be important in the adoption of such practices.

Some studies have found attitudinal and demographic differences between farmers practicing conventional agriculture and those practicing reduced-input agriculture (primarily organic). Farmers with reduced-input practices have been found to have different attitudes about the nature and practice of agriculture (Beus and Dunlap, 1991). Comer et al. (1999) found that such farmers are younger, have more education, and have more off-farm income. However, other studies have found that there are few demographic differences between these groups (Saltiel et al., 1994; Durham, 1999; Lockeretz et al., 1981).

In response to the limited success of currently available frameworks for pesticide use reduction, Pesticide-Free Production (PFP) was developed by Manitoba farmers, researchers (University of Manitoba and Agriculture and Agri-Food Canada - Brandon), and extension workers (Manitoba Agriculture and Food) in 1999. PFP is intended to be a flexible, straightforward framework that will appeal to a broad range of Manitoba farmers. The guidelines prohibit the use of in-crop pesticide use, seed treatments, and prior use of residual pesticides. However, pre-emergent applications of non-residual pesticides like glyphosate are permitted, as is synthetic fertilizer use. As weeds are the major pest problem in Western Canada, PFP is likely to be limited primarily by weed control. The recent development of PFP as an alternative framework for pesticide reduction means that there is limited information available regarding the nature of fields and farmers involved in attempting PFP. In order to provide a basis for assessing the potential for widespread implementation of PFP in Manitoba, the agronomic and demographic characteristics of fields and farmers attempting PFP need to be characterized.

The objective of this study was to describe the agronomic characteristics of fields and farms that were involved in a PFP pilot project, as well as the demographic and attitudinal characteristics of the farmers who participated in the pilot project. Consideration was given to the typical mean and distribution of these variables in Manitoba, in order to provide a basis for assessing the potential of PFP to be widely adopted in Manitoba.

CHAPTER 2

LITERATURE REVIEW

Introduction

The environmental problems of North American agriculture have received increasing attention in recent years. Concerns about soil erosion, nitrate pollution of groundwater, decreasing genetic diversity, and increasing pesticide use have contributed to the promotion of more sustainable farming practices.

Sustainable Agriculture

DEFINITION. There is no generally acknowledged definition of sustainable agriculture (Lewandowski et al., 1999, Rigby and Caceres, 2001). Rigby and Caceres (2001) note that at least 386 definitions of sustainable development exists; however, they argue that this does not mean that the concept is so vague as to be meaningless. Many difficult-to-define concepts are nonetheless valuable. Sustainable agriculture is largely a reaction to the negative aspects of conventional agriculture (Schaller, 1990). Practices referred to as sustainable range from those that easily fit within the current model of agriculture (e.g. reduced pesticide rates), to those that require a complete rethinking of the system (e.g. Natural Systems Agriculture; Soule and Piper, 1992) (Saltiel et al., 1994). In practice, sustainable agriculture generally emphasises reducing the reliance of external inputs, particularly fertilizers and pesticides, by substituting management of a farm's internal resources (Wyse, 1994).

Gips (1988) notes that most definitions of sustainability focus on both short- and long-term success. Definitions of sustainability often include 3 major categories: economic, social, and ecological aspects (Lewandowski et al, 1999; Gips, 1986; Stenholm and Wagonner, 1990). Lewandowski et al. (1999) argue that given the dependence of agriculture on natural resources, ecological concerns should form the basis for defining sustainability. Some definitions of sustainable agriculture focus on methods to achieve sustainability, while others focus on defining the end goal of such methods

(Schaller, 1990). Rigby and Caceres (2001) describe the pursuit of sustainability as asymptotic process converging towards, but never reaching, an endpoint. While many definitions focus primarily on the productive capacity of the agroecosystem, others explicitly include issues of social justice. Virtually every interest group agrees that sustainability should be promoted, leading some authors to argue that its definition is inherently political (Rigby and Caceres, 2001). As a result, the debate over who defines the criteria of sustainability involves issues of race, class, and gender (Dlott et al., 1994), and definitions vary widely.

Many organizations have presented their definitions of sustainable agriculture (e.g. the Leopold Centre, the American Society of Agronomy, the Consultative Group on International Agricultural Research). These definitions are often so broad as to make them seem unachievable. For example, according to the US Food, Agriculture, Conservation, and Trade Act of 1990 (the US "Farm Bill"), sustainable agriculture is

> "an integrated system of plant and animal production practices having a site-specific application that will, over the long term: satisfy human food and fiber needs, enhance environmental quality and the natural resource base upon which the agricultural economy depends, make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, sustain the economic viability of farm operations, and enhance the quality of life for farmers and society as a whole." (Alternative Farming Systems Information Centre, 2002).

ASSESSING SUSTAINABILITY. Despite the difficulties inherent in defining sustainable agriculture, there have been attempts to quantify the sustainability of agricultural systems. Sands and Podmore (2000) argue that such quantification of sustainability is necessary in order to appraise and implement appropriate practices. It may also act as a precursor to legislation promoting sustainability. However, El-Swaify (2000) argues that practices to achieve sustainability are continually evolving, and a complete framework for sustainability, including indicators, criteria, standards, and thresholds, is not necessary before changes to the current system are initiated.

Interest in quantification of sustainability has led to the development of sustainability indices. An example is the Environmental Sustainability Index by Sands and Podmore (2000), which is described by the authors as only one component of a full economic, ecological, and social sustainability index. The authors conclude that the index is capable of demonstrating clear differences between crop management systems.

There are difficulties associated with sustainability indices. Sands and Podmore (2000) note that the index they developed is limited by its site-specificity, which may limit the use of indices in general. Rigby and Caceres (2001) further argue that the scale at which sustainability is assessed will affect the conclusion as to whether or not a system is sustainable.

Pesticide Use in Agriculture

CONCERNS WITH PESTICIDE USE. Much of the focus on the ecological consequences of modern farming is related to the use of agrichemicals, in particular pesticides. Pesticides are designed to reduce crop losses due to pests; however, while pesticide use has increased, proportional crop losses due to pests have not decreased (Pimentel et al., 1993a). In the case of insect pests, crop losses have actually doubled despite a 10-fold increase in insecticide use between 1945 and 1989, attributable in part to the simplification of crop rotations (Pimentel et al., 1993b). This has led some observers (den Hond et al., 1999) to suggest that pesticide technology is not durable. It is estimated that 37% of US crop production is lost to pests (13% due to insects, 12% due to disease, 13% due to weeds) (Pimentel et al., 1993a). Pesticide use in the US has increased 33-fold since 1945 (Pimentel et al., 1993a).

There are a number of issues associated with pesticide use. The publication of *The Silent Spring* by Rachel Carson in 1962 was instrumental in raising public awareness of the effects of pesticides, particularly DDT, on non-target organisms (Paarlberg and Paarlberg, 2000). As much as 99% of all pesticides applied do not reach the target organism (Pimentel and Levitan, 1986).

The resistance of pests to pesticides is a growing concern. One-half of all Prairie fields in Western Canada are estimated to contain wild oats (*Avena fatua* L.) resistant to ACCase inhibitors (group 1 herbicides), resulting in $4 million (Can) in additional control costs for farmers annually (Beckie et al. 1999). While pesticide resistance threatens to render some herbicides ineffective, development of new pesticides is limited as research and development costs have increased (Buhler et al., 2000). Currently, it can take up to 10 years and $100 million (Can) to develop and register a new pesticide (CropLife Canada, 2001). Pesticide resistance can be delayed by reducing the selection pressure of pesticides. Eliminating pesticide applications can act to reduce selection pressure (Beckie et al., 1999).

There is also public concern about pesticide residues on food (Byrne et al., 1991) and in groundwater (e.g. atrazine; Pantone et al., 1992). Acute and chronic pesticide poisoning of humans is a further consideration. Twenty thousand illnesses in the US annually are attributed to occupational on-farm use of pesticides (Van Tassell et al., 1999). In New Zealand, 4.4% of farmers were negatively affected by chemicals within a 1-year period (Fairweather, 1999).

Pesticide use can allow for outbreaks of secondary pests. These are species whose populations were previously controlled by natural enemies, but whose natural enemies were eliminated through pesticide use (Pimentel et al., 1993b). Insect populations can rebound to higher levels when insecticide is applied compared to untreated areas, also due to the loss of natural enemies of the pest (van den Bosch, 1978). These phenomena, coupled with pesticide resistance, led van den Bosch (1978) to argue that pesticide use can lead to more pesticide use. He referred to this idea as 'the pesticide treadmill.'

Pesticide use can also result in the loss of crop pollinators, honeybee losses, losses to the fishery industry, and social and environmental costs incurred by governments to mitigate the effects of pesticides (Pimentel et al., 1993b). Pesticide drift, improper application timing, and soil residual pesticides can reduce crop yields, while the rotational restrictions caused by residual products limit farmers' crop selection (Pimentel et al., 1993b). A conservative estimate suggests that the annual environmental and social costs of pesticides in the US are at least $2.2. billion (US) (Pimentel et al., 1993a). This is in addition to the $7 billion (US) spent on pesticides annually (1994 value) (Fernandez-Cortez and Castaldo, 1998).

BENEFITS OF PESTICIDE USE. There is significant interest in maintaining the use of pesticides in agriculture. The advent of herbicides was one of the most important advances in industrial agriculture (Pike et al., 1991). Since the 1940's pesticides have contributed to a 75% reduction in agricultural labour requirements and a 2.3-fold increase in productivity (Van Tassell et al., 1999). Agrichemicals have allowed farmers to achieve higher yields per unit land area with less labour and lower production costs (Lockeretz et al., 1981). Hall et al. (2000) cite increased food security and soil conservation as benefits of herbicide use. Zocshke (1994) argues that farmers use herbicides because they increase crop yield and quality, aid harvesting, ease working conditions, allow more time for leisure and education, and make more efficient use of land. Urech (2000) argues that in the European Union (E.U.), pesticide testing is so rigorous that many concerns about the hazards of pesticides are unwarranted.

The traditionally dominant attitude in agriculture has been the belief that chemical use is an indispensable part of productive, profitable agriculture, and that serious adverse consequences will occur if it is eliminated (Lockeretz et al., 1981). The agro-industrial sector has the power to influence farmers' pesticide use decisions (Gerlter, 1992). Influence occurs through contract production, advertising and consulting services, particularly when independent consultants are unavailable. Members of the agrichemical industry (e.g. Urech, 2000) argue that chemical control is an integral component of sustainable agriculture because it allows for conservation tillage and harvests of reliable quality and quantity. In addition, Urech (2000) argues that pesticide use allows for intensive crop production so that marginal lands need not be farmed, and can be used instead as wildlife habitat.

At a farm scale, pesticide use has allowed for independence from the traditional reliance on crop rotation and livestock in farming systems; however, this increased specialization has made many agricultural systems vulnerable to disasters like pesticide resistance or extreme weather (den Hond et al., 1999). Ikerd (1990) argues that specialization as a way to improve farm profitability has declined due to rising costs associated with risk and resource depletion. Historical evidence also suggests that extreme specialization is not sustainable. The "Bonanza farms" of the Red River Valley in the late 1800s were exclusively wheat (*Triticum aestivum* L.) farms covering between 40,000 and 80,000 acres. By the 1920s insect, disease, and yield problems associated with exclusively wheat farming forced these farms out of business (Prairie Public Television, 2000).

Critics of agrichemical reduction argue that low input systems are necessarily low output and cannot compete commercially with high-input systems (Ikerd, 1990). In contrast, Scaling (1990) argues that low-input agriculture can, in some cases, reduce costs and increase net profit for farmers. Low-input strategies have also been criticized as relying on out-dated technologies rather than accepting current or future technology; however, others see low-input agriculture as combining traditional concepts with new technology (Ikerd, 1990).

There is ongoing debate as to whether or not reductions in pesticide use would result in significant yield losses. In his extensive review, Stanhill (1990) found that yields of organic crops were the same or higher than conventional crops in half of cases, and lower in half. CropLife Canada (2001) estimated that without pesticides, yields in Canada could decline by as much as 40% and production costs could rise by over 30%. Yield declines due to reduced pesticide use are considered to be particularly important in the face of an increasing world population. However, producing more food does not automatically reduce hunger (Halweil, 2002). Much grain produced in North America is used for animal feed, many crops are grown for non-food uses, and the malnutrition is often due not to lack of food production but rather political issues of food and income distribution, poverty, and war. Indeed, Pimentel (1993a) notes that overproduction in the US is the primary reason price supports for crops are required.

ASSESSING PESTICIDE REDUCTION. Accurate assessment of reduction in pesticide use is complicated by the lack of effective measurement criteria, as well as by underlying trends in the pesticide industry. Griffiths (1994) noted that long-term reduction in the amount of herbicide active ingredient used in US sugar beet production has been due primarily to a shift from pre-plant incorporated and pre-emergence treatments to post-emergence treatments. Pike et al. (1991), in a case study of herbicide use in Illinois since the 1950s, also noted significant shifts in herbicide technology. Herbicide use rates and prophylactic treatments decreased while post-emergent treatments increased. These changes were driven by a desire for more flexible and convenient herbicides, rather than a specific interest in reducing herbicide use (Griffiths, 1994).

Simple measurements of pesticide use reduction include the amount of product applied per hectare, amount of active ingredient applied per hectare (ai/ha), treatment frequency, and number of treated hectares (Bellinder et al., 1994). However, there is no effective way of evaluating pesticide reduction with confidence (Bellinder et al., 1994). The amount of ai/ha applied is relatively easy to measure, but low dose per unit area does not necessarily mean low environmental impact, as toxicity of pesticides varies. Treatment frequency, used by the Danish government, is defined as the number of recommended doses with which the total agricultural area is treated annually (Bellinder et al., 1994). This method is independent of product dosage. The fact that the Danish government was able to mandate a reduction in pesticide use in terms of ai/ha, but not treatment frequency, highlights the inherent differences in these measurement criteria (Bellinder et al., 1994).

A more integrated measurement of the impact of pesticide use is the Environmental Impact Quotient (EIQ), proposed by Kovach et al. (1992). This index is constructed by summing the average toxicities of each pesticide based on several criteria: effects on farm workers, effects on consumers, and effects on the environment. It is then multiplied by the rate at which the pesticide is used as well as the frequency of application. However, this index has been criticized because it failed to consider the impact of environmental variables on the effect of pesticides (Bellinder et al., 1994).

POLICY INITIATIVES TO REDUCE PESTICIDE USE. In response to numerous concerns about pesticides, many government and research agencies have initiated efforts to encourage reductions in pesticide use. For example, the Danish government began taxing pesticides at 25 to 35% in 1995 (Kane et al., 2000). In Canada, 3 provinces (Ontario, BC and Quebec) had pesticide-reduction strategies as of 1994 (Hamill et al., 1994).

Pesticide use reduction by government mandate has been employed in Sweden, Denmark, and Holland (Bellinder et al., 1994). In 1985, Sweden mandated a 50% reduction in agricultural pesticide use by 1990, and further 50% reduction by 1997, based on kilograms of active ingredient (kg ai)(Bellinder et al., 1994). The Danish government mandated a 50% reduction by 1997, but used a combination of ai/ha and treatment frequency as a measurement; Holland mandated a 50% reduction by 2000 (Bellinder et al., 1994). The reductions were accomplished by expanding the extension service to promote pesticide reduction, withdrawing some pesticide products, switching from high-dose (phenoxys) to low-dose products (ALS inhibitors or group 2 herbicide products), improving sprayer precision, and reducing herbicide rates. Most of the use reduction achieved was in cereal crops, highlighting the fact that the cropping system strongly impacts the effectiveness of such strategies: in less competitive crops, efforts to reduce herbicide use were not very effective (Bellinder et al., 1994). During the same time period as the Holland initiative, U.K. countries achieved an equivalent reduction in ai/ha without government intervention, because of changes in herbicide technology; however, the actual area of crops sprayed remained the same (Lawson, 1994). This led Lawson (1994) to point out that advances in technology are as important, if not more so, than government mandates. In Ontario, the Food Systems 2002 initiative announced in 1988 was intended to reduce pesticide use by 50% by 2002, through research, education, and infrastructure (i.e. extension) (Swanton et al., 1993). Gallivan et al. (2001) found that between 1983 and 1998, pesticide use in Ontario (measured as kg ai) decreased by 39%, and risk (as measured by the EIQ) declined by 40%.

Some initiatives designed to improve the adoption of reduced-pesticide practices involve government payments. As of 1995, the UK government provided payments to farmers for recreating wildlife habitat, reducing overstocking and reducing input use (Morris and Potter, 1995). The overall goal of such schemes is to shift farmers' attitudes so that they develop and implement more of a conservation ethic. Despite high enrolment in the program, many participants were only superficially involved, and they met the restrictions only in order to qualify for payment (Morris and Potter, 1995). Land set-asides can allow for significant reductions in pesticide use (Lawson, 1994). However, Morris and Winter (1990) argue that productionism-based approaches are preferable to conservationist approaches like land set aside. They argue that conservationism does not actually challenge the use of pesticides in food production.

Agricultural policies can also work against pesticide reduction. Wyse (1994) noted that US farm policies encouraged simple cropping systems, resulting in high weed populations that subsequently require pesticides. He argued that US farm policies in effect made diversification of cropping systems unprofitable. Similarly, Gertler (1992) argued that Canadian agricultural policies reduce the risks associated with simplified farming systems.

PESTICIDE USE IN CANADA. Canadian use of pesticides accounts for 3% of the world's total. This represents 6% of the amount used in the US and 10% that in the E.U. (CropLife Canada, 2001). Pesticide sales in Western Canada were just below $1 billion (Can) in 2000; herbicides represented 81% of pesticide sales, fungicides 9%, and insecticides 5% (CropLife Canada 2001). Manitoba purchases account for 15% of the total Canadian expenditure on pesticides (CropLife Canada, 2001). In Manitoba, total farm purchases of pesticides in 2000 were estimated at $230.4 million, an increase of 7% since 1999 and 25% since 1995. Pesticide costs represented slightly more than 8% of total farm costs (Manitoba Agriculture and Food Program and Policy Analysis, 2001). The increasing significance of pesticide costs is particularly important in the face of stagnant net farm incomes and rising input costs (Manitoba Agriculture and Food Program and Policy Analysis, 2001).

Herbicides are of particular interest for pesticide use reduction, as these products account for 70% of Canadian pesticide use (Hamill et al., 1994) and 85% of US pesticide use (Edwards and Regnier, 1989). Ninety-nine percent of pesticides applied to cereal grains in Ontario are herbicides (Gallivan et al., 2001). In Manitoba, less than 1% of spring cereal fields, and 0% of flax (*Linum usitatissimum* L.) and canola (*Brassica napus* L. and *B. rapa* L.) fields surveyed received no herbicide application (Thomas et al., 1999a). In Saskatchewan and Alberta, 6% and 3% of cereal fields, respectively, received no herbicide application (Thomas et al., 1999b; Thomas et al.,1999c).

YIELD LOSSES DUE TO PESTS. It is generally acknowledged (O'Donovan, 1996) that yield losses due to weeds are based on Cousens (1985) non-linear regression model. Under this model, crop yield losses are near-linear at low weed densities, but reach an asymptote at higher densities. In Western Canada, the value of such losses is estimated to exceed $500 million (Cdn) annually (Harker, 2001). The majority (84%) of this loss is in field crops rather than hay or horticultural crops (Swanton et al., 1993). There are also numerous studies indicating the yield losses caused by specific weed-crop combinations under experimental conditions (e.g. Bell and Nalewaja, 1968), but fewer that consider losses due to naturally-occurring populations of weeds in fields under farmer-managed conditions. Prior to 1960, estimates of yield losses due to weeds in farmer-managed fields ranged from 7% to 28% of total crop production (Friesen and Shebeski, 1960). Average yield loss was 17% in unsprayed fields of wheat, oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and flax fields in Manitoba, and 10% in herbicide-sprayed fields, compared to weed-free (hand-weeded) plots (Friesen and Shebeski, 1960). A more recent review of various sources (primarily experimental plots) found that average yields of weedy crops as a proportion of weed-free yields were 75% for wheat, 42% for flax, 70% for peas (*Pisum sativum* L.), and 64% for soybeans (*Glycine max* (L.) Merrill) (van Heemst, 1985). Harker (2001) compared weedy and weed-free (hand-weeded) plots in farmers' fields in central Alberta. These fields did not receive a pre-plant incorporated or pre-emergence herbicide. Yield losses were not detectable in 73% of barley, 60% of canola, and 33% of pea fields; yield loss was more closely related to year and environmental effects rather than crop stand, weed biomass, or weed density. Abernathy (1981) estimated that eliminating herbicides in the US and substituting direct non-chemical control measures (e.g. tillage, hand weeding, or biological control) would result in a loss of 31% of annual farm revenue, a rise in food costs of 50%, the need for 46% more land to maintain production, and a cessation of agricultural product available for export. Yield losses due to elimination of herbicides were estimated to be 20% in cereals, 36% in corn (*Zea mays* L.), and 24% in soybeans (Abernathy, 1981).

Swanton et al. (1993) surveyed extension and research weed scientists, who estimated average yield losses due to weeds in Manitoba were 8% in wheat, 11% in oats, 13% in canola, 16% in flax, 6% in rye (*Secale cereale* L.) and 8% in barley. In a similar study, Bridges (1992) surveyed weed scientists in North Dakota, Minnesota, and South Dakota and concluded that the costs associated with moving from current weed control practices to no herbicide use would be 3.7 times the current yield loss due to weeds in barley, 2.8 times in oats, 4.7 times in wheat, 3.8 times in flax, and 3.6 times in rye.

In addition to yield losses due to weeds, losses caused by plant diseases are estimated to exceed $9 billion (Can) annually in Canada (Martens et al., 1998). Yield losses due to insect pests can also be significant. In North America, canola yield losses due to flea beetles are estimated to exceed $300 million (Can) (Manitoba Agriculture and Food, 2001g); while cereal aphids can cause up to 50% reduction in cereal crop biomass (Manitoba Agriculture and Food, 2001h).

The Transition to Sustainable Agriculture: Technology Adoption

TRADITIONAL THEORIES OF TECHNOLOGY ADOPTION. The traditional theory of extension and technology adoption has been based on the "diffusion of innovations" model, with Rogers (1983) cited as the primary advocate of this theory. Important considerations for successful adoption under this model include the relative advantage of the innovation and its complexity (Rogers, 1983). In addition, the ability of a technology to be tried on a small scale ('trialability') or observed prior to full implementation is important. The model assumes sigmoidal growth of the cumulative percentage of adopters, which is normally distributed when graphed over time. This has led to the classification of farmers as innovators, early adopters, or laggards (Vanclay and Lawrence, 1994). Studies of "early adopters" of new farming practices show that they tend to be younger, have more education, be more receptive to risk-taking, operate larger farms, and own rather than rent land (Bultena and Hoiberg, 1983). In a study of Iowa farmers, those most likely to adopt conservation tillage were younger and believed that such practices were accepted by the farming community (Bultena and Hoiberg, 1983). Fernandez-Cornejo and Castaldo (1998) reviewed the most important factors correlated with Integrated Pest Management (IPM) adoption, including larger farm size (which is related to wealth, as well as access to credit and information), higher education, and age (younger farmers). After a practice is adopted, it may be continued, rejected, or modified by the adopter in some way (Rogers, 1983).

The diffusion of innovations theory was generally rejected in the early 1990's with no major new paradigm taking its place (Vanclay and Lawrence, 1994). Criticism of the theory has included its unquestioning acceptance of new technologies without consideration of long-term social, economic, or environmental concerns (the so-called 'pro-innovation' bias); its marginalization of farmers' knowledge, skills, and adaptive abilities; its belief that total adoption of new innovations is inevitable and desirable; and its elitist, "trickle-down" nature (Vanclay and Lawrence, 1994; Black, 2000). Rogers (1983) has also noted the 'individual blame' rather than 'system blame' bias of the model, where non-adopters are held responsible for their lack of adoption, rather than considering the broader context in which their decision not to adopt may be perfectly rational. In addition, the model has traditionally overlooked 're-invention' (modification of an innovation by adopters) (Rogers, 1983). When it has considered such adaptation, it is generally viewed as undesirable, even though it may improve the chances that an innovation will continue to be practiced. This is expressed in the nature of the adoption decision under the diffusion of innovations model, which is considered to be a dichotomous choice rather than a continuum of various levels of adoption (Rogers, 1983). The process of re-invention or rejection of an innovation after initial adoption has also been neglected by the traditional model (Rogers, 1983). Despite these criticisms, some researchers continue to subscribe to the diffusion model (although with some modifications), and it has been found to describe the diffusion of IPM among fruit growers very well (Fernandez-Cornejo and Castaldo, 1998).

It has also been argued that the diffusion model does not adequately differentiate between the adoption of commercial innovations versus "environmental innovations" (Saltiel et al., 1994, Black, 2000). Innovations under the traditional model are generally considered simple, single, add-on, "commodity" innovations (often commercialized), which require no major reworking of farm structure. Environmental innovations, Saltiel et al. (1994) argue, are very different, in that they are complex packages of methods, and they are not universally applicable (different practices are appropriate for different farms). In addition to this, the benefits of such practices do not necessarily accrue to the adopter themselves, but rather to society as a whole (e.g. the protection of water supplies). de Buck et al. (2001) also argue that the transformation to more sustainable forms of farming involves a paradigm shift that is very different from the adoption of an innovation within the same paradigm. The traditional labels of farmers as 'early adopters' or 'laggards' depend on one's perspective. For example, if chemical agriculture is considered to be innovative, the classification of who is an 'early adopter' is very different from 'early adopters' of organic farming (Rogers, 1983). The traditional theory of diffusion of innovations has done little to improve the success of environmental innovations as it has not provide an adequate framework for understanding the adoption process associated with environmental innovations (de Buck et al., 2001; Saltiel et al, 1994; Vanclay and Lawrence, 1994).

Traditionally, the process of adoption involves steps from awareness to information seeking, to opinion-forming (i.e. trial), and finally implementation (Rogers, 1983). Some researchers (cited in Constance et al., 1995), have found that the level of environmental concern is related to adoption of environmentally-friendly practices. Others, however, found that once awareness occurs, implementation does not necessarily follow. Lasley et al. (1990), in a study of Iowa farmers, found that supportive opinions about reduced input farming are not associated with actual use of practices to reduce chemical inputs.

Cochrance (1958) described the "treadmill of technology," where only the earliest adopters of a (yield-increasing) technology receive any benefits from it, because as production rises through wide adoption, prices drop, and a level playing field is again created. Others (Hamilton and Sligh, 2001) have more recently argued that this is still true for US farmers. They also note that the trend towards increased contract production in North American agriculture effectively takes the choice of adoption of new technologies or innovations out of the hands of farmers.

ALTERNATIVES THEORIES OF ADOPTION FOR ENVIRONMENTAL INNOVATIONS. An alternate framework for the adoption of environmental innovations, specifically applicable to sustainable agriculture, has been described by Hill and MacRae (1995). This framework consists of three steps: *efficiency* in the use of existing inputs, followed by *substitution* of inputs with more benign practices, and finally, *redesign* of systems to focus on what causes the need for inputs. Transitions generally follow these steps in order. Hill and MacRae (1995) state that while the first stage, efficiency, has been relatively well-researched (e.g. reduced herbicide rates), redesign has generally not been explored.

There are several considerations in the adoption process of environmental innovations (Vanclay and Lawrence, 1994). The decision to adopt a new practice is often triggered by the recognition of a problem with current operations (Rogers, 1983). Highly complex practices are less likely to be adopted, as are those practices that result in high risk, uncertainty, or a loss of flexibility in farm management. Financial concerns such as low short-term economic gain associated with a practice, as well as high capital and intellectual implementation costs, can limit adoption (Saltiel et al., 1994; Drost et al., 1996). Conflicting information about new practices also contributes to low adoption, as can excessively dramatic images of environmental degradation in the media. For example, images of severe soil erosion may be dismissed by farmers because their own experience of soil degradation is not as serious (Vanclay and Lawrence, 1994). Acceptance by the dominant farming subculture a farmer belongs to is an often cited consideration in the adoption of technology and environmental innovations (Saltiel et al. 1994; Vanclay and Lawrence, 1994; Bultena and Hoiberg, 1983, Gertler, 1992).

Divisibility of practices is also a concern (Vanclay and Lawrence, 1994). If an environmental innovation can be broken down into component parts, farmers can experiment with new ideas more easily and with less commitment than that required by full adoption de Buck et al. (2001) noted that during the adoption of the Integrated Arable Farming Systems concept in the Netherlands, even the most interested farmers often implemented only portions of the concept rather than the whole package, so that the intended coherence of the concept was lost. They note similar experiences in the adoption of IPM practices, suggesting that the "total package" approach of a dichotomous choice between two options is not realistic. Pretty (1995, p. 183) also argues that when a package of practices is finalized without farmer input, partial adoption of a package of practices may be more effective for some farmers. The involvement of farmers in adapting technologies to their conditions should be encouraged (Pretty 1995, p. 184).

CHARACTERISTICS OF FARMERS USING SUSTAINABLE PRACTICES. Several researchers have found that differences between mainstream farmers and those exploring environmentally sustainable practices are smaller than previously thought. Constance et al. (1995), in a study of Missouri farmers, found that the two groups were similar in most attitudinal and demographic variables. Saltiel et al. (1994) cite a number of studies that found no evidence of differences between organic and conventional farmers in terms of farm size, age, tenure status, or education. They argue that factors previously not considered with regard to adoption, such as national farm policies, or structural conditions of farms (e.g. whether or not they include livestock) may limit adoption. Egri (1999) states that while the adoption of environmentally-responsible practices has been found to be related negatively to age, comparative studies have generally not found significant age or educational differences between organic and conventional farmers. Female farmers have been shown to be more interested in environmentally-friendly practices, while evidence regarding the role of farm size and off-farm income is inconsistent (Egri, 1999). Durham (1999) found that organic farmers in Colorado were similar to conventional farmers in terms of age and off-farm employment. Differences lay instead in the fact that many organic farmers had not been raised on farms, had no formal agricultural education, and tended not to use traditional sources of information (universities and extension offices). Lockeretz et al. (1981) found that organic farmers in the Corn Belt were similar to conventional farmers in terms of age, farm size, machinery use, labour, and profitability; similarities between the two groups were far more apparent than differences. Comer et al. (1999) found that farmers in Tennessee self-identifying as sustainable farmers tended to be younger, have more education, and have more off-farm income than conventional farmers. de Buck et al. (2001) noted that farmers implementing the Integrated Arable Farming Systems concept in Holland (similar to IPM) differed very little from conventional farmers.

Because the approach farmers have towards agriculture may contribute to the adoption of certain practices, there have been attempts to characterize the attitudes of farmers. One common change among farmers in transition to sustainable practices is the way they view their farm and the practice of farming (MacRae, 1990). However, Fairweather (1999) notes that, in terms of policy approaches, attitudinal change is notoriously slow and difficult, and there are often other, non-attitudinal reasons for the lack of adoption of specific practices. Farmers may be aware and concerned about environmental issues, but for primarily economic reasons implementation of sustainable practices lags behind adoption (Gertler, 1992). Beus and Dunlap (1991) describe the

Alternative-Conventional Agriculture Paradigm Scale, a series of 24 questions designed to measure the basic beliefs and values assumed to represent the two competing perspectives. The instrument was found to discriminate significantly between alternative and conventional agriculturalists. Comer et al. (1999) used a modified subset of 18 questions of this scale; in a sample of 56 farmers, they found significant differences between the attitudes of conventional and alternative agriculturalists. Egri (1999) found that organic farmers in B.C., Ontario, and Saskatchewan tended to have less years of farming experience, operate smaller farms, be less dependent on farm labour than conventional farmers; but attitudes toward organic farming and agrichemicals were responsible for the most significant differences. Reasons for farmer interest in organic production have traditionally been social and environmental, but have become more economic in recent years (Cacek and Langner, 1986).

While the link between pro-environmental attitudes and organic farmers' behaviour is often evident, conventional farmers' pro-environmental attitudes are often overridden by economic factors such as profitability, productivity, and efficiency (Egri, 1999). Lasley et al. (1990) found that support for low-input practices in Iowa was normally distributed among farmers. This suggests the existence of a continuum of attitudes towards sustainable agriculture rather than discrete groups within the farm population.

In a study of Utah farmers, 90% considered themselves to be farming sustainably despite the fact that 70% had not reduced their fertilizer or pesticide use over the previous 3 years (Drost et al., 1996). Van Tassell et al. (1999), in a study of Wyoming farmers, found that more than half of the respondents used the same or higher levels of pesticides than in the previous 5 years. Of those that were reducing their pesticide use, the most common reason (37%) appeared to be reactive (i.e. because there were fewer pests or more favourable weather for pesticide application) rather than proactive efforts to reduce use.

Many farmers are reluctant to reduce pesticide use, as effective herbicides offer a very good cost-benefit ratio, and require only minimal planning or knowledge for use. The return to pesticides is estimated at $4 for every $1 spent (Pimentel, 1993b); however, in many locations, diminishing returns to increased pesticide use are occurring (Uphoff, 2002). Others argue that returns equivalent to those from pesticide use can be obtained from independent crop consultant advice (Petrzelka et al., 1997). Alternative weed control approaches often add directly to short-term costs, have benefits that become apparent only in the long term, and require more advance planning than pesticides do (Sutherland, 2001).

Organic Agriculture

DEFINITION. Organic farming is the most widely recognized form of "alternative" agriculture. It pre-dates all other alternative approaches, and is the only approach to have a history of regulation and be codified by law in many jurisdictions (Rigby and Caceres 2001). Although definitions of organic vary, and often incorporate broader philosophical elements, the primary feature of this method of farming is that it eliminates the use of all synthetically produced pesticides and fertilizers.

BENEFITS. Proponents of organic production argue that it protects the environment, minimizes pollution, maintains biodiversity, and conserves energy (Organic Producers' Association of Manitoba (OPAM), 2000). MacRae (1990) summarized potential benefits of organic production as including improved food quality, higher farm income, and enhanced human and environmental health. Rigby and Caceres (2001) reviewed the environmental impacts of organic versus conventional agriculture in Europe, and found that organic production tended to be more energy efficient, to have more floral and faunal diversity, conserve soil fertility, and to lower the risk of nitrate leaching. Brandt and Molgaard (2001) reviewed the claim that organic food is nutritional superior to conventionally produced food. They note that surveys of food products in this regard have not been conclusive, as variation among cultivars are usually greater than variation between production systems. Their only conclusive observations were that organic food had lower protein and nitrates; however, there may be some basis for health benefits of organic products via higher production of plant defence-related secondary metabolites in the absence of pesticides (Brandt and Molgaard, 2001).

LIMITATIONS. Detractors criticize organic production for making less efficient use of land resources than conventional production does, which requires marginal land to be cultivated to maintain production (Trevawas, 2001). As well, Trevawas (2001) points out that some "natural" pesticides permitted in organic production are highly toxic. The traditional dependence of organic farmers on tillage for weed control is also cited as contributing to soil erosion (Trevawas, 2001), but Lockeretz et al. (1981) found that organic farmers had adopted conservation tillage at a much faster rate than conventional farmers. More recently, Kuepper (2001) indicated farmer interest in, and described many opportunities for, reducing tillage in organic production. Liebig and Doran (1999b) found that organic farms used tillage less frequently than comparable conventional farms. Lockeretz et al. (1981) stated that some critics of organic production argue that if it were to become widespread, it would result in a sharply lower standard of living, the need for massive return of labour to the countryside, and widespread famine. MacRae's review (1990) found widely varying estimates of the increase in food costs resulting from a widespread conversion to organic production (between a 1% and a 99% increase).

Some authors equate organic production with sustainable agriculture, while others argue that a restriction on all inorganic chemical use is neither a sufficient, nor a necessary, condition for sustainability (Rigby and Caceres, 2001). Organic production has traditionally suffered from the perception that it simply involves negligence, and has had minimal research effort (Decyckx, 2001). For example, the "Bonanza farms" of the late 1800s were technically organic, but were certainly not sustainable (Prairie Public Television, 2000). One of the reasons 'organic by neglect' is a common perception is the fact that it is easier for certification purposes to assess the prohibition of practices than to dictate that positive practices be used (Rigby and Caceres, 2001).

TRANSITION TO ORGANIC PRODUCTION. The transition from conventional to organic farming is described as a decision requiring a high level of commitment and fundamentally different management approaches (Lampkin, 1992). In Manitoba, organic certification requires 3 years of transition without price premiums available (OPAM, 2000). Duram (1999) indicated that this transition is a dramatic operational change, often with increased risk and little informational or community support. MacRae (1990) describes the transition process as isolating, stressful, and unsupported. The level of commitment required to produce certified organic crops is increasing, as standards have become more restrictive. The Organic Producers' Association of Manitoba, the primary certification agency in Manitoba, requires a 10-year conversion plan for the entire farm, and prohibits concurrent production of non-organic crops (OPAM, 2000). US standards require the use of organically-produced seed, which may soon be implemented under Canadian certification programs (Cross, 2002). Stricter organic standards make casual experimentation of certified organic production increasingly difficult. In addition, conventional farmers tend to have very little contact with organic agriculture information sources. Egri (1999) cites this as one of the reasons that large-scale conversion to organic production is unlikely in the current context of Canadian agriculture.

Fairweather (1999) detailed a model of the decision making process of New Zealand farmers considering organic production. Farmers must pass several "elimination criteria" in order to seriously consider their "motivations" to attempt organic. If they pass both these levels, they must not have any "constraints" preventing them from attempting organic. Elimination criteria include satisfaction with conventional farming, lack of knowledge about organic production, and the perception that organic farming is not financially viable. Motivations include consciousness about health and environmental issues, as well as interest in price premiums. Constraints include perceived financial risk and lack of technical expertise.

CROP YIELDS IN ORGANIC PRODUCTION. Dabbert and Madden (1986) cite expected yield and profit reductions as a major reason for lack of adoption of organic practices. Several studies have indicated that crop yields are reduced under organic production. Kramer (1984) found that 60% of Canadian organic farmers surveyed had experienced reduced yields during and after transition, primarily because of higher weed densities. Rydberg and Milberg (2000) also noted increased weed densities in organic versus conventional fields. Stanhill (1990) compared organic and conventional yields around the world, and found that on average differences were less than 10%. In half the cases, organic yields were the same or higher than conventional; in half they were less. Stanhill (1990) noted that organic crop yields tended to be higher under unfavourable conditions while conventional yields were higher under favourable conditions; Petersen et al. (1999) had similar findings in a 15 year trial in Pennsylvania. However, Stanhill (1990) found no evidence for the claim that organic production stabilizes yields. In general, when yield potential is low, the two systems perform similarly; when yield potential rises, conventional systems tend to perform better (Stanhill, 1990). Comparative yield ratios for organic versus conventional production were generally more favourable for on-farm studies rather than experimental studies, perhaps because they account for changes in management with farmer experience; conversely, the typically small scale and high motivation of organic farmers may be the cause (Stanhill, 1990). Overall, variation between fields was found to be higher than variation between organic and conventional systems (Stanhill, 1990). Vandermeer (1995) suggested that low-input or organic crops can yield as well as, or better than, conventionally-produced crops after a transition period. While some studies have found this to be true (Petersen et al., 1999), Stanhill's (1990) review found no evidence of a positive "conversion effect" on yields.

Lockeretz et al. (1981) found that organic yields in the US Corn Belt were typically 10% lower than conventional yields for corn, 5% lower for soybeans, 25% lower for wheat, and about equal to conventional for oats and hay. Entz et al. (2001) found that average yields of organic crops in the Northern Great Plains ranged from 50% lower than conventional yields (canola), to 4% higher (fall rye). Wheat, oats, flax, and feed barley yields were approximately 25% lower than conventional (Entz et al., 2001). Mäder et al. (2002) found that organic yields in Switzerland over the course of 20 years averaged 20% lower than conventional. In that study, organic yields varied by crop, with winter wheat yields averaging 90% of conventional but potato yields averaging only 60% of conventional. Saskatchewan crop insurance assumes a 15-25% reduction in yields for organic field crops; however, it also assumes prices premiums of 30-50%. Manitoba crop insurance assumes transitional grain yields to be 50% of conventional, climbing to 80% for cereals and 60% for flax and canola after transition (Doug Wilcox, Manitoba Crop Insurance Corp., pers. comm.).

ECONOMICS OF ORGANIC PRODUCTION. Yield reductions in organic and low-input systems are often offset by lower operating costs (Lockeretz et al., 1981), and premium prices for commodities. The Rodale Institute's Farming Systems Trial found that after a 4 year transition period, organic systems were competitive financially with conventional systems, even without price premiums (Petersen et al., 1999). Smolik et al. (1995) found that organic systems had reduced risk in terms of income variability and were less dependent on US farm program subsidy payments than conventional production. They also note however, that other studies have varied in their findings with regard to the relative profitability of each system.

Fairweather (1999) found that farmers in New Zealand had conflicting views of the economic viability of organic production. Organic farmers in Canada found organic production to be as economically viable as conventional production (Kramer, 1984). The region of production may also be important in determining profitability. Reduced input systems in the US may be more profitable in areas outside of the Corn Belt, such as the small grains areas (Smolik et al., 1995). Marra and Kaval (2000), in a meta-analysis of 120 organic-conventional comparisons, found that location (region), study type (on-farm versus small plot), and crop type were key factors in determining which system was more profitable. Non-organic reduced input studies were not consistent enough across studies to include in the comparison. In a 10-year follow-up to their extensive survey of organic farmers, Lockeretz and Madden (1987) found that those that were still farming organically had changed little over the 10 years in terms of their opinions of the advantages and disadvantages of organic farming, production and marketing practices, and operation size. Farms tended to be financially healthy, but weeds were cited as being more of a problem to control.

GOVERNMENT SUPPORT FOR ORGANIC PRODUCTION. Because of barriers to organic adoption, some governments have provided support to farmers in transition to organic production. Every E.U. country provides such support during transition, and most provide support for continued organic production (Kane et al., 2000). The U.K has allocated 140 million pounds to promote conversion to organic between 2000 and 2006 (O'Riordan and Cobb, 2001). As of 1999, Minnesota was the only US state to reimburse farmers for organic certification (Sooby, 2001). In Prince Edward Island (PEI), the Organic Certification Assistance Program was introduced in 2000, with funding until 2003. The program provides some financial assistance for certified growers and growers in transition to cover a portion of certification costs No other Canadian province currently has a similar program (Susan MacKinnon, PEI Reduced Input/Organic Development Officer, pers. comm.)

CURRENT ADOPTION OF ORGANIC PRODUCTION. The current level of adoption of organic practices in North America is small, though retail sales are increasing by about 20% per year (Katherine de Matteo, Director, US Organic Trade Association, cited in Van Acker et al., 2001). The organic retail sector in Europe is expected to increase by 40% annually between 2001 and 2006 (O'Riordan and Cobb, 2001). Acreage of organic field crops in Manitoba ranged from 4800 ha to 6500 ha annually between 1999 and 2001 (unpublished data, OPAM). This represents approximately 0.1% of the total area for such crops in Manitoba. Forage crops account for a further 6000 to 7300 ha per year (unpublished data, OPAM). In 1998 to 2001, an average of 514 Manitoba farmers were members of OPAM; however, less than one-third of members achieved organic certification in a given year. OPAM membership has been increasing at about 13% per year (unpublished data, OPAM). Membership in this period accounted for approximately 2% of the population of farmers in Manitoba. In 1997, 0.2% of all US farmland was certified organic (Sooby et al., 2001). It is estimated that 1 to 8% of US farmers are using methods characteristic of organic farming, whether certified or not (Durham, 1999). The number of organic farmers in the US has been increasing by 12% per year (Rigby and Caceres, 2001). As of January 2001, 540,000 hectares in the U.K. were organic or in conversion, making up 3% of agricultural land. This is more than double the area of organic production in 1999 (Rigby and Caceres, 2001). Over 10% of the agricultural land in Sweden and Austria is organic (Rigby and Caceres, 2001).

Non-Organic Reduced-Input Initiatives

RATIONALE. As a result of the barriers associated with the fundamental changes in farm management required during the transition to organic production, some authors have argued that it is crucial to work within existing production practices to make adoption of sustainable initiatives more likely (Swanton and Weise, 1991). Farmers use cultural practices they are familiar with, and adoption of more sustainable practices is most likely if they are compatible with the existing production system (Drost et al., 1996; Gertler, 1992). Stenholm and Wagonner (1990) argued that change toward a low-input system must be "by evolution rather than revolution" in order to be sustainable. Gertler (1992) argues that purist approaches to organic production will only appeal to a minority of farmers. Morris and Winter (1999) argue that organic agriculture occupies only a small portion of land in Europe, and within mainstream agriculture there is considerably greater interest in intermediate strategies like IPM. Terms like "low-input" farming are likely to be more socially acceptable than "organic" (Cacek and Langner, 1986). Scaling (1990) argues that a complete elimination of agrichemical use is unreasonable. Rigby and Caceres (2001) do not consider the use or non-use of synthetic chemicals to be a particularly rigorous basis for determining sustainability.

Instead of considering only dramatic shifts in production practices, several authors suggest that sustainable agriculture should be viewed as a process. Ikerd (1990) notes that a continuum exists between low input and high input levels. Rigby and Caceres (2001) suggest that instead of arguing that a specific system is the only approach to sustainability, the basis should be whether or not farmers are moving towards sustainability, given the current context. El-Swaify (2000) argues that instead of a rigid framework, a progressive, step-wise approach to sustainability is necessary, as this allows researchers and farmers to learn as they go. He argues that tracking general progress towards the goal of sustainability may be more useful than setting specific, rigid targets to be achieved. Other authors have also described sustainable agriculture as a process, rather than an endpoint (Schaller, 1990; Rigby and Caceres, 2001).

Lockeretz et al. (1981), in the first comprehensive study of organic farming in the US, noted that intermediate systems, especially those with reduced pesticides but allowing for modest synthetic fertilizer use, might be more attractive in terms of productivity, profitability, and resource use, than either conventional or organic production. Gertler (1992) suggested that wide adoption of strategies intermediate to organic may have a greater effect in terms of resource conservation than organic production currently does. The potential for reducing or eliminating herbicide use periodically was seen as more promising than reducing fertilizer use in Saskatchewan, in terms of limiting short-term yield loss (Stevenson et al., 2000). In particular, the replacement of cultural practices for herbicides was seen to have little effect on cereal crop production (Stevenson et al., 2000). Reducing nitrogen rates had a greater effect on yields and economics of various crops than reducing herbicide rates (Bowerman et al., 1994). Greek farmers have indicated that herbicides are more appropriate for reduction than fertilizer or seed inputs (Skorda et al., 1995). The potential for reduction in herbicide use may be greater in a no-till system than a conventional-tillage system, due to changes in the population dynamics of the weed seed bank because of limited soil disturbance (Swanton and Weise, 1991). Rigby and Caceres (2001) argue that considering both fertilizers and pesticides as equally unsuitable for sustainable farming is inappropriate because pesticides have no natural equivalent, while fertilizers do. Fairweather (1999) notes that some farmers in New Zealand fail to see why organic standards do not allow for the use of glyphosate herbicide or phosphorous fertilizer, as they consider these inputs to be environmentally acceptable.

In addition to agronomic support for prioritizing pesticide use for reduction over fertilizer use, there is some evidence that this is an appropriate marketing strategy for eco-labelling of food. A survey of 600 eco-label consumers felt that it was more important to have no synthetic pesticide use (77%) compared to elimination of synthetic fertilizer use (59%) (Kane et al., 2000). Byrne et al. (1991), in a survey of 1065 US consumers, found that concern about pesticide residue was high. In fact, it was significantly higher than concern about fat, cholesterol, or fertilizer residues. Various systems intermediate to organic and conventional have been proposed. Over 150 eco-labeling initiatives exist in the US alone, many of which are non-organic (Kane et al., 2000).

INTEGRATED PEST MANAGEMENT. The most widely known reduced-pesticide initiative is Integrated Pest Management (IPM), also known as Integrated Pest Control (IPC). IPM was originally developed as a concept to deal with insect pests, and first appeared in the literature in 1967 (Buhler et al., 2000). During the UN Conference on Environment and Development in Rio (1992), IPM was identified as playing a central role in agriculture

(Kogan, 1998). Over 60 definitions of the concept exist (Kogan, 1998). Buhler et al. (2000) cite two main elements of IPM: multiple control tactics, and the integration of knowledge of pest biology. Common practices include pest monitoring, reduced pesticide rates, and use of alternating pesticide types (Fernandez-Cornejo and Castaldo, 1998), and the use of economically-derived decision making thresholds for pests (Shennan et al., 2001). In a review of the history of IPM, Kogan (1998) noted that after 30 years of development, IPM is still in its infancy. The fact that pesticide use has not declined since the initiation of IPM, as well as the support IPM has received from the agrochemical industry, has led to the perception that IPM is too focussed on pesticide use (Kogan, 1998).

Assessing adoption of IPM is complicated by the fact that IPM practices are not always precisely defined for a given crop in a specific region (Shennan et al., 2001). Appropriate IPM practices change depending on the crop, pest, location, season, and availability of new innovations (Shennan et al, 2001; Fernandez-Cornejo and Castaldo, 1998). The concept is both complex and dynamic. Assessment of IPM adoption has included whether or not one or more specific practices are used, or the use of a points-based system for practices (Shennan et al., 2001). Lack of consensus on the definition of IPM has lead to unwarranted claims that a pest control program is IPM even if it ignores essential IPM principles (Kogan, 1998). In practice, management referred to as IPM does not always agree with IPM theory (Chellemi, 2000).

In 1993, US government agencies set a goal of implementing IPM on 75% of crop acres by 2000 (Riley et al., 1998); however, Fernandez-Cornejo and Castaldo (1998) estimated that under existing conditions, 75% adoption among US fruit growers will only occur prior to 2035. de Buck et al. (2001) note that adoption of IPM practices has often been a partial, rather than a complete, implementation of an IPM package. IPM recommendations may be in conflict with farmers' intuition, which can be a challenge for increased adoption. This is especially true if the IPM recommendation is to do nothing, as this is very different from conventional chemical-based approaches (Fernandez-Cornejo and Castaldo, 1998).

Shennan et al. (2001) found that California farmers overestimated their use of IPM practices when compared to the authors' assessment of their actual management practices. A survey of canola growers in Western Canada found that the primary barriers to increased adoption of IPM for canola were the ineffectiveness of non-chemical control methods, economics, and a lack of knowledge about non-chemical control methods (Canola Council of Canada, 2000); however, the authors concluded that canola growers were well on their way to fully adopting IPM. Less than half of Western Canadian farmers surveyed could provide a definition of IPM (Canola Council of Canada, 2000). Cucurbit (*Cucurbita* spp., *Cucumis* spp., and *Citrullus* spp.) crop farmers in the South-Central US were found to have a fairly good understanding of IPM and generally accepted it as useful; however, pest management still depended heavily on chemical usage (Riley et al., 1998). Almost half of Iowa farmers surveyed thought IPM was complicated and difficult to use (Bultena, 1985). Adoption of IPM has not been evident in Utah, despite the fact that it has been strongly promoted (Drost et al., 1996).

Adoption of IPM has been slow, and many IPM programs still rely on pesticides as the principal pest management strategy (Kogan, 1998). As a result, variations on the theme of IPM have been proposed. "Biologically-intensive IPM" has been proposed as a solution by Frisbie and Smith (1991). Ecologically Based Pest Management (EBPM) is an alternative proposed by the U.S. National Research Council (1996). EBPM is defined as relying primarily on inputs of pest knowledge and secondarily on physical, chemical, or biological supplements for pest control. Integrated Arable Farming Systems (IAFS), developed in Holland, is another concept similar to IPM, but it is not a specific reaction to the deficiencies of IPM (de Buck et al., 2001). Kogan (1998) noted that these concepts are very similar to IPM and questioned the value of introducing a new acronym when IPM is already relatively well-known.

INTEGRATED WEED MANAGEMENT. IPM is intended to encompass management of plant diseases and weeds, as well as insect pests; however, Kogan (1998) noted that most definitions perpetuate the entomological bias of IPM through emphasis on pest populations and economic injury levels (EIL). These concepts are not always applicable to pathogens and weeds. Early US funding for IPM projects maintained this focus, reinforcing the idea that IPM was "entomocentric" (Kogan, 1998). As a result, efforts to use IPM in relation to weeds resulted in the development of Integrated Weed

Management (IWM), a term that has been in use since the early 1970's (Walker and Buchanan, 1982).

While the principles of IPM are not always directly applicable to IWM due to fundamental differences in pest biology (Buhler et al., 2000), both concepts stress similar practices. These include preventative rather than reactive measures, the use of economic thresholds, increasing the competitiveness of the cropping system, pest monitoring, and diversifying cropping systems and control strategies (Buhler et al., 2000). Swanton and Weise (1991) described IWM as including the application of numerous alternative weed control measures, including cultural, genetic, mechanical, biological, and chemical means. Buhler et al. (2000) suggest that weeds may be more easily controlled by integrated management than insects because individual weeds do not move, and weed populations do not rapidly migrate.

IWM has been supported extensively by research, but has suffered from limited adoption. Norris (1992) attributed this primarily to a lack of connection between the goals and needs of academic researchers and those of farmers; as well as a bias towards herbicide-based IWM rather than the development of biologically robust cropping systems. In Australia, farmers have not been strongly pro-active in implementing IWM, and their interest in the concept has more recently been related to the severity of herbicide resistant weed problems they are now experiencing (Sutherland, 2001), suggesting that farmer interest in IWM is related to their direct experience with negative aspects of herbicide use. Buhler et al. (2000) cite economic conditions and policies that tend to favour large scale operations and short-term profit motivations as barriers to implementation of IPM/IWM. In Manitoba, farmers were found to be uninterested in alternative practices to herbicides unless they were very easy to implement (Thomas et al. 1999a).

ECONOMIC THRESHOLDS FOR WEEDS. Controlling weeds when the weed and crop density and growth stage are optimal is the most important consideration in achieving effective weed control (Hall et al., 2000). This principle has led to the concept of economic thresholds (ET's) for weeds. ET's were originally proposed as tools for insect pest management. Economic thresholds for weeds are defined as the weed density at which the cost of control equals the value of crop loss if no control action is taken (Bauer and Mortensen, 1992). Ideally, chemical control measures are only taken when the weed density exceeds the economic threshold.

ET's are often cited as being integral to IWM practices (Buhler et al., 2000), despite the fact that thresholds have been criticized for their ineffectiveness. Yield losses due to weeds depend on many factors, including relative time of weed emergence, environmental variables, weed species, and crop density. In addition, crop yield potential, crop value, and weed control cost are important considerations (Coble, 1994; O'Donovan, 1996; Hall et al., 2000). However, ET's are often based on simple measurements of weed density, with no attention paid to the other factors contributing to yield loss resulting from weed infestations. Since simple measures of weed density do not adequately describe the yield loss potential, thresholds are often extremely low in order to account for worst-case scenarios, leading to the recommendation to apply herbicides in most cases (Buhler et al., 2000).

Economic thresholds that have been developed are generally for only one crop/weed interaction; however, a typical cropping system contains several different weed species with different competitive abilities (Hall et al., 2000). Attempts to broaden single-species ET's to multiple-species thresholds are generally lacking in the information needed to assess the effect of a community of species (O'Donovan, 1996). However, some authors have developed yield-loss estimations for specific weed-crop communities, with some success (e.g. Hume, 1993). Knowledge of weed emergence patterns and spatial heterogeneity of weed densities are important factors contributing to accurate economic thresholds (Hall et al., 2000). In addition, much of the historic literature on crop-weed interaction was developed using different crop production systems and cultivars than are currently used (Hall et al., 2000). ET's also consider the impact of weeds for only one year at a time. Buhler et al. (1997) have criticized the concept for not considering weed seed production and its impact in future years. Jones and Medd (2000) challenge ET's on the basis that they are static (consider one year only), and binary (provide only a dichotomous choice, with no option for variable herbicide rates or other control measures). These authors argue that ET's do not reduce herbicide use, do not contain weeds adequately, and do not maximize profits. Despite the fact that

ET's are designed to reduce pesticide use, some authors have found that scouting fields can lead to increased pesticide use (Yee and Ferguson, 1996). Proven et al. (1991) challenged the usefulness of thresholds, as weeds in winter cereal plots in a wide range of soil types and U.K. locations exceeded thresholds about 80% of the time.

These arguments have lead to the development of a framework for variable herbicide rates known as the optimal dose rate (ODR) (Pannel, 1995), although this strategy still considers only one year at a time and only herbicidal weed control options. Economic optimum thresholds (EOT's) have been proposed as a solution to some of the problems of ET's (Cousens, 1987). This strategy considers the impact of weed seed production and long term profitability. EOT's for two weeds in soybeans were found to be 3 to 8 times lower than their respective ET's (Bauer and Mortensen, 1992).

There have also been efforts to incorporate ET's into weed management models for decision-making (decision support systems; DSS), which show potential to be more objective assessments of the need for herbicide than farmers' subjective assessments (O'Donovan, 1996). However, some authors argue that the 'subjective' assessments of farmers represent the integration of years of site-specific experience and are therefore extremely valuable in DSS (Bostrom and Fogelfors, 2002a). As of 1993, at least 17 DSS dealing with weeds had been reported in the literature (primarily in the US) (O'Donovan, 1996). DSS are seen as a tool that can allow farmers to cope with increasing complexity in agriculture (Moulin, 1996); however, insufficient knowledge about weed biology and ecology has limited the success of such models (Hall et al., 2000). In fact, Wyse (1994) noted that existing weed competition data was not sufficient anywhere in the US to supply the information required by DSS.

Adoption of economic thresholds for weeds has been low among farmers. Proven et al. (1991) note that the inherent patchiness in weed populations makes accurate assessment of densities difficult. As well, the assessment methods used in experimental studies are usually too laborious to be used by farmers (Proven et al., 1991). Czapar et al. (1997) cites estimates of adoption of ET's as ranging from less than 10% to over 50% of farmers. In 1989, 19.5% of corn and 14.4% of soybean acres in the US were estimated to be using economic thresholds (National Research Council, 1989). A survey of Illinois farmers found that only 45% of farmers used the previous year's weed problems as a basis for weed control decisions, and only 9% used economic thresholds (Czapar et al., 1997). Illinois farmers identified harvest problems due to weeds as a major reason for not implementing ET's (64%), followed by weed seed production (38%), landlord perception (38%) and general appearance of the field (36%). Less than 10% listed scouting time, lack of weed competition data, or weed ID skills as limitations (Czapar et al., 1997). The Canola Council of Canada noted that the use and development of economic thresholds for canola (primarily for insect pests) is in its infancy and only 12% of farmers surveyed indicated that they used economic thresholds for weeds (Canola Council of Canada, 2000).

A U.K. study of winter cereals found that broadleaf and grass herbicide treatments at half the recommended rate every year is preferable to the use of spray/no spray thresholds in a given year. This finding is based on finances, seedbank densities, and seedling populations (Lawson, 1994). Even though fields were chosen that had been well-managed and were not particularly weedy, thresholds were exceeded 80% of the time. In contrast, the ½ rate approach was seen as reducing risk, saving more money, and involved no management changes as compared to the elimination of a herbicide application based on thresholds (Lawson, 1994).

OTHER REDUCED INPUT INITIATIVES. In Canada, a recent Quebec initiative called Healthy Grain has been successful in marketing grain produced for one year without pesticides or fertilizer (Pierre Lachance, pers. comm.). Morris and Winter (1999) suggest a 'third way" or middle course between organic and conventional systems, which they label integrated farming systems (IFS). U.K. research on IFS has found that winter wheat and barley yields decreased 8% while fungicide use has been reduced by 52%, herbicides by 48%, and insecticides by 40%. However, the concept has been criticized by some farmers who see it as a 'fancy term for common sense' (Morris and Winter, 1999). Some eco-labelling initiatives appear designed to brand production from an entire region (e.g. PEI Foodtrust) (Tennison, 2002) or for an entire crop (e.g. Integrated Pest Management for canola) (Canola Council of Canada, 2000), to alleviate consumer fears about food safety, without implementing major changes in production systems.

A unique approach to reducing pesticide use is being used in Quebec. Agroenvironmental clubs were initiated in this province in 1998, with a mandate to continue until 2003. These groups are supported financially by the farmer members themselves and the Quebec Fisheries and Agriculture Department. The club's goals include supporting farmers in developing sustainable practices and ensuring that such practices are adopted by a significant number of farmers. Members receive subsidized agroenvironmental advisory services, which may include weed scouting. About 150 environmental advisors are assigned to work with the clubs. The program has been successful in attracting significant numbers of farmers to participate. Over 70 clubs with over 4000 members were involved in 2001. This represented 12% of all farms in Quebec, or 20% of the total cropland area. Less than 4% of the total membership had dropped out of the program since its inception. In 2000-2001, pesticides were reduced by 30-50% on 36% of the farms where pesticides were used. Crops were grown without herbicides on 21,000 ha, and a further 22,000 ha received reduced rates of pesticides. Roughly 25% of the land in cereals, oilseeds, or corn in Quebec was part of a club (Clubs Conseils en Agroenvironment, 2001). However, there is concern that participation in this initiative has reached a plateau (Diane Benoit, Agriculture and Agri-Food Canada, Saint-Jean-sur-Richelieu, Quebec, pers. comm.)

Management for Reduced-Input Crop Production

Pimentel et al. (1993a) estimated that it should be possible to reduce pesticide use in the US by 50% without decreases in crop yield or cosmetic standards. Such reductions would be accomplished by using methods such as crop rotation, resistant varieties, and tillage. Reduced-input strategies often focus on using both knowledge and technology but knowledge tends to play a bigger role than in conventional systems (Ikerd, 1990). Wyse (1994) argued that high weed densities are the major deterrent to the development of more sustainable agricultural systems. The majority of pesticide use in Western Canada is in the form of herbicides (Hamill et al., 1994). As a result, the following discussion will focus on weed control. Pest types are discussed individually below; however, weeds, diseases and insects can interact with each other, and use of one class of pesticides (herbicides, insecticides, or fungicides) may affect of other types of pests (Buhler, 2002).

INSECT PEST MANAGEMENT. There are several non-chemical methods used to minimize the impact of insect pests. These include the use of trap crops (e.g. along field edges), management of natural habitats to enhance natural enemies, the use of semiochemicals (chemicals that mediate interactions between organisms; sex pheromones are of particular use in monitoring populations and in disrupting mating), and the use of genetic engineering or traditional breeding to produce pest-resistant cultivars (Kogan, 1998). However, many of these tactics are geared to high-value crops like vegetables.

Methods of cultural control depend on the biology and lifecycle of the pest. Such method include the destruction of a pest's overwintering habitat or alternate early spring food sources (e.g. weeds). Alternately, the crop can be planted away from these locations. This can delay infestation long enough that economic damage does not occur. Tillage can reduce insect pest problems by eliminating over-wintering habitats or alternate food sources. Crop rotation can be effective against species with long lifecycles and limited dispersal capabilities. Altering seeding and planting date, including the use of short-season cultivars, can avoid serious pest damage. Fertilizer and water management can also affect the impact of insect pest populations by affecting the competitiveness of the crop (Ferro, 1996). Brandt and Molgaard (2001) note that ecological evidence suggests that crops with a high nutrient supply generally suffer from greater pest and disease infestation than those with a lower nutrient supply; in practice this varies. While some insect pests are attracted to poor crop growth that gives more yellowed leaves (e.g. some aphids), others are attracted to succulent, high nutrient growth (Ferro, 1996).

Insect pests can be controlled through biological control (biocontrol). Classical biocontrol involves the release of biocontrol agents which provide continuous control by perpetuating themselves in the environment. Augmentative biocontrol requires periodic releases of the control agent. Augmentative biocontrol may be either inundative, which in effect mimics a pesticide, in that it results in rapid reduction of the pest; or inoculative, relying on frequent introductions of the control agent to keep the population under control (Dorrance, 1994).

Monitoring insect pests may allow for optimization of insecticide use. In Manitoba, monitoring of some insect pests (e.g. Bertha armyworm and diamondback moth) allows farmers to be aware of the potential for outbreaks of these pests (Manitoba Agriculture and Food, 2001a).

DISEASE MANAGEMENT. Non-chemical approaches to plant disease control include the use of resistant varieties, the use of disease-free seed, burying crop residue, field scouting, and sanitation of farm equipment (Dorrance, 1994). Manipulating seeding date may allow for disease avoidance in some situations. For example, early seeded spring cereal crops often escape damage from rusts (*Puccinia* spp.), while late seeding may allow for avoidance of wheat streak mosaic virus (Rymovirus: Potyviridae) (Martens et al., 1988). Late seeding of canola may increase susceptibility to blackleg (*Leptosphaeria maculans* (Desm.) Ces. et de Not.), which generally has higher inoculum levels later in the season (Brandt and Thomas, 2002).

Rotation and tillage system can affect disease pressure. The effectiveness of crop rotation will vary with the longevity and host-specificity of the disease (Dorrance, 1994). Tan spot (*Pyrenophora tritici-repentis* (Died.) Drechs.) and septoria leaf blotch (*Septoria* spp.) were found to be higher in wheat grown after other cereals than after other crop types (Brandt and Thomas, 2002; Bailey et al., 1992). Conservation tillage may lead to more disease problems (Martens et al., 1988). Brandt and Zentner (1995) found leaf diseases of wheat to be higher in reduced-tillage; however, Bailey et al. (1992) found that the effect of tillage on leaf disease ratings was not consistent.

For some crops, plant disease forecasting may allow for the optimization of fungicide use (for example, canola and potatoes (*Solanum tuberosum* L.) in Manitoba; Agrometerological Centre of Excellence, 2002). In addition, there are some efforts to establish biological control agents against field crop pathogens (e.g. sclerotinia head rot of sunflower (*Helianthus annuus* L.); R. Duncan, University of Manitoba Department of Plant Science, pers. comm.).

WEED MANAGEMENT. There are numerous strategies for replacing herbicide use with alternative methods (e.g. Bond and Grundy, 2000). Prior to the advent of herbicides, weed control was achieved by often labour-intensive mechanical and cultural means (Pike et al., 1991). However, use of a single alternative method generally does not provide effective control but rather only suppresses weeds. Therefore, a combination of alternative methods is often required to allow for herbicide use reductions (Hall et al., 2000). Farmer and research interest in alternative weed management methods has been reduced by the effectiveness and advantages of chemical weed control (Hall et al., 2000).

Weed Biology and Ecology

Weeds have been defined as plants growing where they are not wanted (Royer and Dickinson, 1999); however, weeds may also have beneficial attributes. Some weeds have potential as forage crops (e.g. *Kochia scoparia* L.) (Steppuhn et al., 1993). Hall et al. (2000) noted potential benefits of weeds such as their use as nutraceuticals or in phytoremediation of contaminated land.

A thorough understanding of weed biology and ecology is necessary in order to devise strategies to reduce herbicide use (Forcella et al., 1993; Hall et al., 2000); however, current knowledge in this area is limited and largely descriptive, with little information available about the mechanisms of weed responses to various production systems (Hall et al., 2000). While the proportion of weed science publications dealing with biology, ecology, or biocontrol has increased since the 1970's, the largest (though declining) category of publications is still herbicide-related (Abernathy and Bridges, 1994). Several authors argue that more research is needed in the area of weed biology and ecology (Abernathy and Bridges, 1994; Wyse, 1994).

Weed communities in commercial fields in Manitoba have been found to be largely determined by climatic variables, and composed of species responding to conditions more or less independently of one another (Thomas and Dale, 1991). Post-spray average weed densities in Manitoba fields ranged from 34 plants m^{-2} in canola, to 105 plants m^{-2} in oat (Thomas et al., 1998). Uncontrolled weed densities in wheat fields near Regina, SK averaged 470 plants m^{-2} (Hume, 1993).

Weed population dynamics are due to: recruitment (germination + emergence), survivorship to maturity, fecundity (seed produced per plant), seed rain (seeds entering the seedbank), and seed carry-over (seeds surviving in the soil) (Medd and Pandey, 1993). Control of weed populations can be achieved through the disruption of any of these lifecycle stages; however, weed control by herbicides focuses on reducing seedling survivorship (Medd and Pandey, 1993). Through the use of a simulation model, Medd and Pandey's (1993) model found that reducing recruitment, survivorship, or seed rain resulted in a dramatic reversal in *Avena* spp. population growth; however, reducing carryover of weed seeds had a limited effect.

Weed Seedbank Dynamics

The weed seedbank is often the focus of weed management research. Buhler et al. (1997) stated that management practices have major impacts on seedbank dynamics; however, Derksen et al. (1998) indicated that weed seedbank analysis from research conducted in Western Canada that involved in-crop herbicide use does not correlate well with seedling densities, and is therefore limited as the focus of management strategies. However, weed seedbank densities in Manitoba organic crop production research are does predict seedling densities to a greater extent (M. Entz, pers. comm.). Weed seed densities in the seed bank can change rapidly depending on the prevention or allowance of weed seed return (Buhler, 1999a). Burnside et al. (1986) found that weed seed density in soil declined by 95% after a 5 year weed free period, but returned to 90% of original densities at 2 of 5 sites after 1 year without herbicides. Albrect and Sommer (1998) found that an IWM-type system has the potential to maintain the weed seed bank at relatively low levels, compared to organic systems. Longevity of weed seeds in the seedbank and the proportion that germinate each year varies with species (Lampkin, 1992). Forcella et al. (1992) found that percent viable seed emerging from the seedbank ranged from less than 1% to 30% depending on the species.

Germination and Emergence

Individual weed species may have specific environmental requirements to break dormancy and successfully germinate and emerge, and as such there are characteristic emergence periodicities for different species (Lampkin, 1992). Factors affecting germination and emergence of weed species include soil moisture, soil temperature, and depth of seed burial (Blackshaw, 1990). The timing of weed emergence relative to the crop is important in determining the competitive ability of the crop (Blackshaw, 1990).

Knowledge of the emergence periodicity for a weed is valuable because it can facilitate timely herbicide applications or tillage operations to optimize weed control; or it can provide guidance for timing of seeding operations to avoid high weed populations (Forcella et al., 1993).

Critical Period of Weed Interference

The critical period of weed interference is related to the length of time that weed control must be maintained to prevent crop yield loss, and to the length of time weeds can remain in the crop before they reduce crop yield (Weaver, 1984). Weeds that are removed before the critical period or emerge after the critical period will not cause yield loss (Frick, 2000). Understanding the critical period of weed interference can help optimize the timing and dose of herbicide application (Swanton and Weise, 1991). However, the length of the critical period will vary depending on crop type, weed species present, year and location (Frick, 2000).

Residual Weed Populations

Czapar et al. (1997) indicated that weed seed production is a major consideration for farmers in the adoption of economic thresholds; however, little is known about the biology and dynamics of residual weed populations (those that survive or emerge following weed control operations) (Légerè et al. 1996). The major concern of Swedish policymakers charged with developing strategies to reduce herbicide use is that skipping herbicide applications will lead to weed densities in the future that eventually require greater amounts of herbicides to control (Bellinder et al., 1994). The prevention of seed production is viewed as a justification for higher levels of weed control than are necessary to protect crop yields (Buhler, 1999b). Through the use of a simulation model, Medd and Pandey (1993) found that the input of new seed to the seed bank was a critical factor governing the persistence and containment of *Avena* spp. in Australia.

Légère et al. (1996) note that residual weeds are a reality in even the most intensively managed systems, and the maximum level of weed management rarely paid off in terms of yield increases (compared to moderate levels). The threat posed by such residual weed populations was extremely variable and was probably closely related to the overall competitiveness of the cropping system (Légère et al., 1996). Weeds can produce large numbers of seeds under ideal conditions, but weeds with late emergence or competing with crops may have reduced weed seed production. For example, velvetleaf production was reduced by 82% by competition with soybean (Lindquist et al., 1995). Weed seed production should be considered in the context of the subsequent viability and survival of seedlings, as well as the size and longevity of the existing seedbank. It the existing seedbank contains a large number of long-lived seeds, rapid depletion of the seedbank may not be possible even without weed seed return (Légerè et al., 1996).

O'Donovan (1988) suggested that omission of herbicides in some years will increase dependence on herbicides in subsequent years. In continuous barley, wild oat herbicide application every other year provided the best economic returns, but in continuous wheat, application of wild oat herbicide every year gave the best returns (O'Donovan, 1988) However, this study did not consider substituting management changes for herbicide use.

Bellinder et al. (1994) cited a number of Swedish-language studies that researched the implications of skipping herbicide applications. One Swedish-language study (Jensen, 1991, cited in Bellinder et al., 1994) found that over a 16 year period, weed populations in spring barley increased on average 25% per year when there was no control, and decreased an average of 2% and 10% annually at half and full recommended herbicide rates, respectively. In modelling the long-term effects of these strategies on weed populations, Jensen (1991, cited in Bellinder et al., 1994) found that only two strategies gave a constant weed population: an annual application of a half rate, and a full rate 2 out of 3 years. A full or half rate every other year allowed for increases in weed populations. Another Swedish-language paper (Bengtsson et al., 1988, cited in Bellinder et al., 1994), estimated similar weed population dynamics in response to herbicide reduction.

Buhler (1999b) suggested that moderate increases in weed density do not reduce future weed control. Weed control history (weed-free versus various weed control treatments) had little effect on weed control by imazethapyr or crop yields in a subsequent soybean crop. Weed control in 4 years of a corn-soybean rotation was only reduced when weed densities became extremely high. The same study found that in general, weed seed numbers and crop yields were less sensitive to weed control practices when weed densities were low than when they were high. Buhler (1999b) concluded that weed control practices that maintain weed densities below levels that reduce yields on an annual basis (i.e. weed control based on the use of traditional ET's) do not cause serious increases in weed densities in succeeding years. Bostrom and Fogelfors (2002a) suggest that by excluding herbicides only in competitive crops, at low weed densities, and in weed communities where competitive species are the minority, the risk of high weed seed return is minimized.

Cropping Systems-Based Weed Management

Cropping systems are defined as "a crop or pasture community, together with the management practices such as tillage methods and rotations used in its production" (Loomis and Connor, 1992). Some of the major factors defining a cropping system include tillage system, herbicide use, nutrient use, crop rotation, fertilizer placement, seeding date, seeding rate, row spacing, and crop cultivar selection.

Cropping systems research attempts to consider the effect of a number of agronomic factors, acting together, on weed communities. The rationale for this type of approach is that it is likely to be more representative of actual farm-scale weed situations than studies that consider factors in isolation. Leeson et. al. (2000) demonstrated that agronomic management practices can have a significant effect on weed community composition on farms in Saskatchewan.

Some studies have shown environmental factors to have the greatest influence on weed communities (e.g. Derksen et. al., 1993). Herbicide use can mask the effects that other management factors might have on weed communities (Derksen et. al., 1993). Ball and Miller (1990) found that herbicide use produced a shift in the weed seed bank in favour of species less susceptible to herbicides. The high selection pressure imposed by herbicides as compared to other management practices may explain the dominance of this factor in affecting weed communities. Herbicides often result in weed control in the range of 90 to 99% (Jasieniuk et. al., 1996).

Attempts to determine the relative importance of various management practices on weed communities have not been consistent. Tillage is often found to be less important than rotation in affecting weed communities (e.g. Derksen et. al., 1994). Swanton et. al. (1999) found that the disturbance caused by tillage was more important than the N rate or presence of a rye cover crop in corn in influencing weed composition.

Légère and Samson (1999) found that most variability in weed communities in response to tillage, rotation, and inputs was due to interactions between factors, and these interactions varied between sites and years. Buhler et. al. (1994) also found that interactions between environmental factors, management practices, and tillage system were important in regulating weed populations.

Examples of Reduced-Input Cropping Systems Trials

The Wisconsin Integrated Cropping Systems Trial compared 6 different corn-soybean based rotations with different diversity levels and 3 levels of inputs. After 10 years, lower input systems generally had greater energy efficiency, lower groundwater contamination, and better measurements of soil health characteristics. Low-input systems were no riskier than higher input systems in terms of yield and profitability variation. Diverse crop rotations were better suited for a reduction in inputs. Rotations with very low inputs yielded less on average than moderate levels of inputs. The lowest-input system usually had higher weed pressure than the other systems, and was the most variable in level of weed control achieved (Griffith and Posner, 2001).

The Glenlea long term rotation study compared high input, continuous Pesticide-Free Production, and organic systems, as well as treatments with pesticide use but no fertilizer use. After nine years, the highest weed populations were found in the fertilized plots with no pesticide applied; this was especially true of wild oat in an annual grain rotation. Reducing pesticide and fertilizer use resulted in less yield loss in a rotation containing 2 years of alfalfa (*Medicago sativa* L.) compared to annual cropping systems (Entz, 2001).

A continuing study at Scott, Saskatchewan is assessing the effects of 3 different crop input levels (organic, reduced, and high) and three 6-year rotations with different levels of diversity (a low diversity wheat/canola based rotation, a diversified annual grains rotation; and a diversified annual and perennial rotation). Yields were consistently lower in organic systems than the other two. However, organic yields were similar to yields in the high input system when weed control was good, N limitations were overcome by using legumes in the rotation, or in dry years with limited yield potential. Weed control in the organic system improved over the years, due to increased experience with the production system. However, weed problems were increasing in the reduced-input rotations; in particular, pre-seed weed control was a limiting factor (Brandt and Thomas, 2002).

Wander et al. (2002) summarized results from the Morrow Plots (Illinois), the oldest agricultural trial in the US, and found that maximum yield responses were achieved with fewer inputs (less fertilizer and lower seeding rates) in longer and more diverse rotations.

Zhang et al. (1996) found that after 10 years, corn yields in Ontario were significantly higher in plots receiving herbicide applications compared to those receiving non-chemical control (one or two inter-row cultivations in corn/soybeans, or underseeding of red clover (*Trifolium pratense* L.) for weed suppression in winter wheat), which was in turn higher than a no weed control treatment.

Crop Rotation

Crop rotations "work to control the simplification of weed communities through the planned sequences of crops in which each crop differs radically from its predecessor in one or several important variables: including planting date, growth habit, competitive ability, associated cultural practices, and fertility requirements" (Liebman and Dyck, 1993). In addition, crop rotation will play a role in determining herbicide options. Herbicide use can have a larger effect on weed communities than other management factors (Derksen et al., 1993).

Most studies have found that diverse rotations are more effective in reducing weed problems than simpler rotations. Leeson et. al. (2000) found that the inclusion of perennial species (generally forages) in a crop rotation was the primary factor contributing to differences in weed communities on Saskatchewan farms. Kegode et. al. (1999) found that including alfalfa and wheat in corn-soybean rotations in combination with reduced-tillage resulted in less weed seed production than corn-soybean alone.

The reduction in weed pressure in diverse rotations has been attributed to the unpredictability associated with differing times of land preparation, planting, harvesting, and weed control. This makes it less likely that a particular weed or group of weeds will be able to adapt to the cropping system and become dominant. A user-friendly crop diversity index is available for farmers to quantify the level of diversity in a given rotation, providing a method by which rotations can be compared (Dakota Lakes Research Farm, 2001).

Forages are considered to be particularly important in adding diversity to crop rotations. Forages are often perennial, resulting in competition outside of the period that annual crops traditionally offer. The cutting regime used to harvest forages also removes weed biomass, reducing weed competitive ability. The rotational benefits of forages in providing weed control have been noted by Manitoba and Saskatchewan farmers (Entz et. al., 1995). Eighty-three percent of respondents to that survey-based study indicated that weed populations following forages were reduced. Schoofs and Entz (2000) found that suppression of wild oat by annual forages was at least as effective as a sprayed wheat control, although broadleaf weed suppression was variable. Weed density differences in rotations containing a high versus a low frequency of broadleaf crops were attributable primarily to the differences in herbicide use in the rotations (Stevenson and Johnston, 1999), highlighting the importance of this factor in influencing weed populations.

Tillage System

Although significant differences have been found in weed communities associated with different tillage systems (Swanton et. al., 1999), generalizations about the effect of reduced-tillage have been not been particularly useful (Légère and Samson, 1999). Weed community shifts under reduced-tillage are expected to be due, in part, to increased presence of volunteer crops, perennials and wind-dispersed species; however, this is not always the case (Derksen et. al., 1993). Similar weed communities were found in commercial fields that had different tillage histories (Frick and Thomas, 1994). Swanton et. al. (1999) found the relationship between average weed density and tillage system to be inconsistent, while others (Anderson et al., 1998; Frick and Thomas, 1992) have found that weed density is highest in zero-tillage systems.

Response to tillage system is often species-specific, and some species may be only minimally affected by tillage system (Anderson et. al., 1998). Reduced-tillage systems may result in perennial weeds becoming more problematic than in tilled systems. For example, Buhler et. al. (1994) found that perennial weed species were greater in density and diversity in reduced-tillage corn-soybean rotations than moldboard plow treatments. Blackshaw et. al. (1994) found that zero-tillage treatments had higher weed densities than minimum or conventional-tillage after 5 years. In contrast, Thomas and Frick (1992) found lower densities of perennial weeds in commercial fields in Ontario with reduced-tillage than in conventional-tillage. Kegode et. al. (1999) found that reduced-tillage in combination with increased diversity within a rotation reduced weed seed production.

Zero-tillage systems result in less mixing of soil, which is likely to affect the recruitment depth for many weed seeds (du Croix-Sissons et. al., 2000), and will affect species that show differences in germination depending on if they are buried or located on the soil surface. For example, cleavers (*Galium aparine* L. or *G. spurium* L.) showed different densities in zero-tillage and conventional-tillage treatments (Danielle Reid, University of Manitoba, Dept. of Plant Science, unpublished data). Zero-tillage systems generally have lower soil temperatures and higher soil moisture, which will impact the recruitment microsite and may shift weed emergence periodicity. While it is often assumed that lower temperatures and higher moisture in the spring will result in delayed emergence for weeds, Marginet (2001) demonstrated that this may depend on the year. In drier years, the higher moisture in zero-tillage systems may actually result in earlier emergence periodicity of some weed species.

Fallow

Derksen et. al. (1994) discuss the conflicting results regarding the impact of tilled fallow on weed communities. Derksen et. al. (1994) found that weed densities tended to be higher in continuous cropping treatments. At some sites, the effect of fallow on weed communities was more important than tillage system, but the reverse was true at other sites. Blackshaw et. al. (1994) found that crop rotations that included fallow had the lowest weed densities after 5 years.

Intercropping or Cover Cropping

The use of a companion or cover crop may provide weed suppression by competing with weeds, or changing the microclimate so that weed germination does not occur (Frick, 2000). The crop may be sown into an existing crop to provide in-crop weed control, or after harvest to provide suppression of perennial or winter annual weeds. These crops may be removed by herbicide or tillage the following spring; or they may be allowed to grow as forage crops the following year. Species used for this purpose include forage legumes and grasses, fall or winter cereals, or self-seeding species such as annual medics that re-grow every year (Frick, 2000).

Prevention of New Weed Problems

New weed problems can be prevented by proper sanitation. This includes sowing clean seed and cleaning equipment as it moves between fields. Forage crops with viable weed seeds should be ensiled to decrease seed viability, as many weed seeds remain viable after passing through animals. Seed viability in manure may be decreased by storage or composting before application. (Dorrance, 1994). The removal of weed seeds through the use of a chaff cart at harvest can help reduce weed seed return (Shirtliffe, 1999). The McLeod Harvest is an example of a harvesting machine that uses this principle and may reduce weed problems in the future.

Enhancing Crop Competitiveness

Crop competitiveness can be increased by practices that promote rapid, uniform crop establishment (Swanton and Weise, 1991), as well as through crop selection and management. Seeding date, seeding rate, row spacing, allelopathy, and fertilizer management can all impact the competitiveness of the crop.

Crop selection. Competitive ability of crops can be viewed in two ways: the ability to tolerate competition, and the ability to suppress weeds (Frick, 2000). While there is conflicting evidence as to which factors are most important for crop competitiveness (Lemerle et al., 1996; Seavers and Wright, 1999), factors under consideration include rapid germination and emergence, vigorous seedling growth, rapid leaf expansion, rapid canopy development, and extensive root systems (Frick, 2000). The most consistent conclusion among studies is that weed competitiveness is enhanced by vigorous growth that reduces light quality and quantity beneath the crop canopy (Buhler, 2002).

Crops differ in competitive ability with weeds. For example, van Heemst (1985) ranked barley as a better competitor than wheat, and wheat as a better competitor than flax. Fall-sown crops offer excellent early season weed competition (Frick, 2000). A generalized ranking of competitive ability is: barley > spring rye > spring wheat and oats > durum wheat (*Triticum durum* Desf.) > pea > potato > soybean > flax > bean (*Phaseolus vulgaris* L.). Most pulse crops are poor competitors, and canola, while a poor competitor early in the season, can be a good competitor later in the season (Frick, 2000). In the U.K., the TALISMAN (Toward A Low Input System Minimizing Agrichemicals and Nitrogen) project, initiated in 1990, found that flax and winter or spring beans were more suitable for a low nitrogen, low pesticide system than winter oilseed rape (Lawson, 1994).

Variety Selection. Within a given crop, competitiveness among varieties may differ and the selection of more competitive varieties may allow for reduced pesticide application (Hucl, 1998); however, relatively little emphasis has been placed on breeding cultivars for competitive ability with weeds (Frick, 2000; Hall et al., 2000). In fact, the emphasis on breeding for yield may have inadvertently eliminated competitive traits in crops (Hall et al., 2000). Crop competitiveness may vary by site and year (Cousens and Mokhtari, 1998), which may seriously limit the value of breeding for (or making recommendations about) competitive varieties. Hucl (1998) found differences in competitiveness with weeds among spring wheat genotypes, although yields were similar in weed-free conditions. Kirkland and Hunter (1991) found no significant differences in competitiveness of three CPS wheats with wild oat.

Fertility Management. There are two ways that weed-fertilizer concerns affect yield: weeds taking up more nutrients are likely to be more competitive for other resources (e.g. light); and weeds can deplete nutrients that the crop could have otherwise used (Di Tomaso, 1995). The goal of managing fertility to impact weed communities is to increase the crop's access to nutrients while limiting availability to weeds. Strategies that could improve crop competitiveness through fertilizer manipulation were summarized by Di Tomaso (1995), and include considering fertilizer placement (banding rather than broadcasting fertilizer) as well as form of N. Increasing seeding rate, or decreasing row spacing, can also result in improved fertilizer use by the crop rather than weeds. There may also be potential for selecting nutrient-efficient crop cultivars (both through future breeding, and through selection of existing cultivars), although data regarding this is limited. In addition, fertilizer application can be timed to coincide with crop uptake to the greatest degree possible (Di Tomaso, 1995).

Some weeds have been shown to gain a competitive advantage over a crop at higher nutrient levels, while others are less competitive at higher nutrient levels.

However, results can be conflicting even for a given weed-crop combination. Kirkland and Beckie (1998) found that N fertilization increased spring wheat competitiveness more than green foxtail competitiveness; while Peterson and Nalewaja (1992) found that green foxtail responded more to N fertilization than spring wheat. It is likely that the relative competitiveness in the presence or absence of N depends on factors such as site, year, cultivar, and weed biotype. However, it is generally considered true that weeds are often more competitive with crops at higher soil nutrient levels, resulting in situations where fertilization has little benefit for the crop because of increased weed growth (Di Tomaso, 1995). Fertilizer application often increases the dependence on other weed control measures, due to the increase in competitive ability of weeds (Di Tomaso, 1995). Di Tomaso (1995) also suggests that more efficient fertilizer use could result in reduced rates of herbicide required to control weeds.

Rate of nitrogen did not affect weed species composition in a 9-year study of corn-based rotations in Ontario (Swanton et. al., 1999). Anderson et al. (1998) found that the effect of broadcast N on weed densities and communities varied depending on rotation (fallow versus no fallow) and suggested that this was due to excessive levels of N in fallow treatments. Kirkland and Beckie (1998) found that banding fertilizer rather than broadcasting could be an effective cultural practice for managing weeds, but it is unlikely to be reliable as the sole method of weed management.

The use of biological fertilizer sources (organic amendments like composed manures or fresh plant residues) can alter temporal patterns of nutrient availability, releasing nutrients more slowly than 'pulsed' applications of synthetic fertilizer. Given the dependency of many weed species on early season nutrient levels for growth, a change in the timing of nutrient availability resulting from the use of biological N may affect weed density and community composition (Buhler, 2002). Perron et al. (2001) found nutrient source (manure versus chemical fertilizer) to have little effect on weed density or crop yield, although they argued that might change if the manure was a source of weed seeds. In contrast, nutrient source has been found to affect weed community composition and density in a long-term rotation at Glenlea, Manitoba (M. Entz, pers. comm.).

Increasing Crop Density. Narrow row spacing and increased seeding rates should increase crop competitiveness by increasing the speed of canopy closure (Frick, 2000). Organic farmers frequently use higher seeding rates as a weed management strategy (OPAM, 2000). Townely-Smith and Wright (1994) found that increased pea seeding rate reduced weed numbers, and the authors suggested that high populations of peas may not require herbicide application. Similarly, Ball et al. (1997) found that increased lentil (*Lens culinaris* Medik) seeding rate reduced weed density and dry weight. Blackshaw et. al. (1999) found that wheat seeding rate affected foxtail barley (*Hordeum jubatum* L.) growth in most years, while flax seeding rate did not. Kirkland et al. (2000) found that increasing the seeding rate of wheat, barley, and lentil in Saskatchewan to 1.5 times recommended rates had infrequent and inconsistent effects, perhaps because of increased intra-specific competition. They found no conclusive evidence that the use of a higher than recommended seeding rate would maintain crop yields in the presence of uncontrolled weeds (reduced rates or no herbicide). O'Donovan et al. (2001) found suggest that higher barley seeding rates may help compensate for reduced herbicide use.

Swanton and Weise (1991) suggest that in some cases, an increase in plant density does not affect weed biomass because some crops can compensate for lower plant densities through branching or tillering. O'Donovan (1988) found that a specific canola seeding rate does not necessarily translate into a uniform crop stand, and Harker (2001) found that yield of barley, canola, and peas were not well correlated with stand density. Higher seeding rates may speed maturity and result in shorter plants with fewer tillers due to increased intra-crop competition (Frick, 2000).

While narrow row spacing may increase crop competitiveness with weeds, wider row spacing may allow for reduction in herbicide use through inter-row tillage. Wheat or flax row spacing effects were in most cases not significant in terms of their effect on weeds (Blackshaw et al., 1999). Varying row spacing in wheat and barley had no effect on grain yields, while increased seeding rates did increase grain yield (Lafond and Derksen, 1996); however, they note that these results contradict previous studies that found increased yields with narrow row spacing. Kirkland (1993) found that barley yield in the absence of herbicides was reduced when row spacing was increased.

Crop Seeding Date Manipulation. Spandl et al. (1999) found that delayed seeding of wheat could reduce cumulative percent emergence of foxtail (*Setaria* spp.). The effect of changing seeding date will depend on a particular weed's emergence periodicity. Changing the seeding date may make the crop less susceptible to a particular pest but more susceptible to another. All other factors being equal, yield reductions will also result as seeding is delayed. Manitoba Crop Insurance Corporation estimates a 1% loss of yield for every day delay after mid May, due to detrimentally high temperatures during grain filling (Manitoba Agriculture and Food, 2000a). Higher seeding rates and earlier-maturing varieties or crops can partially compensate for late seeding. A 5-10% increase in seeding rate is recommended for each 10 days of delay in seeding beyond May 15 (Manitoba Agriculture and Food, 2000a). Late planting also tends to result in higher grain protein, potentially adversely affect malt quality in barley (Manitoba Agriculture and Food, 2001a). Early seeding may help crops avoid insect pests such as orange wheatblossom midge (*Sitodiplosis mosellana* Gehin), grasshoppers (Orthoptera, various species), aphids (Homoptera, various species), and sunflower seed weevil (*Smicronyx fulvus* LeConte); delayed seeding may avoid wheat stem maggot (*Meormyza americana* Fitch) (Manitoba Agriculture and Food, 2000a). Changing seeding dates may increase or decrease the risk of frost in fall or spring, respectively (Frick, 2000).

Allelopathy. Allelopathy is the production of compounds (by a crop or weed) that inhibit the growth of other plants. This may be either directly, or indirectly through decomposition of plant residues. Crops with allelopathic characteristics may be manipulated to suppress weeds (e.g. by use as a cover crop or green manure). Many crops have been found to have allelopathic characteristics, including wheat, barley, oat, rye, canola, mustards (*Brassica* spp.), buckwheat (*Fagopyrum esculentum* L.) and several forage species (Frick, 2000).

Direct methods of weed control

Optimizing Herbicide Use

Complete eradication of weeds is not always necessary or desirable. Buhler (1999b) argued that the value in maintaining weed-free conditions in a corn/soybean system was questionable, because after 4 years of weed-free conditions, enough weed seeds remained to cause a 22% reduction in soybean yield. Even when weed control is desirable, there are opportunities to reduce the quantity of herbicide used. Herbicide use can be optimized through the application of knowledge of weed biology and ecology, including weed emergence periodicity and the critical period of weed control. In addition, improved application technology, split applications of herbicide, and an understanding of factors that influence herbicide absorption and efficacy can help reduce the amount of herbicide used (Hall et al., 2000).

Precision Agriculture

Precision farming is the use of expert decision-support systems to significantly enhance, or even substitute for, farmers' judgement in farm management (den Hond et al., 1999). Precision farming advocates site-specific and therefore more efficient use of inputs such as pesticides and fertilizers. As such, the concept may provide an opportunity to optimize the use of inputs like herbicides. However, a lack of knowledge about weed control in a site-specific context currently limits the viability of this tool; in particular, cost-effective and accurate methods to map weeds in fields are needed (Hall et al., 2000). Others (Wolf, cited in Boyens, 2001), argue that precision farming is simply an attempt to legitimize chemically based agriculture in an era of increasing environmental concern.

Reduced Herbicide Rates

Herbicide rates are typically selected by the manufacturer to provide reliable weed control over a wide range of environmental conditions that may affect the efficacy of the herbicide. Efficacy of post-emergent herbicides is influenced by spray volume, droplet size, adjuvants, temperature, humidity, light quality, soil moisture content, weed size and weed species (Hall et al., 2000). Under certain environmental conditions, or with the addition of a surfactant, reduced herbicide rates may be adequately effective (Hamill and Zhang, 1995). Proven et al. (1991) found that the differences in weed control between full and half rates of various broadleaf and grass herbicides for winter cereals was small. Spandl et al. (1997) found that reducing herbicide rates for wild oat control generally did not affect yield in wheat and barley; however, eliminating herbicide use usually did decrease yields. The same study found that higher rates of herbicide decreased variability in wild oat control.

Reducing rates could be assisted by manufacturer information about dose-response relationships (Lawson, 1994). The use of below-label rates of herbicides, however, forfeits any legal liability the manufacturer may have for poor weed control, therefore, there may be liability issues associated with providing information to farmers about reducing rates (Lawson, 1994). However, the Quebec agriculture department provides a factsheet for farmers on the issues associated with reducing herbicide rates, and the use of reduced rates is fairly widespread in the U.K. (Proven et al., 1991).

Banding herbicide application is another way to reduce herbicide rates. This practice is best suited to row crops such as corn and soybeans, where tillage is used between wide inter-rows. Hamill and Zhang (1995) indicated that banding reduced rates of metribuzin in corn can be an economically viable weed control practice in Ontario.

Mechanical Weed Control

Tillage can be used in a variety of ways to control weeds. One such method is the stale or false seedbed method. This method uses pre-plant tillage to stimulate a flush of weeds that are then controlled with herbicides or tillage immediately prior to seeding (Frick, 2000). Inter-row cultivation can be practiced for row crops such as soybeans, corn and sunflowers, and a wide variety of implements are available for this purpose (Lampkin, 1992).

Pre-emergent or "blind" tillage can be done after the crop is seeded but before it has emerged, to control recently emerged weed seedlings. The seedlings are killed by uprooting and/or covering with soil. This operation is most successful in firm soil where the soil surface is dry, and deeper seeding and higher seeding rates have been used. Tillage can be done with a rod weeder or harrow, and is usually performed 3-4 days after seeding. It should be less than 5 cm deep and the emerging crop should be less than 2 cm in length. Weeds emerging from a shallow depth are better controlled than those emerging from deeper depths. Dry weather is after harrowing is crucial in order to desiccate the uprooted weed seedlings (Frick, 2000). The risk of increased disease pressure due to deep seeding, as well as potential crop damage from the tillage implement are important considerations when using this practice (Dorrance, 1994).

Post-emergent tillage in cereals can be effective in reducing weed pressure. Cereals should be harrowed before tillering, seeded somewhat deeper than normal, and the seeding rate should be increased by up to 25% (Kirkland, 1995). There is conflicting information as to whether or not harrowing should proceed in the same or a different direction as the crop rows (Kirkland, 1995). The specific implement used and the number of passes made will affect crop damage and weed control (Kirkland, 1995). Mechanical weed control has been reported to be highly variable between years, likely depending on soil moisture conditions during and after harrowing, as well as the similarity in growth habit between the crop and weeds (Kirkland, 1995). Important considerations for effective rotary hoeing of corn in Wisconsin (Griffith and Posner, 2001) included tooth wear, operator experience, driving accuracy, and number of passes; hoe weight and speed were not important in this study. Rasmussen and Rasmussen (2000) suggested that adding the use of high quality (vigorous) crop seed to a weed harrowing strategy may improve the success of mechanical weed control, while Forcella et al. (1992) suggested that knowledge of weed emergence periodicity may help optimize timing of in-crop tillage operations.

Crops vary in their tolerance to harrowing. Pea, fababean (*Vicia faba* L.), sunflower, and lentil can tolerate harrowing, but it is not recommended for canola, oats, or flax (Frick, 2000). Wheat is more tolerant of harrowing than barley (Dorrance, 1994). For wheat and barley, the 2-4 leaf stage is recommended (Frick, 2000).

Heard (1993) suggested that mechanical weeding is generally inferior to herbicides for the level and consistency of weed control; it may also cause some crop injury. In-crop harrowing may delay crop maturity by one or two days (Dorrance, 1994). Careful checking for crop damage by the implement is required by the farmer, and the operation should not be done if the crop is under stress (Dorrance, 1994). Barberi et al. (2000) concluded that given the dependence of successful finger-harrowing on varying soil and weed conditions, mechanical methods alone would not always guarantee adequate weed control and grain yield in low-input durum wheat. Frick (2000) noted that large amounts of trash, compacted soil, and unfavourable weather can make in-crop harrowing an impractical option. Heavy amounts of trash will clog the harrows and cause crop damage (Dorrance, 1994).

Biological Control

Weeds may be controlled through use of other living organisms (mammals, insects, fungi, or bacteria). Biological control of weeds may be classical or augmentative. The use of sheep (*Ovis aries* L.) or flea beetles (*Aphthona* spp.) to control leafy spurge (*Euphorbia esula* L.) has been successful in Manitoba (Dorrance, 1994).

The use of bioherbicides has not become widespread in part because of the expectation that they be similar to chemical herbicides in terms of handling, storage, efficacy, and cost. The major constraint is the development of formulations that retain water so that moisture is available to the pathogen at application time (Auld and Morin, 1995). There have been a few commercially available bioherbicides. BioMal is an example of mycoherbicide that was available for control of round-leaved mallow (*Malva pusilla* Sm.) in Canada but is no longer on the market (Frick, 2000).

Removal of weed seeds by seed pathogens and predators is another form of biological control that may have some potential for reducing weed outbreaks. Approaches include manipulating tillage systems, as long term no-till may increase seed predation (Swanton and Weise, 1991), or the use of herbicides that predispose seeds to attack. However, little is understood about predators and pathogens and how they might successfully be manipulated (Kremer, 1993).

Other Direct Methods of Weed Control

Currently, only herbicides and tillage are widely used weed control tools (Coble, 1994). Other non-herbicidal methods for directly treating weeds include steaming, flame weeding, soil solarization, mulching with live or dead plant material or plastic, and the application of freezing treatments (Bond and Grundy, 2000). However, most of these methods are currently limited in use in Western Canada and are often only feasible in high value crops. Water management can indirectly affect weed control, given its impact on plant health and competitiveness (Walker and Buchanan, 1982). In certain cropping systems (i.e. rice (*Oryza sativa* L.)), flooding can suppress weeds that require oxygen to germinate (Walker and Buchanan, 1982).

Alternative Methodologies for Sustainable Agriculture Research

PARTICIPATORY RESEARCH. Participatory research is a relatively new but growing approach to research involving sustainable agriculture. This strategy was initially developed in the context of agricultural development in the South or developing world in the early 1980's, and is variously referred as farmer-first, rapid rural appraisal, or agroecosystem analysis (Dlott et al., 1994). Black (2000) lists 32 different participatory approaches. In particular, agroecology, which includes a range of alternative agricultural practices, such as no-till, IPM, and agroforestry, is strongly linked with participatory approaches (Uphoff; 2002; Altieri, 2002). Participatory Rural Appraisal (PRA) is another prominent participatory approach used primarily in the developing world. PRA developed from Rapid Rural Appraisal (RRA) and requires long-term connections with, and greater involvement of, participants than RRA (Chambers, 1994). The connection between alternative agriculture and participatory research is based on the recognition that low external-input agriculture is management- and knowledge- intensive. This means that human capital is extremely important for alternative agriculture (Uphoff, 2002).

While participatory research has its roots in agricultural development in the developing world, it can equally be applied to more technologically advanced systems (Lockeretz, 1987). The notion of "participatory" ranges from simply locating research sites on farmers' land, to having farmer participants control the research agenda and contribute to the interpretation of results. Participation can take either an extractive (of limited value to participants) or interactive form (Rocheleau, 1994). Because of the existence of a continuum of farmer involvement in research, some authors suggest that the practice should be qualified as to its degree of farmer involvement. For example, Pretty (1995), suggested a typology of seven approaches to participation. This continuum ranges from very passive participatory approaches, in which farmers are essentially told what to do; to self-mobilization, in which farmers take the initiative to change practices independent of external institutions. At more advanced levels of participation, farmers are actively involved in the planning of the project, on-going decision-making and analysis of results.

Rationale

Traditionally, technology development begins with small-scale research trials on experimental farms, followed by large scale research and demonstrations to farmers. This process can take up to a decade or more (Wuest et al., 1999). Several authors suggest that there are appropriate roles in agricultural research for both research stations and farm-based trials, and the choice of research site should depend on the nature of the research question (Rosmann, 1994; Lockeretz, 1987). For example, Lockeretz (1987) suggests that on-farm research is particularly valuable in assessing a system's performance under realistic farm conditions; as well as evaluating production techniques that are particularly sensitive to management (e.g. IPM). The approach can also be used to assess methods which have received little research attention but are often used by farmers. In contrast, experiments can more be more easily and precisely monitored on research stations, where supporting facilities and staff are readily available (Lockeretz, 1987). Long-term and costly research is better handled on experimental farms (Rossman, 1994). However, the fact that techniques for small plot research are well-developed means that this approach is often used even if it is not the most appropriate (Lockeretz, 1987). Research conducted by universities has sometimes been criticized as being biased towards non-farm economic activity (i.e. agribusiness) rather than improving farming systems themselves (Rosmann, 1994), which may be a function of the origin of available funding sources. Hall et al. (2000) recommend that weed scientists include a wide cross section of organizations in the development of research strategies, including farmers.

On-farm research, while not always actively involving farmers, is often a component of participatory agricultural research. Participatory, on-farm research can be a better approach for studying technology adoption at a farm-scale level. It can be more effective, and can allow for more rapid adoption of technology (Wuest et al., 1999). The sooner a practice is tried on a farm, the sooner it becomes credible to farmers (Thornely, 1990). Participatory, on-farm research can be statistically reliable, cost-effective, and allow for a systems-level approach (Rossman, 1994). Kroma and Butler Flora (2001) suggest that the current model of research and extension, because it is not context-specific, ignores the existence of local knowledge resulting from farmer experience, and maintains the attitude that farmers are recipients and consumers of knowledge rather than active participants in knowledge creation. Farmer knowledge of most soil quality indicators has been shown to be correct over 75% of the time; therefore, direct experiential knowledge can have considerable value (Liebig and Doran, 1999a). Similarly, Andrews et al. (2002) found that farmer knowledge of soil organic matter dynamics was supported by the scientific literature.

On-farm experimentation initiated by farmers has been published (Exner et. al., 1996). This study highlighted the fact that weed management systems are generally the result of years of experience and informal observation on a given farm. That study also demonstrated that it is possible for farmers to undertake their own research projects and in doing so, eliminate the need for broad generalizations across regions, which is often the goal of centralized research institutions. Instead, they can pursue solutions particular to their situation. Some authors have suggested that more site-specific solutions are needed in agricultural research. Andrews et al. (2002) and Wander et al. (2002) argued for more site-specificity in the field of soil quality research.

Participatory research may be related to the idea of action research, meaning that implementation is an explicit and immediate goal of the research process (Gerber, 1992). Conventional research differentiates between knowledge and action, as evidenced by the traditional model of generation and adoption of agricultural technologies. This lack of integration between theoretical research and applied responses has led to calls for research in which investigation and action proceed simultaneously (Reinharz, 1992). Outcomes of action research include improving practical knowledge relevant to a particular situation, empowering and raising consciousness of those involved, and respecting the needs and expertise of all those involved (Hillcoat, 1996).

Limitations

There are numerous barriers to truly effective participatory research, including the humility, teaching ability, and broad knowledge base required of scientists who wish to effectively work with farmers. The physical and social distances between farmers and researchers can be limiting. Time constraints on scientists, especially when travel is required, also limit the interest in such research (Dlott et al., 1994). As the level of participation becomes greater, a fundamental re-evaluation of philosophical and methodological issues at both institutional and individual researcher levels is required. Highly participatory approaches require researchers to subscribe to values of holism rather than reductionism, accept a plurality of research approaches, and recognize that agricultural development occurs in a specific social, political, and economic context (Dlott et al., 1994). Participatory research often requires the consideration of unique circumstances, which may conflict with a researcher's mandate to provide general solutions (Bentley, 1994). Thornely (1990) cites the increasing influence of private funding in research institutions, inadequate funding, top-down administration, incompatible personalities between farmers and researchers, and disciplinary specialization as barriers to increased collaboration between farmers and researchers. He suggests that farmers should be increasingly valued for their participation, including compensation as advisors (rather than voluntary roles) to improve mutual respect. Issues of professional acceptance, the pressure to (frequently) publish, career advancement, and funding as well as bias against multi-disciplinary work, applied research and multiple-authored papers can all limit interest in participatory research (Dlott et al., 1994). Other difficulties include the uncertainty of working with farmers. For example, farmers may choose to drop out of the project at any time, or may not be able to provide complete field records.

Many participatory initiatives have included only limited involvement of farmers in a passive manner (Bentley, 1994), with little effort made to qualify the degree of participation. Rocheleau (1994) argues that participation is wrongly touted as a "silver bullet" solution to problems in agriculture, and many approaches to it are superficial. Black (2000) argues that the belief in a "participation fix" is just as naïve as a belief in a technological fix. Vanclay and Lawrence (1994) suggest that superficial approaches to participation are often aimed at cutting costs and simply use the rhetoric of participation because it has become a popular method. The word participation has also been used to describe existing project designs without any fundamental change in the research (Pretty, 1995). Bentley (1994) argues that participation has in some cases been romanticized and the limitations of farmers' knowledge have been overlooked. Uphoff (2002) argues that local knowledge is essential for effective agroecological development, but that it is seldom sufficient. Some environmental problems may be new to farmers' experience and require outside knowledge (Black, 2000). Andrews et al. (2002) found that while farmer knowledge of some soil quality concepts was supported by scientific evidence, knowledge regarding the availability of nutrients in soil was incorrect compared to scientific literature. Uphoff (2002) argues that the best approach to participatory research is to allow for synergies in the knowledge held by both farmers and researchers, rather than depending too heavily on the expertise of either group.

Criticisms of participatory approaches include the fact that participation may not be representative of all farmers in an area due to varied interest in, and time available for, group-based activities. There may also be conflict within a group that may result in the rejection of ideas and the suppression of diversity among participants. Reliance on small-scale participatory approaches may result in limited transfer of knowledge to those outside the group unless larger networks of groups are developed (Black, 2000). In addition, some environmental problems may require outside resources or policy support and may not be adequately addressed at only a local level (Black, 2000).

Examples of Participatory Research

The Sustainable Agriculture Research and Education Program (SARE) is the primary means by which the US Department of Agriculture (USDA) promotes sustainable practices. This program was initially known as Low-Input Sustainable Agriculture (LISA), and was initiated by the US Food Security Act of 1985 with a $3.9 million grant. Its goal is to help substitute management and on-farm resources for purchased inputs (Stenholm and Wagonner, 1990). In 1992 the project was expanded to directly include farmers in research (Kroma and Butler Flora, 2001). From 1992-1995, 158 on-farm projects were funded in the North Central region of the US. Schaller (1990) notes that some researchers involved in LISA/SARE projects do not agree with the greater role of farmers in selecting and conducting research.

Australian extension initiatives include on-farm IWM demonstrations that occur over several years, are flexible, and are managed by farmers. The initiative has been driven by the problems of herbicide resistance in Australia. These demonstrations are intended to shift farmers' planning horizon to a long-term one. Another initiative involves long-term, farmer-chosen treatments, with field data on factors like crop rotation, weed seedbanks, and weed management practices collected by farmers. The information is summarized and distributed in an annual report. Thirty-one fields are included in the initiative (Sutherland, 2001).

The National Landcare Program is another Australian initiative, formed in 1989 by the National Farmers' Federation (NFF) and the Australian Conservation Foundation (ACF). Government funding allowed Landcare to become a national community movement to tackle land and water degradation. Its goal is to improve the sustainability and profitability of Australian farming through community participation as an alternative to regulatory, top-down control. One of the most common Landcare initiatives is the promotion of soil conservation through treeplanting. As of 1998, 30% of the Australian farming community was involved with Landcare, and is generally regarded as a good investment in terms of limited government resources (Curtis, 1998).

Leeson et al. (2000) and Dale et al. (1992) represent examples of recent on-farm research in Western Canada. There are numerous examples of research that actively involves farmers (Riley et al. (1998), for example, used group workshops with farmers to evaluate IPM). Spaner et al. (2000) used a range of approaches, including on-farm research, to develop basic agronomic principles for feed grain production in Newfoundland. The approaches used included small plot research, as well as on-farm soil sampling, and more participatory farm demonstration sites. Many of these recent examples are relatively superficial approaches to participation, when compared to a continuum of increasingly participatory approaches (Pretty, 1995). Andrews et al. (2002) conducted a study that incorporates more elements of participation. Their study involved changing the design of the study to suit farmers' needs and including their input in the analysis of results.

While some research institutions have attempted to implement participatory research, the Practical Farmers of Iowa (PFI) is an example of a farmer-initiated collaboration with researchers. This organization was founded in 1985, with a goal of producing information about environmentally sound, lower cost, profitable farming methods. The organization does not subscribe to any one particular reduced-input approach. By 1994, it had a membership of 450. The methodological cornerstones of this group are the use of conventional farm equipment, to have at least 6 randomized long, narrow strips running the length of the field, to compare 2 treatments at a time, and to have all plot work and appropriate measurements made by the farmer. PFI has demonstrated that farmers can conduct their own statistically reliable research (Rossman, 1994). Work by members of this group has even been published in peer-reviewed journals (Exner et al., 1996). There has been some provision of government funds to support approved on-farm research by farmers. In 2001, the PEI Department of

Agriculture and Forestry provided up to $5,000 per farm for organic on-farm research carried out by farmers.

CASE STUDIES. Case studies have been defined as research that focuses on a single case or issue, in contrast with studies that seek generalization through comparative analysis or compilation of a large number of instances (Reinharz, 1992). In agriculture, case studies have often been used in the context of international development. Case studies involve the detailed examination of relatively few persons or items, the participants of which are generally not chosen by formal sampling processes (Casley and Lury, 1989). A case study provides an in-depth detailed analysis of a situation within its real-life context, rather than a contrived experimental setting (Roberts, 1996). Case studies can complement traditional research by illustrating generalizations and exceptions to generalizations; its strengths lie in such illustrations rather than in building theories (Roberts, 1996). A case study is unique (Roberts, 1996), therefore findings cannot be generalized beyond the study; however, one may be able to reject existing generalizations (Casley and Lury, 1989; Reinharz, 1992). Such studies can more easily be related to everyday experience and may be more accessible to lay readers (Roberts, 1996). Lampkin (1988) suggests that the case study approach fulfills two roles: to identify problem areas, and to identify possible solutions. Such studies should strive to be more than simply a descriptive exercise, but rather contribute to better understanding of the subject (Lampkin, 1988).

Robertson et al. (2000) used an on-farm participatory case study approach to assess a new production system for mungbeans in Australia. Farmers perceptions as well as agronomic data were collected. These authors attribute the rapid adoption of the new production system to the on-farm approach, in contrast to traditional extension methods. This work demonstrates the value of including a range of approaches (multiple methods) in assessing a given research problem. Examples of case studies in agriculture include Gameda and Dumanski (1995), who used this approach to assess the use of a framework for sustainable land management in Alberta; Pike et al. (1991), who used a case study to examine herbicide use reduction in Illinois; and Petrzelka et al. (1997) who used this approach to describe the adoption of Integrated Crop Management practices.

Pesticide Free Production

In response to the limited success of currently available frameworks for pesticide reduction, Pesticide-Free Production (PFP) was developed by Manitoba farmers, researchers (University of Manitoba and Agriculture and Agri-Food Canada - Brandon), and extension workers (Manitoba Agriculture and Food) in 1999. This group is known as PFP Canada and is dedicated to researching ways to reduce the use of pesticides within cropping systems. Farmers identify priorities and provide direction for research in this area. In addition, the original definition of PFP was guided by the farmer members of this group. The PFP trademark is held by the University of Manitoba.

PFP is intended to be a flexible, straightforward framework that will appeal to a broad range of Manitoba farmers. The guidelines prohibit the use of in-crop pesticide use, seed treatments, and prior use of residual pesticides (see www.pfpcanada.com). However, pre-emergent applications of non-residual pesticides like glyphosate are permitted, as is synthetic fertilizer use. As weeds are the major pest problem in Western Canada, PFP is likely to be limited primarily by weed control.

Conclusion

There is growing interest in more sustainable agricultural practices. Pesticide use reduction is a frequent goal of proposals to improve the sustainability of agriculture. There have been numerous initiatives proposed to provide a framework for reductions in pesticide use, including organic production and IPM. However, no one framework has resulted in significant adoption among mainstream farmers. There is a need for new initiatives that draw more farmers to reduce pesticide use. In addition, the stagnation of farm incomes means that there is a need for initiatives that retain value on farms through the reduction of input costs. Pesticide Free Production is one such initiative. As a new strategy to achieve these goals, basic information regarding the agronomic and demographic characteristics of fields and farmers involved in PFP attempts is necessary in order to evaluate the potential of PFP to be widely adopted in Manitoba.

CHAPTER 3

AGRONOMIC CHARACTERISTICS OF FIELDS AND FARMS ON WHICH PESTICIDE FREE PRODUCTION (PFP) WAS TESTED BY FARMERS IN MANITOBA

INTRODUCTION

Extensive pesticide use in Western Canada has led to concerns about its impact on the environment, public health, and the economic viability of farming (Carson, 1962; Beckie et al., 1999; Pantone, 1992; Boyens, 2001; den Hond et al., 1999). Initiatives to promote reduced pesticide use include government-funded strategies, grassroots initiatives such as organic production, frameworks proposed by academics such as IPM, and eco-label marketing strategies. However, existing strategies for reducing pesticide use in Manitoba have suffered from limited adoption. The area in organic production in Manitoba comprises just over 0.1% of field crop acreage in Manitoba (unpublished data, OPAM). Several authors have called for more flexible frameworks for reduced pesticide use such as IPM or IWM (Swanton and Weise, 1991; Stenholm and Wagonner, 1990; Morris and Winter, 1999); however, such concepts have not been widely implemented (Sutherland, 2000).

In response to the limited success of currently available frameworks for pesticide reduction, Pesticide-Free Production (PFP) was developed by Manitoba farmers, researchers (University of Manitoba and Agriculture and Agri-Food Canada - Brandon), and extension workers (Manitoba Agriculture and Food) in 1999. PFP is intended to be a flexible, straightforward framework for reducing pesticide use that will appeal to a broad range of Manitoba farmers. The guidelines prohibit the use of in-crop pesticide use, seed treatments, and prior use of residual pesticides. However, a pre-emergent application of a non-residual pesticide such as glyphosate is permitted, as is synthetic fertilizer use. In order to provide a basis for evaluating the potential of PFP as a strategy to reduce pesticide use in Manitoba, the agronomic characteristics of fields and farms that PFP is being implemented on need to be characterized.

Studies of the agronomic characteristics of fields and farms practicing low-input agriculture address a range of production systems, from organic agriculture to various frameworks for reduced inputs (e.g. IPM). Several studies have found that organic yields are reduced from conventional yields for some crops; however, this is not true in all cases (Lockeretz et al., 1981; Stanhill, 1990).

In Western Canada, weeds dictate many crop production practices (Wyse, 1994), and herbicide use represents over 70% of total pesticide use in Canada (Hamill et al., 1994). As a result, weed control is likely to be the major limitation to pesticide use reduction in Western Canada. Weed densities and spectrum have been found to be different in organic versus conventional fields (Leeson et al., 1999; Entz et al., 2001).

Reducing herbicides has led to concern about escalating weed populations and yield reduction in future years (Czapar et al., 1997; Bellinder et al., 1994); others have found this to be a manageable issue (Buhler, 1999b). However, little is know about this issue. The impact of residual weed populations in future crops varies, and its seriousness is likely related to management of the cropping system (Légerè et al., 1996).

A broad range of mechanical and cropping-systems based methods of weed control are used in organic production (Bond and Grundy, 2000; Frick, 2000). Biologically robust cropping systems that are less susceptible to weed proliferation and competition may allow for reduction in herbicide use (Van Acker et al., 2000). For example, crop rotation is often beneficial in allowing for reduced inputs (Liebman and Dyck, 1993). Forages are often cited as being particularly beneficial (e.g. Schoofs and Entz, 2000). Some crops (Lawson, 1994) and regions (Constance et al., 1995) may be particularly appropriate for reduced-input systems.

The objective of this study was to describe the agronomic characteristics of fields and farms which participated in a PFP pilot project, and provide a comparison (where possible) to typical values for these variables in Manitoba.

MATERIALS AND METHODS

Participant Selection

The specific requirements for Pesticide Free Production meant that the number of available participants was constrained by the level of interest in PFP among Manitoba farmers. This situation resulted in non-random, purposive sampling known as convenience sampling, dictated by the need for voluntary samples (Tashakkori, 1998). Alternately, this type of sampling framework in which the population of interest has a circumstantial definition can be described as a historical sampling framework, in contrast to experimental or survey sampling frameworks (Stokes et al., 2000).

In the late winter of 2000 and 2001, newspaper and radio advertisements were run asking farmers interested in participating in a Pesticide-Free Production (PFP) on-farm research project to contact the University of Manitoba via a toll-free number. Word of mouth amongst farmers and promotion by agricultural representatives in various regions also led to some recruitment of volunteers. Several farmers volunteered more than one field for the project. Farmers that had expressed interest in PFP in 2000 were contacted in the spring of 2001 to determine their interest in participating in 2001. Farmers were selected to participate if they met the requirements for attempting a PFP crop that year. This meant that they could not use a seed treatment and could not have used a herbicide considered to leave a residual in the soil in previous years (See Appendix A for complete details of restrictions regarding prior use of residual herbicides for certifiable PFP).

Field Selection

During the first year of the project (2000), there was uncertainty as to how many fields would be volunteered for the project, so all volunteered field crops were included. Fields sown to forage crops were not included. Cereal fields which were being used for greenfeed or silage were not included. This was due to the initial focus of PFP marketing efforts on grain for human consumption rather than forage or feed crops. However, if the farmer was uncertain what the end use of the crop would be (forage or grain), the field was included. Because PFP may be viewed as an alternative to certified organic production, volunteered fields that were certified organic were not included in the project.

However, if the farmer was unsure at the beginning of the season if the field would be certified organic that year, the field was included. Fields in transition to organic were included.

In 2001, it was apparent that there was sufficient interest in PFP that particular crops could be chosen for participation. Only wheat, oats, barley and flax were included in 2001 in order to narrow the focus of the study to those crops that had the highest interest from farmers.

Field Survey

ASSESSMENT OF WEED DENSITIES. A total of 66 fields were surveyed in 2000 and 55 in 2001. Most fields were surveyed twice, once early in the season to assess weed densities, and once later in the season to assess disease and insect pest levels. Due to the logistics of obtaining the correct timing to assess certain pest infestations, some fields were surveyed 3 times. Fields that were volunteered by farmers later in the season only received one visit, timed to assess weed densities as well as disease pressure and insect pest levels. If a field had subsections with significant differences in field history (e.g. different crop rotation history), those subsections were treated as separate fields for the purposes of the study. On several occasions, part of a field was sprayed after the initial visits, while the remainder of the field was left as a PFP crop. In these cases, subsequent assessments of pest levels were made only on the unsprayed sections of the field that met the criteria for PFP certification.

Weed densities in most fields were assessed in early spring, prior to the time when post-emergent herbicide applications would normally occur. For fields which were volunteered for the project later in the season, assessments were made as soon as possible after they were volunteered. In some cases this was not until late July or early August. Weed densities were assessed in 20, 0.1 square metre quadrats throughout the field. An effort was made to obtain representation from as much of the field as possible.

ASSESSMENT OF INSECT PEST LEVELS AND DISEASE PRESSURE. The decision as to which diseases and insects were assessed in PFP fields was based on a consideration of each pest's significance in Manitoba and the extent to which it was often controlled using pesticides. Diseases or insect pests for which there was no effective pesticide control, or for which pesticidal control was rarely used were not prioritized for assessment, as they would not impact decision-making about producing a PFP crop. Notes were made, however, of all pest and disease problems in surveyed fields. Insect and disease levels were scouted for in a pattern similar to that used for weeds.

In cereal crops, leaf rusts and leaf spot diseases were assessed. For wheat, leaf spot diseases included tanspot, spot blotch (*Cochliobolus sativus* (Ito and Kurib) Drechsl. ex Dast.), Stagonospora nodorum blotch (*Phaeosphaeria nodorum* (Muller) Hedjaroude), Stagonospora avenae blotch (*Phaeosphaeria avenaria* f. sp. *triticea* (Weber) Eriksson), Septoria leaf blotch, and Septoria tritici blotch (*Mycosphaerella graminicola* (Fuckel) Schroeter); for barley these included net blotch (*Pyrenophora teres* Drechs), scald (*Rhynchosporium secalis* (Oudem.) J.J. Davis), spot blotch (*C. sativus*), and Stagonospora blotches (*Phaeosphaeria avenaria* f. sp. *triticea*) (Fernandez, 2001). Leaf rusts assessed included wheat leaf rust (*Puccinia recondita* Roberge), stripe rust of wheat and barley (*Puccinia striiformis* Westend.), barley leaf rust (*Puccinia hordei* Otth), and crown rust of oats (*Puccinia coronata* Corda). The following insect pests were assessed in cereal crops: aphids, grasshoppers, and orange wheatblossom midge (wheat midge). Flax fields were assessed for aphids and grasshoppers.

Aphid infestation levels were assessed as the number of aphids on the main stem, at 20 locations in each field. The economic threshold is 12-15 aphids per stem, prior to the soft dough stage (Anonymous, 2001a).

Grasshoppers infestation levels were assessed as the number in a 1 m^2 area disturbed while walking through the crop, at 20 locations in each field. The economic threshold is approximately 12 grasshoppers m^{-2} (Anonymous, 2001a).

Leaf spot diseases and leaf rust were assessed in a manner similar to that used by the Canadian Plant Disease Survey (Agriculture and AgriFood Canada., 2001a). The percent leaf disease coverage on the flag leaf in wheat and oats, and the penultimate leaf in barley, was determined in 20 locations in each field (methodology proposed by Jeannie Gilbert, Agriculture and AgriFood Canada, pers. comm.). Leaf spot diseases are caused by several fungi, many of which cannot easily be identified based on visual symptoms alone (Fernandez, 2001). Therefore, all leaf spotting diseases were combined for assessment in this study. Leaf diseases were assessed later in the season, after the ideal window for fungicide application. In this way, the measurement gave some indication of the severity of infection in fields involved in the study.

The most common method for assessing orange wheatblossom midge (wheat midge) is to determine the number of adults present during egg-laying. However, this method must be conducted in the late evening when adults are active, and the window for assessment is short. Due to the logistical difficulties associated with using this method for fields spread throughout a wide geographic area, wheat midge was determined by an alternative method proposed by J. Gavloski (Provincial entomologist, Manitoba Agriculture and Food). Twenty heads were collected at the early grain filling stage from each field. In the lab, 10 kernels per head were examined to see if wheat midge larvae were present. The economic threshold is approximately 6-10% of the kernels infected (J. Gavloski, pers. comm.).

Grading of Grain Samples

Grain samples from surveyed fields that achieved PFP certification were mailed-in from participating farmers after harvest. Grading of samples (indicating major downgrading factors) and dockage assessments were completed by the Canadian Grain Commission (Winnipeg Service Centre, Winnipeg, MB).

Questionnaire Design

Questionnaire design was based on guidelines and discussion provided by Jackson (1988), May (1993), Babbie (1990), Sudman and Bradburn (1982). All questionnaires were offered in accordance with ethical approval requirements of the Joint Faculty Research Ethics Board, University of Manitoba.

POST-HARVEST QUESTIONNAIRE. All participating farmers were asked to complete a detailed questionnaire after harvest of the crop (Appendix B). Questionnaires were mailed to participating farmers and were returned by mail throughout the winter. There were two main sections to the questionnaire: agronomic, (field history) questions, and demographic questions including an instrument designed to determine farmers' attitudes towards agriculture (Alternative-Conventional Agriculture Paradigm Scale; Beus and Dunlap, 1991). Questions allowing for feedback about PFP were included in this section. Many agronomic questions were the same as those included in the 1997 Manitoba weed survey questionnaire (Thomas et al., 1999), and the 1996 Census of Agriculture (Statistics Canada, 1997). The questionnaire was pre-tested on 10 subjects at the University of Manitoba who had farm backgrounds. Where clarification was required based on the pre-test results, the questionnaire was modified. After questionnaires were returned by participants, questions that were unanswered or unclear were clarified through telephone conversations.

Some modifications were made to the survey in 2001 (Appendix C). Some open-ended questions were modified for 2001 due to poor response in 2000. These questions were replaced by a list of options for which responses could easily be checked off by participants. Options included in the list were based on the responses received in 2000. In addition, farmers that participated in both 2000 and 2001 received a subset of demographic questions as it was not necessary to repeat all of the questions for these farmers in 2001 (Appendix D).

FOLLOW-UP QUESTIONNAIRE. Another questionnaire instrument was used to follow up with farmers who had produced certifiable PFP fields in 2000, conducted in the late summer and early fall of 2001 (Appendix E). Questions were open-ended, and designed to elicit responses about problems with weed densities the year after PFP, future interest, and any other comments about PFP.

BASELINE SURVEY OF MANITOBA FARMERS. To provide information for comparing the characteristics of PFP participants to typical Manitoba farmers, a telephone questionnaire was conducted by Ipsos-Reid Corporation (Winnipeg, Manitoba) in February 2002 (Appendix F). A stratified random sample of 154 farmers, with proportions representing the population distribution in each Manitoba census district, was used. The questionnaire consisted primarily of the same attitude questions used in the written questionnaire for PFP participants (Beus and Dunlap, 1991). A number of demographic questions were also included.

Researchers at Ipsos-Reid determined that a telephone survey would be the most appropriate format for this questionnaire because it minimizes the self-selection of respondents. Respondents to mailed surveys can read the survey before they agree to participate, while telephone respondents agree to participate before the questions are known (Joanna Karman, Ipsos-Reid Corp., pers. comm.). Respondents were restricted to farmers with more than 320 acres of seeded cropland. This is the standard restriction used by Ipsos-Reid to obtain samples of commercial farmers in Western Canada. The margin of error for this survey was +/- 8% at the 95% level of confidence. The refusal rate for the study was 30.3%, which is within the normal range of refusal rates for agricultural surveys conducted by Ipsos-Reid (25-35%; Chad Greenall, Ipsos-Reid Corp., pers. comm.).

Categorization of Fields and Farmers

Fields and farmers were categorized into three distinct groups, representing different levels of commitment to pesticide reduction in the year the PFP crop was attempted. Grouping categories for field-based and farm-based variables were comparable, but determined by different criteria because of the differing scale of observation for these variables. Fields were categorized into three groups: 1) non-certifiable PFP fields, 2) certifiable PFP fields but not in transition to organic certification, and 3) certifiable PFP fields in transition to organic production. Therefore the classification was not based on an objective determination of the "successfulness" of a field in terms of pest pressure. It was based solely on the farmer's ability to meet the requirements for PFP certification. Farmers were categorized into three groups comparable to the grouping for fields: 1) farmers with no certifiable PFP fields, 2) farmers with certifiable PFP fields whose farms were not in transition to organic, and 3) farmers with certifiable PFP fields whose farms were in transition to organic. It should be emphasized that the 'non-certifiable' designation does not imply typical 'conventional' fields or farmers; rather, the grouping is solely based on the meeting of PFP certification criteria. In fact, two fields in the 'non-PFP' group were actually in transition to organic but were not certifiable PFP because a residual herbicide had been used in previous years. The three categories can be considered ordinal as per Pretty (1998, p. 288) who described a proposal for reformation of the European Union Common Agricultural Policy which would include a several-tiered system of payments to farmers for farm practices ranging from basic practices (conventional production), to practices considered to be part of a transition to more sustainable agriculture, with organic production as the highest tier.

In the discussion of our study's results, the following terminology is used. Fields not certifiable as PFP are referred to as *non-certifiable fields*; fields certifiable as PFP that are not in transition to organic are referred to as *certifiable, non-transitional fields*; and fields certifiable as PFP that are in transition to organic are referred to as *certifiable, transitional fields*. For variables that are measured on a farm or farmer-basis, the three groups are referred to as *farmers with non-certifiable fields*, *farmers with certifiable fields, non-transitional farms*, and *farmers with certifiable fields, transitional farms*. When considered together, the non-certifiable fields and certifiable, non-transitional fields are referred to as *"conventional" fields.* Quotations are used around the word conventional to indicate that these fields do not necessarily represent typical conventional fields or farmers. In fact, some of the fields that were not certifiable were actually in transition to organic but were not certifiable as PFP because of the use of a residual herbicide in previous years, or because the crop was terminated due to weed pressure. When considered together, the certifiable, non-transitional fields and certifiable, transitional fields are called *certifiable fields*.

Categorization of Questionnaire Responses

Responses to several variables were categorized to facilitate comparisons between these groups. Where possible, responses were classified into one of two categories for ease of presentation of results. Categories were selected to correspond with those used in sources of comparative information, if available.

Seeding disturbance level was determined by calculating the seedbed utilization (SBU; calculated as the width of the seeding implement opener divided by the row spacing). Fields with 20% SBU or less were classified as low disturbance, while fields with greater than 20% SBU were classified as intermediate to high seeding disturbance.

Seeding rate was categorized as high if it was within the top 25% or greater of the recommended seeding rate range as indicated by the Field Crop Production Guide for

Manitoba (Anonymous, 2001a). All other rates were categorized as low to intermediate. While it is frequently recommended that seeding rates be reduced if a forage species is underseeded to a crop, there was no evidence in this study that farmers who underseeded to forage species used reduced seeding rates more frequently than the entire group of participant farmers, so all observations were included in the analysis.

Tillage system was self-defined by participants as conventional, minimum, or zero-till. Categorization of individual pre- or post-harvest tillage operations did not include seeding or fertilizer applications.

Fields were classified as having fallow in the rotation history if there was at least one fallow year in the 5 years previous to the year in which PFP was attempted. This included chem-fallow and unplanned fallow due to wet conditions; however, in the majority of instances, planned, tilled fallow was used.

Fields were classified as having a forage or green manure in the rotation history if such crops were grown at least once in the 5 years previous to the year in which PFP was attempted.

Fields were classified as having the PFP crop grown following the same crop type based on the following categories: pulse, forage, cereal, or oilseed.

Row spacing of 7.5 inches or less was classified as narrow. Wider row spacing was classified as intermediate to wide.

Fields were classified as receiving a patch treatment for weeds if a weed patch was mowed or sprayed with herbicide.

Fields were classified as having complete record-keeping if the crop rotation was known for at least 4 of the 5 years previous to the PFP crop.

Comparative Data

Data for comparison with study results was obtained from several sources. Manitoba Crop Insurance Corporation provided historical yield averages for conventional crop production through its on-line Manitoba Management Plus Program (Manitoba Crop Insurance Corporation, 2002), as well as the (unpublished) grade distribution for major crops. The Organic Producers' Association of Manitoba (OPAM) provided unpublished data regarding membership and acreage of organic crop production. Long-term yields of organic crops in the Northern Great Plains region were obtained from Entz et al. (2001). Pre-weed control weed densities for sites within 60 miles of Winnipeg were obtained from Friesen and Shebeski (1960). Statistics Canada provided demographic variables through the Census of Agriculture (Statistics Canada, 1997 and 2002). Where possible, recently released data from the 2001 Census of Agriculture was used for comparison. Otherwise, the 1996 Census was used. Regional distribution of participants was assessed by comparison with the distribution of cropped acreage among Manitoba ecoregions (as indicated by Thomas et al., 1999a), and census agricultural regions in the 2001 Census of Agriculture (Statistics Canada, 2002). The latter was more useful for this purpose as it described the distribution on a smaller scale. Comparative data for many agronomic and demographic variables was obtained from the results of the 1997 Manitoba Weed Survey (Thomas et al., 1998 and Thomas et al., 1999a). Some information was also obtained from a Canola Council of Canada study, in which over 800 farmers in Western Canada were surveyed (Canola Council of Canada, 2000). Additionally, a randomized survey of Manitoba farmers carried out by Ipsos Reid Corporation (described above) provided a comparison for the Alternative-Conventional Agricultural Paradigm Scale (Beus and Dunlap, 1991) as well as several demographic variables. Comparative information for dockage levels in Manitoba crops is not readily available in published form. Instead, estimates from elevator managers were used for comparison.

Statistical Analysis

Prior to analysis, it was determined that observations would be combined across the 2 years of the study. The rationale for this approach was the inherent diversity of the fields and farmers involved in the project, which allows for the distinction of groups based on several criteria, including ecoregion, soil type, tillage system, rotation history, or year. Given the relatively small number of participants, and the exploratory nature of the study, it was impractical and unnecessary to separate observations based on each of these criteria. The resulting groups would have been so small as to prohibit meaningful comparison. In addition, the variability resulting from the range in regions and management practices is likely to be as large as or larger than the variability associated with year effects. The maintenance of one data set from our purposive sampling method provided representation of a broad description of farmers and fields involved in PFP. We were therefore able to examine whether differences among fields or farmers implementing pesticide use reduction to varying degrees are robust across site-years and agronomic management practices. Similarly, Rydberg and Milberg (2000) argued that geographic differences were of limited interest in a survey of weed flora on organic farms because such factors cannot be manipulated by farmers.

Grade distribution of PFP grain and average dockage in PFP crops were presented for both certifiable groups combined. This was because these variables are meaningful only in the context of particular crops. Presenting the data for each crop and group would have meant very small sample sizes in some cases. Thus, it was preferable to combine the data across groups in order to present a general indication of the grade distribution and dockage present in certifiable PFP crops for both those fields in transition to organic and those that were not.

In the case of repeat participants over the two years, duplicate values for farmer-based demographic variables were removed, so each farm was only included once. For variables for which the farmer's response could vary from year to year, farmers who provided the same response both years were included (as a single observation), while those who provided different responses each year were eliminated from the dataset.

Statistical analysis was carried out using SAS (SAS Institute, North Carolina, USA). PROC GLM was used to perform analysis of variance (ANOVA) for comparisons of continuous numerical variables among groups. Group was the only source of variation included in the model.

Normality was tested using Shapiro-Wilk's W, and Bartlett's test was used to test for homogeneity of variances among groups. In several situations, distribution of data did not meet the assumption of normality, and transformations did not confer normality. In these cases, PROC NPAR1WAY was used to generate Mann-Whitney U tests (for 2-group tests) and Kruskal-Wallis tests (for tests among more than 2 groups). These tests are considered to be non-parametric equivalents of 2-sample t-tests and one-way ANOVA, respectively (Stokes et al., 2000). In cases where the outcome of a non-parametric test agrees with the outcome of ANOVA (i.e. significant or not significant at the $p<0.05$ level), the result of the ANOVA was presented. This was true in most cases with the exception of the comparison of farm size between study participants and the random sample of Manitoba farmers. For some variables, data could be transformed to meet normality. However, if results agreed with the outcome of ANOVA on the untransformed data, the results for the untransformed data were presented. This was the case for average farm size and average weed density.

For variables analyzed using ANOVA, Fishers Protected LSD was used to separate means. For variables that required analysis with non-parametric methods, pairwise comparisons of groups using the Mann-Whitney U test were carried out if the overall Kruskal-Wallis test was significant at the 0.05 level. For categorical variables, contingency tables were used to generate pairwise comparisons between groups when the overall chi-square test was significant ($p=0.05$).

PROC FREQ was used to generate contingency tables and chi-square statistics for comparisons of frequencies of categorical data. For tables with two groups and two response variables, Pearson's chi-square was used to test for the null hypothesis of no general association between treatment and response. For larger tables with three group categories and ordinal or binomial response categories, the Mantel-Haenszel chi-square was used to test for linear response (Stokes et al., 2000). Ordinal response variables with more than 2 categories could not be considered evenly spaced integer values, so standardized midranks were used (Stokes et al., 2000). If the response variable was not considered ordinal, Pearson's chi-square was used. This was the case for comparisons between the random sample of Manitoba farmers and farmers involved in the PFP study. It was also the case for some questions to which there were more than two possible responses that could not be considered to be a linear progression. When zero counts were generated in a table, or if more than 20% of table cells had an expected value of less than 5, Fisher's exact test was used (Stokes et al., 2000).

The grade distribution and dockage of certifiable PFP grain was only meaningful when considered by crop. Results for these variables were presented across both certifiable groups for each crop in order to maintain as large a sample size as possible for each crop. This resulted in a general indication of the grade and dockage characteristics of PFP certifiable grain, regardless of whether or not the crop was produced from a field in transition to organic production.

Despite the relatively large number of variables considered in the study, no adjustment was made for increasing risk of type I error. Multivariate Analysis of Variance (MANOVA) was not appropriate for use in this study given its inability to handle categorical and missing data. Due to the nature of this study, which depended on the ability of farmers to provide information, missing values were common for many variables. MANOVA requires a complete matrix of observations, and as such, could have only been performed on a small subset of the original data. An alternative to the MANOVA procedure, Bonferonni's adjustment (or Bonferonni's correction), was also not applied because of its very conservative nature, which prohibits adequate discussion of the outcome of this exploratory study. In a non-experimental study of this type, inferential methods are limited because of the observational nature of the study. Therefore, outcome of statistical tests should always be treated with caution in terms of implying cause and effect. Given the conservative context in which the study can be discussed, it was not necessary to use extremely conservative hypothesis testing procedures.

RESULTS AND DISCUSSION

Participation

Farmer response to requests for potential PFP fields was very good, considering that typically less than 1% of fields in annual cereal or oilseed crops are not sprayed with herbicide in Manitoba (Thomas et al., 1999a). A total of 71 farmers and 120 fields were included in the project in 2000 and 2001.

In 2000, 78 farmers expressed interest in participating in the project, and 47% (37) had fields included in the project. In 2001, 119 farmers expressed interest in participating, and 52% (62) had fields on which they attempted to grow a PFP crop. However, only 40 of these farmers were actually included in the project in 2001, due to a restriction of which crops were considered for the study (only wheat, oats, barley and flax in 2001).

In total, 81 fields belonging to 79 farmers offered in early spring 2001 were not included in the project. The primary reason for lack of inclusion (the reason for 44% of fields) was that the crop being grown was not one of the 4 crops targeted for the 2001 season (wheat, oats, barley or flax). The second most common reason (the reason for 33% of fields) was that the farmer decided to spray the field for weed pressure before a visit could be made to the field. Other reasons for lack of inclusion were past use of a residual herbicide on the field (12% of fields), distance from the research station (7% of fields) and the use of a seed treatment (5% of fields).

Thirty-five percent (13) of the participants in 2000 who were contacted in the spring of 2001 planned to grow a PFP crop in 2001. However, only 8 of these farmers had fields included in the project in 2001, for the reasons indicated above. Excluding participating fields in transition to organic production, only one farmer attempted PFP on the same field 2 years in a row; however, in the second year this field was sprayed for weed control and it did not achieve PFP certification.

Crops Offered for Participation

Fields seeded to a total of 16 crops were volunteered for the project. Only 11 crops were included because in 2001 we restricted which crops were being considered in the study (only wheat, oats, barley and flax in 2001) (Table 3-1). Primary interest by farmers was in spring and winter cereals (spring wheat, winter wheat, fall rye, barley, and oats), as well as flax. In 2000, all grain crops volunteered by farmers were included; in 2001, only spring wheat, oats, barley and flax were included. Soybean, buckwheat, hemp (*Cannabis sativa* L.), and canola were included in 2000. In 2001, a small number of fababean, alfalfa seed, corn, peas, sunflower and various forage crop fields were volunteered but not included in the project due to the restriction regarding which crops were eligible in 2001.

Table 3-1. Number of fields volunteered for the on-farm research project and proportion certifiable as Pesticide Free Production (PFP) by crop.

Crop	Number included in project	Proportion certifiable
Spring wheat	36	67%
Oats	33	79%
Barley	20	65%
Flax	8	63%
Fall rye	8	100%
Winter wheat	6	17%
Canola	3	0%
Buckwheat	3	100%
Soybean	1	100%
Durum wheat	1	0%
Hemp	1	100%
All crops	120	68%

Regional Participation

Participants volunteered from virtually all agricultural regions of Manitoba (Table 3-2) (See Appendix H for maps of Manitoba ecoregions and census agricultural regions; Appendix M for map of participating fields). However, there were proportionally fewer participating fields from the highly productive south-central region of the province (adapted from Manitoba Crop Insurance Corporation, 2002), and proportionally more participating fields from regions that typically have higher levels of cattle and forage production (adapted from Statistics Canada, 2002), and reduced or zero-tillage (Thomas et al., 1999a). As compared to the distribution of cropped land in the 2001 Census of Agriculture, there were more participating fields from the south-western corner of the province (Census agricultural regions 1 and 2; 45% of participating fields), compared to the census distribution (22%, Statistics Canada, 2002). There were also more participating fields from the Interlake region (regions 11 and 12; 22% of participating fields) compared to the census distribution (11%). In contrast, there was less participation in the south-central area of the province (regions 7, 8 and 9; 16% of participants) compared to the census distribution (37%). The south-central area of Manitoba is the most intensively farmed region of the province, as indicated by the proportion of farms applying agrichemicals (adapted from Statistics Canada, 2002). The regional distribution of participants in this study was consistent with the idea that higher yield potential increases the incentive for herbicide use (Pannel, 1990), and farmers from regions with lower yield potential would therefore be more likely to participate in PFP. Other studies have also found region to be an important consideration for the adoption and success of reduced pesticide use. Smolik et al. (1995) suggested that reduced-input systems may be more profitable in regions outside the U.S. Corn Belt. Marra and Kaval (2000) found that crop type and region were significant factors in determining the relative profitability of conventional versus organic production. Constance et al. (1995) found that region was a better predictor of support for pesticide reduction than individual farm characteristics. Rydberg and Milberg (2000) noted that organic farms in Sweden tend to be located in specific regions. Bellinder et al. (1994) found that cropping system, which is regionally determined, strongly influenced the effectiveness of European pesticide reduction strategies.

Table 3-2. Number and distribution of fields volunteered for the Pesticide Free Production (PFP) on-farm research project by ecoregion and census agricultural region[z]

Ecoregion or Census Agricultural Region	Distribution of Manitoba agricultural acreage	Number of project fields in each region	Proportion of project fields in each region
Distribution of Manitoba ecoregions[y]			
Aspen Parkland	50%	67	56%
Lake Manitoba Plain	36%	29	24%
Interlake Plain	8%	21	18%
Mid-Boreal Uplands	1%	3	3%
Southwest Manitoba Uplands	1%	0	0%
Boreal Transition	4%	0	0%
Lake of the Woods	1%	0	0%
Total	100%	120	100%
Distribution of Manitoba census agricultural regions[x]			
Region 1	11%	25	21%
Region 2	11%	29	24%
Region 3	10%	12	10%
Region 4	4%	0	0%
Region 5	4%	0	0%
Region 6	8%	7	6%
Region 7	14%	11	9%
Region 8	16%	2	2%
Region 9	7%	6	5%
Region 10	2%	1	1%
Region 11	5%	11	9%
Region 12	6%	14	12%
Total	100%	120	100%

[z]See Appendix F for maps of Manitoba ecoregions and census agricultural regions.
[y]Distribution of cropped acreage in spring cereals and oilseeds (Thomas et al., 1999a).
[x]Distribution of land in crops in the 2001 Census of Agriculture, adapted from Statistics Canada (2002).

PFP Certification

In total, 2368 ha of the land area volunteered for the project was certifiable as PFP. This represented 83% of the total land area volunteered for the project. Over the two years of the project, 68% of all fields included in the project were certifiable as PFP. The proportion of certifiable fields varied depending on the crop type (Table 3-1). No canola fields were certifiable, as PFP certification does not allow for the use of seed treated with a fungicide or insecticide. Ninety-five percent of canola growers use a seed treatment (Canola Council of Canada, 2000), and forgoing the insecticidal seed treatment in particular requires diligent scouting for flea beetles (*Phyllotreta cruciferae* Goeze and *Phyllotreta striolata* Fabricius) in case foliar insecticide application is required. Some farmers interested in attempting PFP canola indicated that they were not prepared to make the time commitment required to scout fields for potential insecticide treatment. A preventative seed treatment was seen as much more convenient by these farmers. This fact is likely to limit the success of PFP canola, although the elimination of a seed treatment may be more feasible during years when the flea beetle population is low and if practices such as trap crops are used to limit their impact (J. Gavloski, pers. comm.). Canola is a major crop in Manitoba, covering over 750 000 ha in 2001 (Statistics Canada, 2002). Despite this, only 4% of fields volunteered for the project in 2000 were canola fields. This suggests relatively low levels of interest in canola as a PFP crop on the part of farmers.

Only 17% of the winter wheat fields were certifiable, due to the application of fungicide to control leaf diseases. Winter wheat is an excellent candidate for elimination of in-crop herbicide because it competes well with weeds. The fact that Fusarium head blight (*Fusarium* spp.) (FHB) is usually avoided because winter wheat flowers earlier than spring wheat (Agriculture and Agri-Food Canada 2001a) adds to the potential of winter wheat as a PFP crop. However, current varieties grown in Manitoba are susceptible to leaf diseases. In 2000, less than 2% of the total wheat acreage in Manitoba was winter wheat (Agriculture and Agri-Food Canada, 2001a), although the acreage has increased in recent years (Fowler, 1997). Given the small acreage that winter wheat covers in Manitoba, it is worth noting that 10% of fields offered for participation in 2000 were winter wheat. This indicates significant interest in winter wheat as a potential PFP crop. The first variety of winter wheat (UM 5089) with resistance to leaf spot diseases has been proposed for registration (Anonymous, 2002). This may improve the prospects for PFP winter wheat.

Other crops were more successful in terms of PFP certification. All fall rye and buckwheat fields included in the project were certifiable. These two crops are traditionally not sprayed with in-crop herbicide. Fall rye is an excellent competitor with weeds, partly because of its fall planting date. Buckwheat is usually seeded later than most other crops in this region due to frost sensitivity, and this may allow it to escape competition with early-emerging weeds. In addition, there are few in-crop herbicides registered for buckwheat and no registered seed treatments (Manitoba Agriculture and Food, 2001f). Sixty-three percent of flax fields were certifiable. This proportion can be considered relatively high as flax is not a good competitor with weeds. The high proportion of certifiable flax fields can be attributed in part to the fact that half of the flax fields were in transition to organic, or underseeded to forage species that did not allow for herbicide application. Three of the five farmers producing certifiable PFP flax rated their satisfaction with its production to be poor. This represented a higher proportion of farmers indicating low satisfaction with a certifiable PFP crop than was evident for farmers producing cereal crops. A high percentage of oat, spring wheat, and barley fields were also certifiable (79%, 67% and 65% respectively), indicating the potential of PFP to be successfully implemented in the production of these significant Western Canadian crops.

Questionnaire Response Rate

On a per-farmer basis, the questionnaire response rate from PFP participants was 96%. On a per-field basis, the response rate was slightly lower, at 95%, because a few farmers completed questionnaires for some, but not all, of the fields they included in the project.

Even after clarification was attempted via telephone, many surveys were missing some information. Many farmers either did not have complete field records, or had recently rented land for which they did not have complete field history. In addition, University of Manitoba ethical guidelines required a clause to be included in the survey indicating that respondents could refuse to answer any questions they preferred not to. As a result, variables differ in the number of observations available for analysis. In addition, because several farmers volunteered more than one field for the project, the number of observations for farm-based variables is less than those for field-based variables.

Field and Farm Size

Differences in field size among participant groups were not significant at the p=0.05 level, but because the level was only p=0.065, the trends in the data warrant discussion (Table 3-3). Field size for the entire group ranged from 3.2 ha to 130 ha. The largest difference in average field size was between the two groups of certifiable fields. Certifiable fields in transition to organic averaged 38.6 ha, while certifiable fields not in transition to organic averaged 25.5 ha. Average field size of non-certifiable fields was intermediate to both of these groups at 31.3 ha. Farmers growing certifiable PFP crops on fields which were not in transition to organic were more likely to attempt PFP on smaller fields than those with certifiable fields where commitment has been made to convert to organic production. If the two 'conventional' groups are considered (non-certifiable fields and certifiable fields not in transition to organic), it is apparent that smaller fields were more likely to achieve PFP certification, indicating that perhaps, where no long-term commitment to reduced pesticides has been made farmers are more likely to experiment with pesticide use reduction on smaller fields. Alternately, farmers may be more likely to remove larger fields from PFP attempts because of the greater risk involved. This is consistent with traditional technology adoption theory which suggests that during the initial stages of technology adoption, a new practice is likely to be implemented on a smaller scale than practices which are already accepted (Rogers, 1983).

Average field sizes for all three participant groups were somewhat larger than the 21 ha average field size for spring cereal and oilseed crops in Manitoba (Thomas et al., 1999a). The average field size for all three groups in the project was also larger than the average field size on organic farms on the Northern Great Plains (17.6 ha) (Entz et al., 2001). This indicates that while there may be some evidence that for fields not in transition to organic production, it is the smaller fields that tended to be retained for PFP certification, these fields are not small in the context of typical Manitoba farms. This is important to note because even at this early stage of implementation, PFP is being attempted on large fields, suggesting a willingness on the part of these farmers to experiment with pesticide use reduction on a relatively large scale.

Total farm size was not significantly different among participant groups (Table 3-3). However, the average size of farms with certifiable fields on farms in transition to

Table 3-3. Characteristics of farms and farmers attempting to produce Pesticide Free Production (PFP) crops

Group	Average field size (ha)[z]	Average farm size (ha)	Average number of crops grown regularly per farm	Percentage of farmers: Regularly growing forages	Percentage of farmers: Regularly growing winter cereals[y]	Percentage of farmers: Producing livestock	Percentage of farmers: Who expect to increase future pesticide use[x]
	(n=120)[w]	(n=66)	(n=65)	(n=65)	(n=65)	(n=66)	(n=30)[v]
Farmers without certifiable PFP fields	31.3 (4.29)	668.5 (98.5)[u]	5.13 (0.31)	53.3	40.0	46.7	-
Farmers with certifiable fields non-transitional farms	25.5 (2.30)	654.5 (87.8)	5.23 (0.34)	60.0	30.0	42.9	6.0
Farmers with certifiable fields, transitional farms	38.6 (6.09)	528.0 (79.0)	5.85 (0.63)	65.0	20.0	43.5	0.0
P-value for PFP participant group effect[t]	0.065	0.51	0.51	0.49[s]	0.20[s]	0.87[s]	1.00[r]
Random sample of Manitoba farmers (n=154)[q]	-	495.2 (34.1)	5.03 (0.15)	60.4	15.6	37.7	-
P-value for Manitoba farmers versus PFP groups	-	0.16	0.34	0.92[p]	0.052[p]	0.84[p]	-

[z]This is a field-scale variable, therefore grouping was based on certification and organic transition status of individual fields, not farmers.
[x]On the PFP field, as a result of having grown a certifiable PFP crop. Therefore, responses from farmers without certifiable fields are not applicable.
[w]Number of observations within PFP groups for a particular variable.
[v]Small sample size because question asked of producers only in 2001.
[u]Numbers in parentheses represent standard errors).
[t]See Materials and Methods for details of statistical tests used.
[s]P-value for Mantel-Haenszel chi-square (linear association).
[r]Fishers exact test was used due to small sample sizes.
[q]Random sample of 154 Manitoba farmers conducted by Ipsos Reid Corp. (Winnipeg, MB).
[p]P-value for Pearson chi-square (general association).

organic was smaller than the other two groups. This is consistent with other comparative studies of organic farms (Stanhill, 1990). However, the role of farm size in the adoption of sustainable farming practices has been inconsistent in most comparative studies (Egri, 1999). There was no significant difference in farm size among the three participants groups and the random sample of Manitoba farmers. Average farm size for all three participant groups was larger than the average Manitoba farm size of 361 ha in 2001 as reported by Statistics Canada (2002). This suggests that PFP is of interest to farmers operating relatively large farms and is more evidence that Manitoba farmers are interested in implementing pesticide reduction on large, commercial-scale farms.

Crop Yields

Average yields of crops from all three groups were somewhat reduced from both the 10-year and the same-year yield average on the basis of comparison within each variety and risk area (Table 3-4). There were no significant differences in yield among groups. Cereal yields in Manitoba in 2000 were considered to be average (Agriculture and AgriFood Canada, 2000) and average to below average in 2001 (Agriculture and AgriFood Canada, 2001c). Yields in all three groups may have been reduced from baseline yields because of the tendency of some farmers to select their less productive fields for PFP attempts, because it is less risky to attempt a new practice on such fields (Scott Day, Agricultural Representative, Boissevain, MB, pers. comm., in addition to my own observations). This is consistent with the concept of initially implementing new practices in a low-risk fashion (Rogers, 1983).

Table 3-4. Average crop yields for fields on which Pesticide Free Production (PFP) was attempted. Means are followed by standard errors in parentheses.

Group	Yield as a percentage of:		
	10-year yield average[z] (n=98)[x]	Same-year yield average[z] (n=95)	Long-term organic yield average[y] (n=105)
Non-certifiable fields	84.5 (5.69)	85.5 (5.54)	133.1 (10.02)
PFP-certifiable fields not in organic transition	90.0 (4.30)	92.0 (3.83)	135.1 (6.10)
PFP-certifiable fields in transition to organic	83.8 (8.61)	82.4 (7.88)	109.4 (10.32)
p-value for group effect[w]	0.673	0.397	0.075

[z]Yield averages for comparison were determined for each risk area and cultivar combination (Source: Manitoba Crop Insurance Corporation, Management Plus Program).

[y]Yield average for comparison were determined for each crop within the Northern Great Plains (Source: Entz et al., 2001).

[x]Number of observations within PFP groups for a particular variable.

[w]See Materials and Methods for details of statistical tests used.

It might have been expected that greater declines in yield would be evident with reduced pesticide use. Numerous studies have demonstrated increased yields when pesticides are used (e.g. O'Donovan et al., 2001). However, this study provides no evidence that this generalization is true in all cases. Several studies have found that yields are often, but not always, reduced under organic production (Stanhill, 1990; Kramer, 1984; Lockeretz et al., 1981; Entz et al., 2001). Other studies have found no yield differences between cropping systems with different levels of pesticide use. Swanton et al. (2002) found that yield of winter wheat grown in a manner consistent with PFP guidelines in rotation with corn and soybean was not significantly different from winter wheat yield in treatments relying more heavily on herbicide use. Stanhill (1990) found that variation in yield between conventional and organic crop production was less important than variation between fields, independent of production system.

While regional and cultivar effects were accounted for in the assignment of comparative yield values, yield differences can also be masked by many variables including low or excess water availability, salinity, drought, or low soil fertility (Boyer, 1983). These factors are in turn influenced by management practices such as planting date, tillage system, and crop rotation. For example, preliminary results from a Saskatchewan study indicated that in dry years, yields of reduced-input systems were similar to those of high-input systems, but in wet years, demand for nitrogen led to reduced yields in reduced-input systems (Brandt and Ulrich, 2001). In the same study, yield reductions in organic treatments were attributed both to increases in weed competition as well as to reduced nitrogen supply. Harker (2001) found that environment and year effects were more important than weed density or crop stand in determining yield of field crops in Alberta.

The broad nature of this project, encompassing various regions, soil types, and production systems may be responsible for the lack of yield differences among groups. It is also true that research exploring the benefit of a given input (for example, herbicide use) is generally carried out with optimal levels of all other inputs. This may lead to an over-estimation of the value of a single input (Flaten, 2001). The true economic value of an input may be significantly less than that indicated by such research. For example, Harker (2001) found that yield losses due to weeds in Alberta were not detectable in the majority (73%) of barley fields. Herbicide application would not have increased yields in these situations, despite popular perception that such applications do increase yields. Crop yields can in fact be reduced if herbicide application causes crop injury (Pimental et al., 1993b), or if residual herbicides cause damage in subsequent crops (Brandt and Ulrich, 2001).

High yields do not always generate high economic returns. Incomes from high input, high yield farms and lower input, lower yield farms can be similar because of differences in costs (Lockeretz et al., 1981). Therefore, yield cannot be used alone as a measure of the profitability of a cropping system. Yields of crops from all three groups were not significantly different when compared as a proportion of the long-term organic yield averages for each crop in the Northern Great Plains area (Entz et al., 2001). Both 'conventional' groups however had yields over 30% higher than the organic yield averages for this region. This indicates the potential of certifiable PFP crops to be higher yielding than certified organic crops.

Grades of Certifiable PFP Grain

A total of 65 grain samples were graded by the Canadian Grain Commission (Table 3-5). For various reasons, some farmers were unable to submit grain samples, so a complete set of samples from certifiable fields was not obtained. Grade distribution was difficult to assess on a long-term basis because grade distributions vary widely among years. For example, the proportion of Canadian Western Red Spring wheat (CWRS) that graded No. 1 ranged from 1% to 66% of the crop from 1993-1996 (Manitoba Agriculture and Food, 2000b). However, the grade distribution of PFP crops tended to be skewed toward lower grades as compared with the distribution of grades for Manitoba grain in 2000 and 2001, as reported by Manitoba Crop Insurance Corporation (Appendix L).

Table 3-5. Grade distribution of certifiable Pesticide Free Production (PFP) crops[z]

Crop	Malt	No. 1	No. 2	No. 3	No. 4	Sample or feed	Number of samples
Spring wheat[y]	n/a	5%	50%	36%	0%	9%	22
Oats	n/a	9%	23%	27%	9%	32%	22
Barley	0%	13%	75%	n/a	n/a	13%	8
Flax	n/a	100%	0%	0%	n/a	0%	5

[z]As determined by inspectors at the Canadian Grain Commission, Winnipeg Service Centre, Winnipeg, MB.

[y]Primarily Canadian Western Red Spring. One sample was Canadian Western Extra Strong.

The most common downgrading factors for certifiable PFP grain were low test weight for oats (especially in 2001) and Fusarium damaged kernels (FDK) for spring wheat. These factors are not directly attributable to non-pesticide use. There are no fungicides that provide control of Fusarium head blight, although some products provide suppression of this disease (Manitoba Agriculture and Food, 2002). Cereals with low test weight were common throughout Manitoba in 2001 (Agriculture and AgriFood Canada, 2001b), while weathering and sprouting were the primary causes of quality loss in cereals in 2000 (Agriculture and AgriFood Canada, 2000).

Between 1992 and 2000, less than 1% of field crops in Manitoba were downgraded for reasons directly attributable to reductions in herbicide use (i.e. inseparable seed or mixed grain due to seed production by weeds or volunteer crops)

(Unpublished data, Manitoba Crop Insurance Corporation). Two certifiable PFP grain samples (3.1% of samples) were downgraded because of inseparable weed seeds. One barley sample had 2.4% wild oats in barley; another barley sample contained 14% volunteer oats. In addition, 1 sample (1.5% of all samples) was downgraded due to wheat midge damage.

Many different factors affect the grade of grain achieved. Post-harvest weather, heat or drought stress during grain filling, variety, fertility, timing of nutrient availability, planting date, post-harvest handling and storage can all affect grain grade. Grade can also be influenced by the use of crop inputs. Low levels of hard vitreous kernels (HVK) can result in downgrading of wheat and durum, and this has been attributed to insufficient supply of nitrates to the kernels during development (Matsuo, 1993). The effect of crop pests (weeds, diseases, and insects) on grade may be direct or indirect. Pests can affect the plant's ability to compete for water or nutrients, indirectly affecting grades. As a result, the use of pesticides may improve grades, but our results suggest that this may not be true if fields are selected or prepared for reduced pesticide use.

Weeds can affect grades in several ways. If the end use of cereal grain is milling, the presence of other cereal grains or weeds in wheat can cause a reduction in milling yield or baking quality. Contamination is more serious for oats in wheat than barley in wheat, and wild oat is a more serious concern than either of these volunteer cereals (Dexter, 1993). The problem is similar in other crops. For example, a potential buyer of PFP flax indicated low tolerance for barnyard grass (*Echinochloa crus-galli* (L.) P. Beauv.), smartweed (*Polygonum* spp.), wild buckwheat (*Polygonum convolvulus* L.), and lambsquarters (*Chenopodium album* L.) (Brenda Tjaden Lepp, PFP marketing manager, pers. comm.). An additional concern is the staining effect of fresh weed growth on grain during harvest. While this has been shown not to affect the quality of red spring wheat, it has quality implications for durum wheat (Dexter, 1993), and can be very significant in other crops such as field beans (Manitoba Agriculture and Food, 2001b). Non-use of fungicides may also cause increased protein levels in barley which is detrimental for malt quality (Manitoba Agriculture and Food, 2001e). Non-use of herbicides can improve the quality of wheat by increasing protein levels through competition for moisture by weeds

(Pannel, 1995). However, Holm et al. (2002) found that level of herbicide use had little or no effect on pea, canola, barley, or wheat quality characteristics.

Diseases and insect pests can also negatively affect grades. Puppala et al. (1998) found that test weight and grain protein content in some, but not all, varieties of hard red winter wheat were increased with fungicide application. McKendry et al. (1995) found significant linear decreases in test weight, milling quality, and flour yield, but not protein or baking quality, as the level of Septoria leaf blotch infecting hard red winter wheat increased. High levels of midge-damaged kernels can drastically reduce baking quality (Dexter, 1993). Fungal diseases such as red smudge (*Pyrenophora tritici-repentis* (Died.) Drechs) and Fusarium head blight (FHB) can also be downgrading factors, although red smudge is far less serious than FHB. Root rot of cereals, which may be prevented by the use of a fungicidal seed treatment, may result in shrunken kernels, which negatively affects milling and baking qualities (Dexter, 1993). Kernel plumpness and sample uniformity are key grading factors for malt barley. Non-use of fungicides (or herbicides) in barley may result in downgrading to feed (Manitoba Agriculture and Food, 2001e). Although there are penalties for pesticide residues in grain (Nowicki, 1993), this is not considered as a grading factor at the 'farm gate'.

Downgrading attributable to the absence of pesticide use may not always be detrimental to the farmer. If the end use of a cereal crop is feed rather than milling or malting, the presence of other cereal grains is not particularly detrimental and may in fact be advantageous. The same may be true for some weed seeds. In addition, price differences between the highest and second-highest grades are not always large and the cost of obtaining the highest grade may not justify the use of additional inputs. For example, on June 28, 2002, the Canadian Wheat Board listed the value of No. 1 CWRS, 14% protein as $201.55/tonne compared with $195.85 for No. 2 CWRS, 14% protein. This may partially explain the higher frequency of relatively low grades of certifiable PFP grain.

Dockage in Certifiable PFP Grain

Dockage "consists of all the readily removable material that must be removed from a sample of grain using approved methods and equipment prior to assigning an official grade" (Canadian Grain Commission, 1993). Dockage is an important consideration for farmers because it results in a deduction upon delivery of grain, based on the volume of dockage as well as cleaning costs. It is also a consideration for grain handling companies in terms of cleaning costs, although screenings can have significant value for these companies in some years and can be used to increase the volume of clean grain by blending to meet minimum export specifications.

Dockage in PFP certifiable crops ranged from 1.1% for fall rye to 10.6% for flax (Table 3-6). Dockage in certifiable PFP oats and barley (2.5% and 2.8%, respectively) was slightly higher than that expected for conventional crops (1% and 1%, respectively; Jack Ryrie, elevator manager, Louis Dreyfus Canada, Rathwell, MB, pers. comm.). One estimate of dockage in organically-produced oats and barley on the Canadian Prairies is 3% (Neil Strayer, Growers International Organic Sales Inc., Belle Plaine, SK, pers. comm.). Average dockage in certified PFP spring wheat was 4.8%, which is somewhat elevated from typical conventional dockage (1.5%, Jack Ryrie, pers. comm.). However, this level was similar to that expected for organic spring wheat in this region (~4%, Neil Strayer, pers. comm.). Average dockage in certifiable PFP flax was 10.6%, less than that expected in organic crops (~20%; Neil Strayer, pers. comm.), but higher than that expected for conventional crops (5%; Jack Ryrie, pers. comm.). Dockage levels can vary by year and region depending on environmental conditions and resulting weed pressure. However, variation in dockage in 2000 and 2001 in most regions of Manitoba was minor (Jack Ryrie, pers. comm.). An exception is the Red River Valley region of Manitoba, which experienced wet conditions in both 2000 and 2001 and resulting poor weed control (Jack Ryrie, pers. comm.). However, most fields participating in this study were located outside of this region.

Table 3-6. Average dockage in certifiable Pesticide Free Production (PFP) crops[z]

Crop	Average dockage (%)	Number of observations
Spring wheat	4.6	22
Oats	2.5	22
Barley	2.8	9
Flax	10.6	5
Fall rye	1.1	4

[z]As determined by inspectors at the Canadian Grain Commission Winnipeg Service Centre, Winnipeg, MB.

The implications of high levels of dockage depend on the end use of the grain. Not all weed seeds are detrimental if the grain is to be used as feed. The development of the McLeod Harvest (McLeod Harvest Inc., Winnipeg, MB), or the use of local seed farmers' cleaning facilities may allow farmers to capture the value of screenings, particularly if livestock are part of the farm operation. Provincial forage specialists recently suggested using screenings for emergency feed in drought-affected areas (Dawson, 2002).

Pest Levels

WEED DENSITIES. While there were no significant differences (p=0.065) in average weed density among groups, pre-spray weed densities in non-certifiable fields were higher than either of the certifiable groups (Table 3-7). This suggests that farmers were choosing to apply herbicides to those fields with the highest weed densities and leave those with lower weed densities as certifiable PFP fields. Certifiable, transitional fields had average weed densities very similar to certifiable, non-transitional fields.

Average weed densities ranged from 110 plants m^{-2} (certifiable, non-transitional fields) to 155 plants m^{-2} (non-certifiable fields). Average weed densities ranged from 1.9 times (certifiable, non-transitional fields) to 2.7 times (non-certifiable fields) the average post-weed control weed density by ecoregion (Thomas et al., 1998) (Table 3-7). However, weed densities were only 0.58 times (certifiable, transitional fields) to 0.73 times (non-certifiable fields) pre-weed control densities for this region (Friesen and Shebeski, 1960) (Table 3-7). Average weed densities in certifiable fields were also less than 0.25 times the average uncontrolled weed density found in wheat fields near Regina, SK (470 plants m^{-2}) (Hume, 1993). This suggests that farmers chose relatively weed-free fields (on a pre-spray basis) for PFP attempts, and of these fields, it was fields with relatively low weed densities that were retained for PFP certification.

Table 3-7. Average weed densities in fields on which Pesticide Free Production (PFP) was attempted. Means are followed by standard errors in parentheses.

Group	Average weed density (plants m^{-2}) (n=119)[x]	Average weed density as a percentage of: Post-spray weed density[z] (n=119)	Pre-spray weed density[y] (n=119)
Non-certifiable fields	155.8 (26.3)	274.3 (49.09)	72.7 (12.86)
PFP-certifiable fields not in organic transition	110.0 (14.4)	193.3 (23.94)	65.2 (8.64)
PFP-certifiable fields in transition to organic	112.4 (24.1)	239.2 (51.83)	57.9 (12.87)
p-value for group effect[w]	0.065	0.292	0.693

[z]Weed densities for comparison were determined for each ecoregion in 1997 Manitoba Weed Survey (Thomas et al., 1998).

[y]Weed densities for comparison were determined for annual field crops in a region of central Manitoba within 60 miles of Winnipeg (Friesen and Shebeski, 1960).

[x]Number of observations within PFP groups for a particular variable.

[w]See Materials and Methods for details of statistical tests used.

The selection of fields with relatively low weed densities is supported by participating farmers' observation of weed densities in their fields. Compared to the questionnaire results from the 1997 Manitoba Weed Survey (Thomas et al., 1999a), a higher proportion of farmers with certifiable fields rated the weed density in the field designated for PFP attempt as 'light' (45% versus 17% in weed survey) rather than 'average', 'heavy' or 'very heavy'.

Other studies have found differences between weed densities in organic and conventional crop production. Farmers often find weed densities increase during the transition to organic production (Macey, 2001). Rydberg and Milberg (2000) found that organic fields had much higher weed densities than conventional fields. Brandt and Ulrich (2001) also found that weed densities were higher in organic versus conventional plots; however, differences in weed competition were relatively small between low and high-input conventional systems. While differences in weed densities in organic and conventional fields would have been expected, the lack of difference in weed densities between certifiable, non-transitional fields and certifiable, transitional fields may be due to the early stage of transition for the certifiable, transitional fields. In contrast, most comparative studies consider established organic production versus conventional production.

WEED POPULATIONS THE YEAR FOLLOWING CERTIFIABLE PFP. Weed seed return and escalating weed densities have been cited by many authors as a major issue when reductions in herbicide use are considered (Bellinder et al., 1994; Czapar et al., 1997; Medd and Pandey, 1993). Uncontrolled weeds in a given year can in some cases result in up to a 14-fold increase in the weed seed bank (Leguizamon and Roberts, 1982); however, crop competition can reduce weed seed return (Lindquist et al., 1995).

In the year after certifiable PFP, the proportion of farmers indicating that weed density on the former PFP field was heavy or very heavy was higher than reported in the questionnaire results from the 1997 the Manitoba Weed Survey (42% versus 23% in weed survey) (Thomas et al. 1999a). In addition, 25% of certifiable, non-transitional fields (n=20) and 67% of certifiable, transitional fields (n=9) were rated as having higher weed pressure the year after certifiable PFP than would be expected if the field had been sprayed. However, only 5% of the certifiable, non-transitional fields required increased costs (time or money) to control the perceived increased weed pressure. The majority of the farmers indicated that their regular herbicide program was adequate to control increased weed infestations. In addition to the effectiveness of the typical herbicide program, rotational considerations for the year after PFP were often mentioned by farmers in the follow-up survey. Légerè et al. (1996) suggested that the impact of residual weed densities likely depends on the competitiveness of the cropping system. The choice of a competitive crop the year after certifiable PFP may reduce the impact of increased weed densities. If farmers rotated into a crop that allowed for good herbicidal weed control (e.g. Clearfield® canola), any increased weed densities attributable to PFP were not problematic. For farmers who rotated into a non-competitive crop (e.g. peas), weeds were more of a problem. Farmers indicated that 44% of the certifiable, transitional fields would probably result in increased costs due to escalating weed populations the year after certifiable PFP. The projected increased costs were generally for increased tillage. For most of the farmers in this group, the increased costs were not a major concern as they had already made a commitment to convert to organic production and expected price premiums in the near future.

In 2001, farmers with certifiable fields were asked if they thought they would have to increase their future pesticide use as a result of producing a PFP crop (Table 3-3). Only 6% of farmers with certifiable, non-transitional fields said they might have to increase pesticide use. This was not significantly different from the proportion of farmers with certifiable, transitional fields stating that they expected to increase pesticide use (0%). The fact that the majority of farmers (~95%) were satisfied with the weed control they achieved the year after PFP suggests that the efficacy of currently available herbicides (Jasieniuk et. al., 1996) is high enough to provide adequate control despite some cases of increased weed densities. This is consistent with comments made by Buhler (1999b) who noted that moderate increases in weed densities did not reduce the level of weed control in subsequent years. Our results also agree with the findings of Swanton et al. (2002), who conducted a 9-year rotation of winter wheat grown in a manner consistent with PFP in rotation with conventional corn and soybean. While average weed density in their study was highest in the rotation including the 'PFP' winter wheat compared to treatments with higher herbicide use, time and density were not correlated, so these authors concluded that there was no increase or decrease in weed density over time. Similarly, Bostrom and Fogelfors (2002a) found that after 10 years, there was no significant difference in weed densities between an untreated control and spring cereals treated with a full dose of herbicide every other year. Results of these studies suggest that eliminating herbicide use on a regular schedule (with no consideration given to annual crop and weed conditions, and no alternative weed management efforts) does not increase weed densities in the long term compared to no treatment. It would be expected that with the elimination of herbicide use based on annual field selection and implementation of alternative weed management practices it would be even less likely that weed populations would increase.

DISEASE PRESSURE. Disease pressure was not a concern in most fields involved in the project (Table 3-8). An exception was the winter wheat crops which were not certifiable due to the application of fungicide for leaf disease control. There is no well-defined

Table 3-8. **Disease and insect pest levels in fields on which Pesticide Free Production (PFP) fields was attempted. Means are followed by standard errors in parentheses.**

Group	Barley	Spring wheat	Oats	Flax
	Aphid infestation[z]			
	(n=13)[y]	(n=31)	(n=30)	(n=8)
Non-certifiable fields	0.00 (-)	2.72 (1.55)	7.70 (7.08)	0.00 (-)
PFP-certifiable fields not in organic transition	1.11 (0.85)	1.33 (1.00)	2.05 (0.93)	0.00 (-)
PFP-certifiable fields in transition to organic	0.00 (-)	0.08 (0.05)	0.31 (0.08)	5.00 (4.56)
P-value for group effect[x]	0.536	0.243	0.132	0.201
	Grasshopper infestation[w]			
	(n=15)	(n=32)	(n=30)	(n=8)
Non-certifiable fields	0.60 (0.55)	0.38 (0.17)	0.30 (0.20)	0.47 (0.23)
PFP-certifiable fields not in organic transition	0.40 (0.37)	0.20 (0.12)	0.76 (0.50)	0.02 (0.02)
PFP-certifiable fields in transition to organic	0.04 (0.04)	0.32 (0.15)	0.2 (0.06)	0.08 (0.08)
P-value for group effect[x]	0.701	0.173	0.743	0.670
	Leaf rust score[v]			
	(n=14)	(n=30)	(n=30)	-
Non-certifiable fields	0.00 (-)	0.27 (0.15)	0.02 (0.02)	-
PFP-certifiable fields not in organic transition	0.00 (-)	0.09 (0.07)	0.27 (0.09)	-
PFP-certifiable fields in transition to organic	0.77 (0.77)	0.29 (0.13)	0.34 (0.16)	-
P-value for group effect[x]	0.309	0.343	0.360	-
	Leaf spot score[v]			
	(n=14)	(n=30)	(n=30)	-
Non-certifiable fields	0.97 (0.61)	0.27 (0.47)	1.17 (0.19)	-
PFP-certifiable fields not in organic transition	0.66 (0.22)	0.20 (0.23)	0.92 (0.06)	-
PFP-certifiable fields in transition to organic	0.81 (0.57)	0.30 (0.23)	0.82 (0.12)	-
P-value for group effect[x]	0.140	0.343	0.738	-
	Wheat midge infestation[u]			
	-	(n=31)	-	-
Non-certifiable fields	-	1.61(0.65)	-	-
PFP-certifiable fields not in organic transition	-	2.01(0.61)	-	-
PFP-certifiable fields in transition to organic	-	4.81(2.07)	-	-
P-value for group effect[x]	-	0.183	-	-

[z]Average number of aphids present on the main stem of the plant.

[y]Number of observations within PFP groups for a particular variable.

[x]See Materials and Methods for details of statistical tests used.

[w]Average number of grasshoppers present per square meter.

[v]Average leaf coverage score for the flag leaf for wheat and oats or the penultimate leaf in barley. Categories ranged from 0-4 where 0=no or trace coverage; 1=under 25%, 2=under 50%, 3=over 50%, 4 = complete coverage.

[u]Percentage of kernels per head infested with wheat midge larvae.

economic threshold for leaf diseases in cereals (Manitoba Agriculture, 2001e), because many factors affect the need for fungicide application. This makes it difficult to assess the appropriateness of fungicide application based on a one-time assessment of disease pressure alone. The decision to apply a fungicide must be made early in the development of the disease. Disease control in wheat is warranted especially when yield potential is high, if the field was planted to wheat last year (especially under reduced-tillage), if the environment is favourable for disease development (high humidity), and if the crop is winter wheat, which is more susceptible to these diseases (Manitoba Agriculture and Food, 2001c).

Annual plant disease surveys give an indication of the severity of leaf diseases across Manitoba, though not all crop and disease combinations are included. Crown rust of oats, leaf spot diseases of wheat and barley, and leaf rust of wheat were generally less severe than historical levels in 2000 and 2001. Exceptions occurred in specific regions, for susceptible varieties, and for fields seeded later than normal (Agriculture and Agrifood Canada, 2001 and 2002). For example, late seeded fields of wheat may have seen losses of 5-10% due to leaf rust in 2000 (Agriculture and Agrifood Canada, 2001a). Losses due to leaf spot in barley were estimated at less than 5% in 2001 (Agriculture and Agrifood Canada, 2002). Fernandez (2001) found that changes in the prevalence of various leaf spotting pathogens of cereal crops in Saskatchewan were associated with environmental conditions, but not with cropping system diversity or input levels. In that study, a lack of differences between cropping systems was attributed to overall high or low disease pressure in certain years, the presence of airborne inoculum, or the presence of alternative hosts.

INSECT PEST LEVELS. In general, insect pest infestation levels in certifiable PFP fields were below economic threshold levels for this region (Table 3-8). There were no significant differences among groups in terms of aphid, grasshopper, or wheat midge infestation levels. One certifiable, transitional field had a grain sample that was downgraded due to wheat midge damage.

Rotation

ROTATION OF CROP TYPES. There were no significant differences among groups in terms of the proportion of fields following the same crop type in rotation (Table 3-9). All three groups had proportions in the range of 25-35% of fields for this variable. In comparison, 39% of spring wheat, 60% of barley, 52% of oat, and 10-15% of broadleaf crops grown in Manitoba between 1994 and 1998 were planted following the same crop type in rotation (Manitoba Crop Insurance Corporation, 2002). Thomas et al. (1999a) found that 57% of surveyed cereal fields were grown on cereal stubble. This suggests that farmers attempting to produce a PFP crop are rotating among crop types to the same degree or greater compared to what is typical in Manitoba. Reduced reliance on pesticides may necessitate the use of more diverse cropping systems to reduce pest levels. For example, Liebig and Doran (1999b) found that organic farmers tended to use more diverse crop rotations than comparable conventional farms. Crop rotation was indicated as a useful management practice for PFP by all groups of participating farmers. It ranked in the top 5 of 25 suggested management practices for all groups (Table 3-10). Rotation was the most common non-pesticide pest management practice rated as useful by farmers surveyed in the 1997 Manitoba Weed Survey (Thomas et al., 1999a). In the 2001 Census of Agriculture, 71% of Manitoba farmers indicated that they use crop rotation, although this term was not defined in that questionnaire (Statistics Canada, 2002). The average number of crops grown regularly on a given farm was not significantly different among groups (Table 3-3). It was also not significantly different between PFP participant groups and the random sample of Manitoba farmers, although PFP participant groups tended to report a greater number of crops grown regularly than the random sample.

USE OF FALLOW. While tilled fallow has traditionally been used for water conservation on the Prairies, standing stubble can retain as much water or more and tilled fallow leaves land prone to erosion. In this study, all three groups of participating fields had higher levels of tilled fallow in the 5-year rotation history than is typical for Manitoba (6% of fields according to Thomas et al. 1999a). Another survey found that 15% of Manitoba farmers indicated that they used fallow in rotation at least occasionally (Canola Council

Table 3-9. Crop rotation characteristics of fields on which Pesticide Free Production (PFP) was attempted

Group	Percentage of fields					
	Under-seeded to a forage species (n=120)[w]	With forage or green manure in rotation history[z] (n=112)	With forage or green manure year previous to PFP attempt (n=100)	With fallow in rotation history[y] (n=113)	With fallow year previous to PFP attempt (n=100)	With PFP crop same as previous crop type[x] (n=111)
Non-certifiable fields	5.4*b*	24.2	9.4*a*	27.3	12.5	25.8
PFP-certifiable fields not in organic transition	21.8*a*	29.4	13.2*ab*	26.9	13.2	34.0
PFP-certifiable fields in transition to organic	28.6*a*	35.7	28.6*b*	39.3	21.4	33.3
P-value for group effect[v]	0.038	0.33	0.048	0.34	0.59[u]	0.52

a - *b* Means followed by the same letter are not significantly different ($P > 0.05$).

[z]Forage or green manure grown at least once in the 5 years previous to the year in which PFP crop was attempted.

[y]Fallow occurred at least once in the 5 years previous to the year in which the PFP crop was attempted. Includes chem-fallow and unplanned fallow due to wet conditions. In the majority of instances, this represents planned, tilled fallow.

[x]Crop type classified as cereal, oilseed, pulse, or forage.

[w]Number of observations within PFP groups for a particular variable.

[v]P-value for Mantel-Haenszel chi-square (linear association). See Materials and Methods for details of statistical tests used.

[u]Fishers exact test was used due to small sample sizes.

Table 3-10. Management practices suggested for use by farmers attempting to produce a Pesticide Free Production (PFP) crop[z]

Farmers with non-certifiable fields (n=14)		Farmers with certifiable fields, farms not in transition to organic (n=29)		Farmers with certifiable fields, farms in transition to organic (n=24)	
Practice	Percent of farmers indicating usefulness for PFP	Practice	Percent of farmers indicating usefulness for PFP	Practice	Percent of farmers indicating usefulness for PFP
High seeding rates	50%	High seeding rates	59%	Forages in rotation[x]	54%
Delayed seeding	36%	Competitive crop or variety[y]	55%	High seeding rates	54%
Competitive crop or variety[y]	29%	Forages in rotation[x]	48%	Alfalfa in rotation	50%
General crop rotation	29%	General crop rotation	48%	Delayed seeding	50%
Pre-emergent glyphosate	29%	Alfalfa in rotation	45%	General crop rotation	46%
Alfalfa in rotation	21%	Pre-emergent glyphosate	45%	Post-emergence tillage	42%
Early seeding	21%	Low soil disturbance or zero tillage	28%	Intercropping[v]	38%
Forages in rotation[x]	21%	Pre- or post-harvest glyphosate	28%	Competitive crop or variety[y]	33%
Pre- or post-harvest glyphosate	21%	Delayed seeding	24%	Fallow[w]	33%
Choose relatively weed-free fields	14%	Early seeding	21%	Mow or spray patches of weeds	33%
Fallow[w]	14%	Fallow[w]	21%	Use of livestock	29%
Good fertility	14%	Herbicide use in previous years	21%	Low soil disturbance or zero tillag	25%
Herbicide use in previous years	14%	Narrow row spacing	21%	Pre- or post-harvest glyphosate	25%
Low soil disturbance or zero tillage	14%	Good fertility	17%	Colllect chaff[s]	21%
Mow or spray patches of weeds	14%	Band instead of broadcast fertilizer	14%	Early seeding	21%
Narrow row spacing	14%	Use of livestock	14%	Narrow row spacing	21%
Use of livestock	14%	Various tillage techniques[r]	10%	Pre-emergent glyphosate	21%
Intercropping[v]	7%	Choose relatively weed-free fields	7%	Herbicide use in previous years	8%
No advance planning[u]	7%	Intercropping[v]	7%	Optimize seeding depth	8%
Post-emergence tillage	7%	Mow or spray patches of weeds	7%	Various tillage techniques[r]	8%
Various fertilizer techniques[t]	7%	No advance planning[u]	3%	Band instead of broadcast fertilize	4%
Band instead of broadcast fertilizer	0%	Post-emergence tillage	3%	Choose relatively weed-free fields	4%
Colllect chaff[s]	0%	Various fertilizer techniques[t]	3%	Good fertility	4%
Optimize seeding depth	0%	Colllect chaff[s]	0%	No advance planning[u]	4%
Various tillage techniques[r]	0%	Optimize seeding depth	0%	Various fertilizer techniques[t]	4%
Average number of practices suggested per farmer	4.0	Average number of practices suggested per farmer	5.5	Average number of practices suggested per farmer	6.4

P-value for effect of groups on average number of practices suggested = 0.12[q]

Table continued on next page.

[z]In 2000, this question was open-ended. In 2001, respondents were asked to check as many options from a list as were applicable (open-ended responses also permitted). For farmers who were involved in both years, all practices mentioned in either year were included.

[y]Includes use of fall seeded crops.

[x]Includes the use of alfalfa, green manure, silage or greenfeed.

[w]Includes chemfallow, but the majority of responses indicated tilled fallow

[v]Primarily in the form of underseeding forage species.

[u]Includes responses that indicated PFP would be implement based only on spring weed densities.

[t]Includes responses such as: 'maintain proper nutrient cycling to minimize weeds', 'don't use fertilizer so weeds don't' have a competitive advantage' and 'broadcast N after crop emergence'.

[s]Chaff collection to minimize weed seed return.

[r]Includes responses that indicated specific use of a rod weeder, moldboard plough, or pre-seed tillage.

[q]See Materials and Methods for details of statistical tests used.

of Canada, 2000). The most recent Census of Agriculture recorded 30% of Manitoba farms with land in tilled fallow, and 5% of farms with chemical fallow (Statistics Canada, 2002). Entz et al. (2001) found that for organic farms on the Northern Great Plains, 6.4% of the land area was in tilled fallow.

The occurrence of tilled fallow in the 5-year rotation history ranged from 27% for certifiable non-transitional fields, to 39% for certifiable, transitional fields (Table 3-9). However, there were no significant differences between the three groups. In particular, the non certifiable group and the certifiable, non-transitional group had very similar proportions (~27%). However, the proportions for these two 'conventional' groups were lower than for the group in transition to organic (almost 40%). In addition, both 'conventional' groups had similar proportions of tilled fallow immediately prior to the PFP crop (13% for both), yet 21% of certifiable, transitional fields had tilled fallow immediately prior to the PFP year, but differences were not significant. In comparison, Thomas et al. (1999a) found that 3.4% of surveyed fields in Manitoba followed a fallow year. A higher proportion of certifiable fields in transition to organic were also indicated as being rotated into fallow the year following PFP (7%) compared to the other two groups (3% for non-certified and 0% for certified, non-transition to organic) (Table 3-11). However, these differences were not significant (p=0.09).

Fallow was suggested by some participants as an important management practice for PFP. This practice was most commonly noted by farmers with certifiable, transitional fields (it ranked 9th of 25 suggested management practices, and 33% of farmers in this group suggested it) (Table 3-10). It was less frequently cited as important by farmers in the non-certifiable group, ranking 11th of 25 suggested practices (14% of farmers) and also 11th (21% of farmers) for the certifiable, non-transitional group.

The high occurrence of tilled fallow among PFP participants is of concern because of the potential for soil erosion with this practice. However, fallow was less common in certifiable, non-transitional fields compared to certifiable, transitional fields, suggesting that farmers implementing PFP or other pesticide-reduction strategies intermediate to organic production may rely less on fallow than do farmers who are in transition to organic.

Table 3-11. Field plan for year following Pesticide Free Production (PFP) (n= 115)

Group	Percentage of fields					
	Fallow[z]	Hay or forage crop	Conventional field crop	PFP	Transition to organic	Unsure
Non-certifiable fields	2.9	8.8*ab*	52.9	14.7	5.9	14.7
PFP-certifiable fields not in organic transition	0.0	24.5*a*	56.6	9.4	1.9	7.6
PFP-certifiable fields in transition to organic	7.1	3.6*b*	n/a[y]	14.3	n/a[y]	0.0
P-value for group effect[x]	0.09[w]	0.02	0.74	0.71[w]	0.56[w]	0.12[w]

a - b Means followed by the same letter are not significantly different (P > 0.05).

[z]Fallow indicates primarily tilled fallow.

[y]Value not included for group with certifiable fields in transition to organic because all of these fields were planned to be in transition the year after PFP.

[x]P-value for Pearson chi-square. See Materials and Methods for details of statistical tests used.

[w]Fishers exact test was used due to small sample sizes.

USE OF FORAGES. The proportion of forage or green manure in the 5-year rotation history was not significantly different between groups (Table 3-9). Proportions ranged from 24% in the non-certifiable group, to 36% in the certifiable, transitional group. Forage crops included in the rotation history were primarily alfalfa or alfalfa/grass mixtures. Entz et al. (2001) found that 42% of the land base of organic farms on the Northern Great Plains was in hay, forage, pasture or green manure crops. Fifty-four percent of Manitoba farms with land in crops were growing alfalfa or alfalfa mixtures, 20% were growing other hay crops, and 3% were growing green manure crops in 2001 (Statistics Canada, 2002). In contrast, a survey of fields in Manitoba in 1997 found that only 1.2% of 5-year field histories contained a forage crop (Thomas et al., 1999a). Entz et al. (2002) stated that the percentage of arable cropland that is rotated with forages is also lower than the census values would suggest. Only 5 to 15% of arable cropland in the Northern Great Plains region is rotated with forages (Entz et al., 2002). This discrepancy may be due to the fact that while forages may be grown on a high proportion of farms, the land area devoted to these crops per farm may be low. This is supported by Entz et al. (1995), who found that difficulties in stand termination resulted in limited cycling of forages throughout a farm's land area.

There was a significant difference (p=0.048) among treatment groups in the proportional use of forage the year immediately prior to PFP (Table 3-9). The level of use was highest for certifiable, transitional fields (29% of fields versus under 15% in the other two groups). In addition there were significant differences in the proportion of fields intended for forage production the year after PFP (p=0.02) (Table 3-11). Nine percent of non-certifiable fields were to be forage crops the year after PFP, as were 25% of certifiable, non-transitional fields, and 4% of certifiable, transitional fields. The proportion in certifiable, non-transitional fields was significantly higher than that in certifiable, transitional fields. No other differences were significant. Intentions to rotate to a forage crop were also indicated by the number of fields that were underseeded to forage species. While 22% of certifiable, non-transitional fields and 29% of certifiable, transitional fields were underseeded to a forage crop, only 5% of non-certifiable fields were. These particular non-certifiable fields were not eligible because of the use of residual herbicide or seed treatment, but they were not sprayed with pesticides (Table 3-

9). However, the proportion of farmers indicating rotation to forage crops (Table 3-11) may have been underestimated, particularly in the group with certifiable, transitional fields. Farmers may have responded that the field would be 'in transition to organic production' the following year, rather than specifying that they would be growing a forage crop. This would account for the difference in the proportion of fields in this group that were underseeded to a forage species during the PFP year, which was higher than the proportion of fields indicated to be rotated into forage the year following PFP. Given the low frequency of forage in typical crop rotations in Manitoba (Thomas et al., 1999a, Entz et al., 2002), the proportion of fields intended for forage crops the year after PFP can be considered relatively high for all groups. There were no significant differences between the three groups of farmers in terms of whether or not they stated that they grew forages regularly (Table 3-3). The proportion in each group ranged from 53% to 65%. There was also no difference between the three participant groups and random sample, in which 60% of farmers indicated that they regularly grew forages. However, as indicated previously, this likely over-estimates the actual use of forage on an acreage basis.

While there is no indication of differences in the use of forages on a whole-farm scale between groups, or between project participants and various measurements of use in Manitoba, there is some evidence to suggest that the use of forages in the field rotation history, particularly immediately prior to a PFP attempt, is more common among all participant groups and particularly for certifiable, transitional fields. The implementation of certifiable PFP was also common during forage establishment years.

Several authors have noted the beneficial effects of forages in rotation, particularly for suppression of weeds (Schoofs and Entz, 2000; Entz et al., 1995; Ominski et al., 1999). Farmers involved in our project also indicated the benefits of forages for PFP attempts (Table 3-10). Close to half of the farmers in both certifiable groups rated the growing of forage crops as useful. However, only 21% of farmers with non-certifiable fields rated the use of forages as useful. The use of alfalfa in particular was mentioned almost as frequently as the use of forages generally for all groups.

Despite the benefits of forage crops, forage stand termination, if ineffective, can result in reduced yields in subsequent crops (Bullied et al., 1999). Water use by forages may also be detrimental to a subsequent crop, particularly if tillage is used for stand termination (Bullied and Entz, 1999). Several certifiable PFP fields that followed alfalfa stand termination had high levels of volunteer alfalfa. In these situations, some farmers noted that they did not consider alfalfa to be a particularly detrimental weed, and others did not feel that they could justify the cost of in-crop control.

USE OF WINTER CEREALS. There was no significant difference among groups in the proportion of farmers stating that they regularly grew winter cereals among groups. However, as farmers moved towards reducing pesticide use, the proportion of farmers growing winter cereals declined from 40% to 20% (Table 3-3). This may be related to the tendency for tillage to be substituted for herbicide use, which reduces the proportion of high-residue fields appropriate for winter wheat. However, a higher proportion of farmers in the study were growing winter cereals compared to the random sample of Manitoba farmers (15%) ($p=0.052$). The proportion of farmers in the study growing these crops was also higher than that found in the 2001 Census of Agriculture (5% growing winter wheat and 2% growing fall rye) (Statistics Canada, 2002). This may be an indication of a relatively high level of crop diversification among farmers involved in the project. Winter cereal production varies by census agricultural region as it is related to the proportion of direct seeded fields; therefore, the relatively high levels of winter cereal production in this study may be related to the location of participants in regions that tend to have higher levels of reduced-tillage.

Winter cereals are particularly competitive with weeds because they provide early-season competition. Thomas et al. (1999a) found that 86% of farmers rated the use of competitive crops as useful, and this practice was ranked 2nd of a group of 10 management practices. In the same study, 65% of farmers rated growing competitive varieties as useful (ranking 4th). In our study, the use of competitive crops or varieties was ranked in the top 3 of 25 management practices suggested by farmers with non-certifiable fields or certifiable, non-transitional fields (suggested by 29% and 55% of farmers in these two groups, respectively) (Table 3-10). Thirty-three percent of farmers with certifiable, transitional fields suggested this practice, but it was ranked lower on the list of useful management practices than for the other groups.

Use of Tillage

TILLAGE SYSTEM. The proportion of fields under reduced-tillage (i.e zero- or minimum-tillage; self-defined by farmer) was significantly different among groups (Table 3-12). The proportion of reduced-tillage in non-certifiable fields and certifiable, non-transitional fields was relatively high with no significant differences between groups (65% and 47%, respectively). The proportion of reduced-tillage practices in both of these groups was higher than what was typical in most regions of Manitoba. Provincially, 38% of fields are under reduced-tillage, and the proportion ranges from 23% to 47% depending on the ecoregion (Thomas et al.,1999a). In contrast, only 19% of certifiable, transitional fields were under reduced-tillage. This was significantly different from the proportion in both other groups. Tillage can be substituted for herbicide use and there is some evidence that this trade-off is occurring among farmers involved in this project. However, reduced pesticide use does not necessarily require high levels of tillage (Kuepper, 2001). Lockeretz et al. (1981) found that organic farmers tended to be more interested in soil conservation practices than conventional farmers in the same region. More recently, Liebig and Doran (1999b) found that organic farms used less tillage than comparable conventional farms. Their study found that higher levels of soil organic C and total N on organic farms may impart greater resistance to erosion compared with conventional farms. Even though tillage can directly control weeds, some authors have suggested that fields under zero-tillage may be more amenable to herbicide reduction because of increased weed seed decay and predation (Swanton and Weise, 1991). Weed communities have been found to be significantly different among tillage systems by some authors (Swanton et al., 1999) but not by others (Frick and Thomas, 1994). In particular, the effect of tillage system on weed densities is uncertain. Some authors conclude that weed densities are higher in zero-tillage (Anderson et al., 1998; Frick and Thomas, 1992) while others have found inconsistent effects due to tillage system (Swanton et. al., 1999).

The high proportion of reduced-tillage among non-certifiable fields does not necessarily mean that reduced-tillage is causatively linked to a lack of PFP certification. The influence of tillage on weed densities is uncertain and likely interacts with other cropping system factors (Kegode et al., 1999; Légerè and Samson, 1999). The low

Table 3-12. **Tillage and herbicide use characteristics of fields on which Pesticide Free Production (PFP) was attempted**

Group	Percentage of fields					
	Under reduced tillage[z] (n=114)[y]	Receiving a pre-seed herbicide (n=114)	Receiving a pre- or post-harvest herbicide[y] (n=114)	Receiving pre-seed tillage (n=110)	Receiving post-harvest tillage[y] (n=108)	Receiving in-crop tillage n=(114)
Non-certifiable fields	64.7*a*	42.4*a*	30.3*a*	33.3*a*	38.7	12.1*a*
PFP-certifiable, non-transitional fields	47.2*a*	32.1*a*	22.6*ab*	41.5*a*	50.9	0.0*b*
PFP-certifiable, transitional fields	18.5*b*	0.0*b*	7.1*b*	87.5*b*	62.5	17.9*a*
P-value for group effect[w]	0.0004	0.0003	0.03	0.0002	0.08	0.0026[v]

a - *b* Means followed by the same letter are not significantly different (P > 0.05).
[z]Zero or minimum tillage; self-defined by farmer.
[y]The fall previous to PFP attempt.
[x]Number of observations within PFP groups for a particular variable.
[w]P-value for Mantel-Haenszel chi-square (linear association).
[v]Fishers exact test was used due to small sample sizes.

proportion of reduced-tillage among certifiable, transitional fields is not unexpected as organic farmers may substitute tillage for herbicidal weed control. It is important to note that the level of reduced-tillage in the certifiable, non-transitional group was higher than typical provincial levels. This indicates that certifiable PFP has been implemented on a proportion of reduced-tillage fields similar to what is typical in Manitoba. These results demonstrate that there was a high level of interest in pursuing PFP from farmers practicing reduced-tillage. Even though reduced-tillage fields were less likely to be certified in the group as a whole, the level of certification among reduced-tillage fields was not unexpected considering provincial levels of reduced-tillage. This is important to note because farmers practicing reduced-tillage, particularly zero-tillage, may not believe they can implement organic production without increasing tillage. PFP may be a reduced-pesticide strategy more appropriate for reduced-tillage production than is organic production.

USE OF PRE-SEED TILLAGE. The proportion of fields receiving a pre-seed tillage operation was significantly different among groups (p=0.002) (Table 3-12). Non-certifiable fields received this operation 33% of the time, while certifiable fields not in transition to organic received it 42% of the time. The proportion in these groups was not significantly different, and both groups had proportions lower than the provincial average of 52% (Thomas et al., 1999a). Certifiable fields in transition to organic had the highest proportion, receiving pre-seeding tillage on 88% of fields, a proportion significantly higher than both other groups, and much higher than the provincial average. This reflects a trade-off between tillage and herbicide use occurring within the group of certifiable fields in transition to organic production.

USE OF POST-HARVEST TILLAGE PRIOR TO PFP CROP. The proportion of fields receiving a post-harvest tillage operation the fall prior to PFP was not significantly different among groups (p=0.08) (Table 3-12), however, tillage tended to increase when pesticide use decreased.

USE OF IN-CROP TILLAGE. The 2001 Census of Agriculture found that 7% of farms with land in crops used mechanical or hand-weeding, although this was over-reported due to response errors (Statistics Canada, 2002). There were significant differences in the proportion of fields receiving in crop tillage among groups (Table 3-12). Twelve percent of non-certifiable fields received in-crop tillage. For half of these cases, the field was subsequently sprayed because of poor weed control with in-crop tillage. These fields tended to be those on which farmers were experimenting with in-crop tillage for the first or second time. For the other half, fields were in transition to organic but not certifiable due to residual herbicides. Eighteen percent of certifiable, transitional fields received this operation, a proportion not significantly different from non-certifiable fields. No certifiable, non-transitional fields received in-crop tillage, a result that was significantly different from both other groups.

Herbicide Use

USE OF PRE-EMERGENT HERBICIDES. Not surprisingly, none of the certifiable fields in transition to organic received a pre-emergent or pre-seed herbicide (Table 3-12), an outcome that was significantly different from both other groups. A pre-emergent application of herbicide is acceptable under PFP regulations and was allowed in part to accommodate reduced-tillage and direct-seeding farmers. Reduced-tillage and direct seeding is common particularly in western Manitoba and has been increasing in recent years (Statistics Canada, 2002). Such applications would be expected to reduce weed pressure in the crop and increase the likelihood of a certifiable PFP crop. Greater use of this practice would have been expected among certifiable fields. Despite a lack of significant difference among certifiable and non-certifiable 'conventional' fields, a higher proportion of fields in both groups received pre-emergent herbicide than the provincial average of 18% (Thomas et al., 1999a). This indicates that this practice may play a role in contributing to successful PFP certification for some fields.

USE OF PRE- OR POST HARVEST HERBICIDES PRIOR TO PFP CROP. The proportion of fields receiving a pre- or post-harvest herbicide decreased as pesticide use decreased among groups (Table 3-12). Differences among groups were significant (p=0.03). Some fields in transition to organic did receive such an application the fall prior to the initiation of the transition process (7%). In contrast, 23% of certifiable fields not in transition to organic received such an application, and 30% of non-certifiable fields did. These latter two groups were not significantly different from each other. Values in both groups were similar to values found for Manitoba (33%) (Thomas et al. 1999a).

Fertilizer Use

There were significant differences in the proportion of fields that received synthetic fertilizer in the PFP crop year (p=<0.001) (Table 3-13). Certifiable, transitional fields were significantly different from both other groups. Seventy-six percent of non-certifiable fields received synthetic fertilizer as did 83% of certifiable non-transitional fields, but these groups were not significantly different from each other. Thomas et al. (1999a) found that 99% of field crops received synthetic fertilizer in Manitoba. While the difference between the transitional group and the non-transitional group is not surprising, it is surprising that the level of fertilizer use is lower in the "conventional" groups compared to typical Manitoba levels. This may in part be due to the fact that a number of fields followed leguminous forages, so relatively high levels of nitrogen would be expected. It also may be indicative of the level of livestock production among participants, who make use of manure rather than synthetic fertilizer. Or, it may suggest that PFP is being attempted on more marginal land where any inputs, fertilizer or pesticides, are being reduced in order to cut costs in areas where the return on input costs is lower. Fertilizer management was infrequently mentioned by participants in all groups as a means to achieve PFP certification (Table 3-10), while Thomas et al. (1999a) found that 47% of Manitoba farmers rated this as a useful practice for increasing crop competitiveness with weeds. There is conflicting evidence over the ability of fertilizer use to enhance crop competitiveness relative to weeds (Kirkland and Beckie, 1998; Peterson and Nalewaja, 1992). Although specific fertilizer management practices can give a crop a competitive edge (Di Tomaso, 1995), the lack of difference in fertilizer use between the two 'conventional' groups gives no evidence to suggest that, for these fields, the use of fertilizer helped to improve crop competitiveness and higher levels of PFP

Table 3-13. Agronomic characteristics of fields on which Pesticide Free Production (PFP) was attempted

Group	Percentage of fields						
	Receiving synthetic fertilizer year of PFP attempt[z] (n=114)	With low seeding disturbance[y] (n=112)[t]	Using high seeding rate[x] (n=112)	Using narrow row spacing[w] (n=110)	Using certified seed (n=110)	With complete record-keeping[v] (n=115)	Receiving patch treatment of weeds[u] (n=114)
Non-certifiable fields	75.8*a*	65.7*a*	27.3*a*	34.4	62.5	52.9	6.1
PFP-certifiable, non-transitional fields	83.0*a*	46.0*ab*	49.0*b*	51.9	40.0	58.5	13.2
PFP-certifiable, transitional fields	3.6*b*	40.7*b*	57.1*b*	53.9	60.7	39.3	0.0
P-value[s]	<0.001	0.04	0.02	0.12	0.78	0.34	0.13[r]

a - b Means followed by the same letter are not significantly different (P > 0.05) according to Fishers protected LSD.
[y]Less than 20% seed bed utilization (SBU); calculated as the width of seeding implement opener divided by row spacing.
[x]Seeding rate within the top 25% of the recommended seeding rate or higher (Manitoba Agriculture and Food Field Crop Production Guide 2001).
[w]Less than 7.5 inch row spacing.
[z]Synthetic fertilizer use in the PFP crop year.
[v]Crop rotation records kept for the field in which PFP was attempted on for past 4 of 5 years prior to PFP crop.
[u]Farmers indicated that part of the field was mowed or received a herbicide application.
[t]Number of observations within PFP groups for a particular variable.
[s]P-value for Mantel-Haenszel chi-square (linear association). See Materials and Methods for details of statistical tests used.
[r]Fishers exact test was used due to small sample sizes.

certification. Alternately, there is no evidence that fertilizer use was detrimental in terms of achieving PFP.

Seeding Practices

SOIL DISTURBANCE AT SEEDING. The proportion of fields with low seeding disturbance (less than 20% seedbed utilization) was higher in non-certifiable fields (66%) than in either of the certifiable groups (46% for non-transitional fields; 41% for transitional fields) (Table 3-13). However, the only significant difference among groups was between non-certifiable fields and certifiable, transitional fields. While the effect of tillage system on weed populations is variable (Swanton et. al., 1999, Anderson et al., 1998), some authors have suggested that minimizing soil disturbance may reduce weed densities and consequently facilitate reduced herbicide use (Swanton and Weise, 1991). Ominski and Entz (2001) found that zero-tillage termination of alfalfa led to lower summer annual weed populations than termination with tillage. The lower proportion of low disturbance seeding in the certifiable, transitional group is most likely related to the lower proportion of zero and minimum-tillage practices within that group.

SEEDING RATE. There was a significant difference in seeding rates among groups (p=0.02) (Table 3-13). Approximately half of all certifiable fields were seeded at a high rate (49% of certifiable, non-transitional fields; 57% of certifiable, transitional fields) and these two groups were not significantly different from each other. In contrast, only 27% of non-certifiable fields were seeded a high rate, a significantly lower proportion than either of the certifiable groups.

The use of a higher than recommended seeding rate is a commonly used practice by organic farmers (OPAM, 2000). It was also commonly cited as a PFP management practice by participants. Farmers in all three groups ranked it in the top 2 suggested management practices (Table 3-10). Over 50% of farmers in all groups rated it as a useful management practice for PFP. The Canola Council of Canada (2000) found that 15% of Western Canadian canola growers said that they used a higher than recommended seeding rate for canola in their area. Thomas et al. (1999a) found that 56% of farmers rated increased seeding rates as useful to some degree as an alternative practice to herbicides. Thomas et al. (1999a) also found that oilseed crops tended to be seeded with higher than recommended seeding rates more often than cereal crops. In Manitoba, less than 1% of cereal fields were seeded with a higher than recommended rate.

In addition to increasing the competitiveness of the crop, higher seeding rates may also result in earlier, more uniform maturity. However, under drought conditions lower seeding rates may provide the highest yields. Higher rates may also impact quality by affecting grain protein levels (Geleta et al., 2002). Several authors have found higher seeding rates to compensate for reduced herbicide rates (O'Donovan et al., 2001; Roberts et al., 2001); however, Kirkland et al. (2000) found inconsistent effects of seeding rate depending on crop, year, and location. Higher seeding rates may be particularly advantageous for less competitive crops or less competitive varieties such as semi-dwarf or hull-less barley (O'Donovan et al., 2001).

ROW SPACING. There were no significant differences in the use of narrow row spacing among groups (p=0.12) (Table 3-13). There tended to be less use of narrow row spacing among the non-certifiable group (34%) than either of the certifiable groups (just over 50%). Both certifiable groups had levels of narrow row spacing similar to that found by Thomas et al. (1999a). Like the use of high seeding rates, the use of narrow row spacing may increase grain yields under weed competition (Kirkland, 1993). Some authors have found that this practice is not effective for increasing crop competitiveness (Blackshaw et al., 1999, O'Donovan et al., 1999, Roberts et al., 2001). Seeding rate may be a more effective method of increasing crop density and competition (O'Donovan et al,. 1999, Roberts et al., 2001). Seeding rate may also be more easily modified than row spacing. Most farmers in this study used the same row spacing for all fields included in the project. This implies that choice of row spacing is generally not made on a per-field basis. In addition, the higher use of wide row spacing in the non-certifiable group could be related to the higher proportion of fields under reduced-tillage in this group. Zero-till farmers tend to use wider row spacing for residue management (O'Donovan et al., 2001).

SEED SOURCE. The use of certified seed among groups was not significantly different. The proportion of fields using certified seed varies by crop, making this a difficult factor to compare when values are considered across different crops. For example, Thomas et al. (1999a) found that 52% of wheat fields were seeded with certified seed, compared to 100% for canola fields. However, the majority of the crops involved in our project were cereals, and except for certifiable, non-transitional fields, the proportion of fields using certified seed was similar to that found for cereals by Thomas et al. (1999a) (57%). For all crops, only 40% of certifiable, non-transitional fields were seeded with certifiable seed. The high level of certifiable seed used on certifiable, transitional fields is surprising because organic farmers might be expected to be more likely to use farm-saved seed, because they already have a favourable attitude towards reducing off-farm inputs. However, the use of certified seed may improve crop competitiveness and reduce the risk of introducing new weed seeds (Anonymous, 2001). There is no evidence to suggest that its use impacted the success of PFP certification.

SEEDING DATE. Seeding date as compared to crop and regional average was not significantly different among groups, but fields for all groups were seeded close to a week later than the appropriate average (Table 3-14). Both certifiable groups had the latest seeding dates (8.1 days later than average for non-transitional fields and 6.7 days later than average for transitional fields). Non-certifiable fields were seeded an average of 6 days after the average seeding date. Delayed seeding was mentioned by 50% of farmers in the certifiable, transitional group as a useful pesticide use reduction management strategy but this practice was mentioned less often by the other two groups (Table 3-10). Thirty-six percent of farmers with non-certifiable fields cited this practice, while only 24% of farmers with certifiable, non-transitional fields did. Early seeding was also mentioned by 21% of participants in each group as an important management practice for pesticide use reduction. The Canola Council of Canada (2000) found that 40% of Manitoba canola growers made a conscious effort to seed canola early, while 14% of farmers across Western Canada said that they tried to seed canola late. Forty percent of Manitoba farmers rated seeding date manipulation as at least somewhat useful as a non-herbicidal weed management practice, but it was ranked 7^{th} of 10 management practices (Thomas et al., 1999a). These results suggest that farmers in all groups, but particularly farmers with certifiable, transitional fields are using delayed seeding to in-crop reduce weed competition.

Table 3-14. Seeding date of fields on which Pesticide Free Production (PFP) was attempted compared to average seeding date for year, crop and crop district[z]. Means are followed by standard errors in parentheses.

Group	Number of days before (+) or after (-) average seeding date (n=44)
Non-certifiable fields	-6.0 (1.9)
PFP-certifiable, non-transitional fields	-8.1 (3.4)
PFP-certifiable, transitional fields	-6.7 (3.0)
P-value for group effect[y]	0.88

[z]Source: Environment Canada Climate Services Agrometerological Bulletin; data available for wheat and barley only.

[y]See Materials and Methods for details of statistical tests used.

While delayed seeding can result in reduced weed pressure if early-emerging weeds are eliminated prior to seeding (Spandl et al., 1999), it can also result in yield declines. In particular, late seeding of oats has typically been used to avoid heavy wild oat infestations (Robbins et al., 1952). Wheat, barley and flax yields decline to about 80% of average yields if seeding is delayed until the first week in June, but yield potential is close to 100% if seeding occurs before the end of May (Manitoba Crop Insurance Corporation, 2002). Later seeding increases the susceptibility of cereals to rusts, aphids and Barley Yellow Dwarf Virus (Manitoba Agriculture and Food, 2001d) as well as heat stress during grain filling (Agriculture and AgriFood Canada, 2001b). Farmers using delayed seeding may benefit from the use of emergence forecasting to determine appropriate seeding dates for specific weed problems (Marginet, 2001).

Treatment of Weed Patches

Relatively few farmers with non-certifiable or certifiable, non-transitional fields rated 'mowing or spraying weed patches' as a useful weed management practice (14% and 7%, respectively). In contrast, 29% of farmers with certifiable, transitional fields suggested that this was an important practice. Thomas et al. (1999a) found that while 30% of farmers rated mowing weed patches as a useful weed management practice, it was ranked only 9th of 10 practices. There were no significant differences in the proportion of fields in each group that had a part of the field sprayed or mowed (Table 3-13). Thirteen percent of certifiable, non-transitional fields were treated in this manner, while 6% of non-certifiable fields were. While these non-certifiable fields had part of the field left untreated with herbicides, they were nonetheless not certifiable because of the use of a residual herbicide prior to the PFP year. The majority of fields treated on a weed patch basis received herbicide applications rather than mowing. Often fields with a weed patch treatment were relatively large fields. There may be an advantage to selecting a large field for PFP and treating part of the field with herbicides while leaving smaller portions of the field unsprayed. Farmers that were treating weed patches, particularly by cutting for green feed or silage, noted that having a backup plan gave them piece of mind during the PFP season should weed pressure exceed their expectations. The attractiveness of mowing weed patches as a weed management practice is likely related to the availability of livestock on the farm to make use of such crops as feed. It is surprising that no farmers with certifiable, transitional fields indicated that they had mowed weed patches, given the frequency with which this practice was suggested as a useful weed management practice. This may have been due to under-reporting in response to the open-ended question used to determine if patch treatment was used. Alternately, if mowing weed patches is a relatively common practice used in organic production, these farmers may not have identified such a practice as a notable or unique non-chemical pest management method.

Livestock Production

There were no significant differences between groups in terms of the proportion that were producing livestock as part of the farm operation. Proportions ranged from 44 to 47% of farms per group (Table 3-3). There were no significant differences between PFP study participants and the random sample of Manitoba farmers (38%) (Table 3-3). The majority of farms producing livestock in all groups had beef cattle operations. Fifty-four percent of census farms in Manitoba have cattle (adapted from Statistics Canada, 2002). The higher level of cattle production in the census than in the random sample of Manitoba farmers may be due to the fact that cattle farms in the census are not necessarily significant field crop producing farms, a requirement for inclusion in both the PFP study and the random sample. Small and McCaughey (1999) found that 70% of Manitoba beef cattle farmers also produced cereals and oilseeds, which implies that approximately one-third of cattle farms are not significant producers of annual grain crops.

Integration of livestock into the farm operation can have significant implications for cropping system management and the potential for herbicide use reduction. The use of perennial forages, silage, or green feed in rotation can have significant weed management benefits. The inclusion of livestock in the farm operation was less often cited than the use of forages in rotation as an important management practice (Table 3-10). While the use of forages is usually related to the presence of livestock on-farm, other marketing arrangements may allow for the use of forages in rotation without livestock on-farm (e.g. high value hay for export). Farmers who depend more heavily on livestock for their farm income may be more likely to reduce pesticide use. A high level of dependence on farm income from crops (rather than livestock) has been shown to be negatively related to farmers' concern about the environment (Constance et al., 1995).

Use of Non-Chemical Weed Management Practices

Farmers with certifiable fields tended to indicate their current use of, or future plans to use, more non-chemical weed management practices than farmers without certifiable fields; however, there were no significant differences among groups ($p=0.12$) (Table 3-10). The number of non-chemical weed management practices used is important because when implemented in order to reduce herbicide use, such practices are likely to be most effective when used in combination rather than singly (Hall et al., 2000). The singular use of one non-chemical management practice, such as increasing seeding rate, is unlikely to compensate for reduced herbicide use (O'Donovan et al., 2001). Comer et al. (1999) found that sustainable farmers had adopted more practices in the previous 5 yrs with the intention of improving the sustainability of the farm than those that were self-identified as conventional. Overall, farmers suggested 25 different management strategies for producing PFP crops. The most commonly mentioned strategies across groups were the use of high seeding rates, delayed seeding, crop rotation including forages (especially alfalfa), and the use of competitive crops or varieties. However, the use of forages in rotation was mentioned less frequently by farmers without certifiable fields. Recent surveys of Western Canadian farmers have suggested that a large proportion of farmers do not have knowledge of, or do not use, non-chemical weed management practices. The Canola Council of Canada (2000) found that on average, canola growers in Western Canada said that they placed a 75%:25% weighting on chemical versus non-chemical techniques for pest control. In that study, only 5% of farmers relied on chemical control for less than half of their pest control measures and 25% indicated that they were not aware of non-herbicidal weed control methods. Thomas et al. (1999a) found that farmers were uninterested in non-chemical weed management strategies unless they were relatively easy to implement.

Record-Keeping by Participants

For all groups, less than 60% of fields had near-complete rotation history (crop rotation known for at least 4 of the 5 years previous to PFP) (Table 3-13). There were no significant differences among groups in this respect. In a few cases, this was due to the fact that land was recently rented and history was not known. This lack of record-keeping is surprising because reduced-input farming can be supported by the input of farmers' knowledge of the cropping system (Van Acker et al., 2001, Bostrom and Fogelfors, 2002a). The proportion of fields on which the planting date history was near-complete was also low, with less than 35% of farmers in all groups keeping these records. Such records are important because varied crop rotation, including varied planting dates can reduce weed adaptation to a specific cropping system (Buhler 2002). Over half of farmers in all groups kept records of pesticide use history. The Canola Council of Canada (2000) found that farmers with larger farms were more likely to record field history information. In their study, 79% of respondents stated that they kept field history records for the year previous to the survey, while 89% kept seeding date records and 98% kept records of pesticide products used. The short-term nature of assessing record-keeping in their study and the fact that farmers were asked directly about record-keeping rather than inferring it from field records likely account for the significantly higher indication of record-keeping among respondents in the Canola Council study versus our study.

Summary

Participation in the project was very good considering that typically a very low proportion of fields are untreated with herbicides in Manitoba. Farmers participated from most of the agricultural regions in Manitoba, but participation tended to be highest from regions with a history of relatively lower agrichemical input use, higher levels of cattle and forage production, and higher levels of reduced-tillage cropping. Almost 70% of participating fields were certifiable as PFP, which represented 83% of the land area included in the project. This indicates that the pursuit of PFP certification was successful for the majority of participating fields. Farmers were interested in pursuing PFP for most major crops in Manitoba, but PFP was most successfully achieved for spring cereals and fall rye. These are relatively low-value crops in Manitoba. There was some interest and success with PFP in flax; however, there was less interest in PFP in this crop in terms of number of fields volunteered for the project versus cereal crops. There were relatively fewer certifiable canola and winter wheat fields due to the use of seed treatments and fungicides for leaf disease, respectively.

There were no significant differences in farm and field sizes among groups of participating farmers, or between PFP groups and the random sample of Manitoba farmers. However, there was a tendency for certifiable, non-transitional fields to be the smallest of the three participating groups. This, combined with the specific crop choices for certifiable PFP, as well as the regional distribution of participants, suggests that farmers are initially implementing PFP in relatively low-risk situations. Yet, PFP was still of interest to farmers from across Manitoba, and the concept was implemented for major crops on relatively large fields and within large farm operations.

Yields of crops as a percentage of conventional yield averages were not significantly different among groups. However, yields for certifiable, non-transitional fields and non-certifiable fields were over 1.3 times long-term organic yield averages. This demonstrates that the elimination of pesticides for one crop season, when performed on fields selected by farmers, does not necessarily result in yield reductions. Most downgrading factors for PFP grains were not directly attributable to non-use of pesticides.

Weeds were the major pest problem requiring pesticide application for most non-certifiable fields. An exception to this was winter wheat which was treated with fungicides for leaf disease. Otherwise, disease and insect pests were not a problem in most certifiable or non-certifiable fields. Weed densities, as well as farmers' ratings of weed pressure in certifiable fields suggest that farmers tended to retain relatively weed-free fields for PFP implementation while fields with higher weed densities tended to be treated with herbicides.

In most cases, weed densities the year following PFP were not a concern in certifiable fields that were not in transition to organic. Most farmers with certifiable fields indicated that they did not expect to increase their pesticide use in future years as a result of any increases in weed densities associated with implementing PFP. This is a significant finding as escalations in weed populations are frequently cited as a constraint for the implementation of herbicide use reduction.

Farmers attempting PFP tended to implement general crop rotation to at least the same degree as typical farmers in Manitoba. Use of forage crops in the rotation history for fields in all groups was higher than is typical for Manitoba fields. Forage crops were also important in the context of PFP as crops underseeded to forages are often limited in options for herbicide application. Farmers in all PFP groups, but particularly those with certifiable fields, transitional farms, cited the use of forages as an important management practice for PFP. The regular use of winter cereals in rotation was also higher in fields on which PFP was attempted in comparison to typical Manitoba fields.

A high proportion of farms in the PFP group were producing livestock, and these levels were typical for Manitoba. Use of livestock on the farm was cited less frequently as an important management practice for achieving PFP than the use of forages. While livestock production and forage production are linked, forage crops can also be produced on farms without livestock.

Pesticide Free Production, as an intermediate system of pesticide reduction, may allow for higher levels of soil conservation practices than organic (or transition to organic) production. Significant differences among groups were found for several tillage and herbicide-related variables. In general, there was an increasing use of specific tillage practices and decreasing use of specific herbicide practices as pesticide use reduction was implemented. Despite evidence of this trade-off, it should be noted that herbicides can be used in addition to tillage, rather than as a substitution (Thomas and Leeson, 2001). In addition, several authors have reported high usage of conservation tillage practices among organic farmers (Liebig and Doran, 1999b; Lockeretz et al., 1981). Therefore, it may be possible in some cases to reduce herbicide use without increasing tillage.

Increased seeding rate was one of the most commonly cited management practices for implementing PFP. Both groups of certifiable fields were seeded with higher seeding rates more frequently than non-certifiable fields. The use of row spacing to increase crop competitiveness was not considered as important a practice by participants.

Seeding date was not significantly different among groups, but for all PFP groups was approximately 1 week later than average regional seeding dates. Delayed seeding was a frequently mentioned management practice, particularly by farmers with certifiable, transitional fields. Early seeding was also mentioned as an important management practice by both 'conventional' PFP groups, although less frequently than delayed seeding.

For several management practices, there was no evidence of differences in level of use among groups. However, management practices were considered independently of each other, and combinations of management practices may be more important than single practices in allowing for pesticide use reduction. Other studies have found that the use of a single alternative weed management practice is not sufficient to replace herbicide use (Kirkland and Beckie, 1998; O'Donovan et al., 2001; Hall et al., 2000). The use or non-use of fertilizer between 'conventional' PFP groups was not significantly different and did not appear to influence the degree of PFP certification. Similarly, seed source was not different between these two groups, nor was the use of a pre- or post-harvest herbicide the year prior to PFP. The use of a non-residual pre-emergent herbicide the year of PFP also did not differ among groups. However, the frequency of this practice was relatively high for both 'conventional' groups, suggesting that it may play a role in contributing to PFP certification.

Less than 60% of farmers in the study had complete field records for crop rotation history. Lack of field records is likely to be a hindrance in implementing knowledge-intensive management for reduced pesticide use. While herbicide use can be reduced or eliminated on occasion when farmers select fields that have low weed densities, in order to regularly reduce or eliminate herbicides, alteration of the cropping system is necessary in order to reduce pest invasion, proliferation, and competition (Van Acker et al., 2001).

In general, the fields and farmers included in the two 'conventional' PFP groups were similar to typical Manitoba levels for most agronomic variables. Management practices, farm and field size, and yields for certifiable fields, particularly those not in transition to organic, were typical for Manitoba. This suggests that PFP is of interest to typical Manitoba farmers. Implementation of PFP seems to generally fit with the traditional technology adoption concept of initial trial in a relatively low-risk manner, with an exception being that PFP was being implemented on a large commercial-scale, rather than on a trial scale on individual farms.

CHAPTER 4

EVALUATION OF FARMERS INVOLVED IN A PESTICIDE FREE PRODUCTION (PFP) PILOT PROJECT IN MANITOBA.

INTRODUCTION

Extensive pesticide use in Western Canada has led to concerns about its impact on the environment, public health, and the economic viability of farming (Carson, 1962; Beckie et al., 1999; Pantone, 1992; Boyens, 2001; den Hond et al., 1999). Initiatives to promote reduced pesticide use include government-funded strategies, grassroots initiatives such as organic production, frameworks proposed by academics such as IPM, and eco-label marketing strategies. However, existing strategies for reducing pesticide use in Manitoba have suffered from limited adoption. The area in organic production in Manitoba comprises just over 0.1% of field crop acreage (unpublished data, OPAM). Several authors have called for more flexible frameworks for reduced pesticide use such as IPM or IWM (Swanton and Weise, 1991; Stenholm and Wagonner, 1990; Morris and Winter, 1999); however, such concepts have not been widely implemented (Sutherland, 2000).

In response to the limited success of currently available frameworks for pesticide reduction, Pesticide-Free Production (PFP) was developed by Manitoba farmers, researchers (University of Manitoba and Agriculture and Agri-Food Canada - Brandon), and extension workers (Manitoba Agriculture and Food) in 1999. PFP is intended to be a flexible, straightforward framework for reducing pesticide use that will appeal to a broad range of Manitoba farmers. The guidelines prohibit the use of in-crop pesticide use, seed treatments, and prior use of residual pesticides. However, a pre-emergent application of a non-residual pesticide such as glyphosate is permitted, as is synthetic fertilizer use. In order to provide a basis for evaluating the potential of PFP as a strategy to reduce pesticide use in Manitoba, the demographic and attitudinal characteristics of fields and farms that PFP is being implemented on need to be characterized.

According to the traditional theory of technology adoption, the adoption of new technologies in agriculture is related to demographic characteristics and has often been found to occur initially among farmers who are younger, have more education, operate larger farms, and own rather than rent land (Bultena and Hoiberg, 1983). However, 'environmental innovations' in agriculture (such as IPM) are considered to be fundamentally different from traditional agricultural technologies (Vanclay and Lawrence, 1994; Saltiel et al., 1994; Black, 2000; de Buck et al., 2001). Environmental innovations differ from traditional technological innovations in that they are complex packages of methods, and they are not universally applicable (different practices are appropriate for different farms). In addition to this, the benefits of such practices are not necessarily restricted to the adopter themselves, but benefit society as a whole (for example, practices that prevent groundwater contamination) (Saltiel et al., 1994). Therefore, traditional theories of technology adoption may not adequately describe the adoption of environmental innovations. In particular, different demographic and attitudinal variables may be important in the adoption of such practices.

Some studies have found attitudinal and demographic differences between farmers practicing conventional agriculture and those practicing reduced-input agriculture (primarily organic). For example, farmers with reduced-input practices have been found to have different attitudes about the nature and practice of agriculture (Beus and Dunlap, 1991). Comer et al. (1999) found that such farmers are younger, have more education, and have more off-farm income. However, other studies have found that there are few demographic differences between these groups (Saltiel et al., 1994; Durham 1999; Lockeretz et al., 1981).

The objective of this study was to describe the demographic and attitudinal characteristics of farmers who participated in a PFP pilot project, with consideration given to the typical mean and distribution of these variables in Manitoba. In addition, we wanted to document feedback about PFP from participants in the pilot project.

MATERIALS AND METHODS

Participant Selection

The specific requirements for Pesticide Free Production meant that the number of available participants was constrained by the level of interest in PFP among Manitoba farmers. This situation resulted in non-random, purposive sampling known as convenience sampling, dictated by the need for voluntary samples (Tashakkori, 1998). Alternately, this type of sampling framework in which the population of interest has a circumstantial definition can be described as a historical sampling framework, in contrast to experimental or survey sampling frameworks (Stokes et al., 2000).

In the late winter of 2000 and 2001, newspaper and radio advertisements were run asking farmers interested in participating in a Pesticide-Free Production (PFP) on-farm research project to contact the University of Manitoba via a toll-free number. Word of mouth amongst farmers and promotion by agricultural representatives in various regions also led to some recruitment of volunteers. Several farmers volunteered more than one field for the project. Farmers that had expressed interest in PFP in 2000 were contacted in the spring of 2001 to determine their interest in participating in 2001. Farmers were selected to participate if they met the requirements for attempting a PFP crop that year. This meant that they could not use a seed treatment and could not have used a herbicide considered to leave a residual in the soil in previous years (See Appendix A for complete details of restrictions regarding prior use of residual herbicides for certifiable PFP).

Field Selection

During the first year of the project (2000), there was uncertainty as to how many fields would be volunteered for the project, so all volunteered field crops were included. Fields sown to forage crops were not included. Cereal fields which were being used for greenfeed or silage were not included; however, if the farmer was uncertain what the end use of the crop would be (forage or grain), the field was included. Because PFP may be viewed as an alternative to certified organic production, volunteered fields that were certified organic were not included in the project. However, if the farmer was unsure at the beginning of the season if the field would be certified organic that year, the field was included. Fields in transition to organic were included.

In 2001, it was apparent that there was sufficient interest in PFP that select crops could be chosen for participation. Only wheat, oats, barley and flax were included in 2001 in order to narrow the focus of the study to those crops that had the highest interest from farmers.

Questionnaire Design

Questionnaire design was based on guidelines and discussion provided by Jackson (1988), May (1993), Babbie (1990), Sudman and Bradburn (1982). All questionnaires were offered in accordance with ethical approval requirements of the Joint Faculty Research Ethics Board, University of Manitoba.

POST-HARVEST QUESTIONNAIRE. All participating farmers were asked to complete a detailed questionnaire after harvest of the crop (Appendix B). Questionnaires were mailed to participating farmers and were returned by mail throughout the winter. There were two main sections to the questionnaire: agronomic, (field history) questions, and demographic questions including an instrument designed to determine farmers' attitudes towards agriculture (Alternative-Conventional Agriculture Paradigm Scale; Beus and Dunlap, 1991). This is a series of 24 questions designed to measure the basic beliefs and values presumed to represent the two competing perspectives. This instrument was selected because it had been extensively tested previously, and allowed for comparison with other farmers used in the original study. The only modification made to this instrument was to change the term "U.S. agriculture" to "North American agriculture." Questions allowing for feedback about PFP were also included in the demographic section. Many agronomic questions were the same as those included in the 1997 Manitoba weed survey questionnaire (Thomas et al., 1999), and the 1996 Census of Agriculture (Statistics Canada, 1997). The questionnaire was pre-tested on 10 subjects at the University of Manitoba who had farm backgrounds. Where clarification was required based on the pre-test results, the questionnaire was modified. After questionnaires were returned by participants, questions that were unanswered or unclear were clarified through telephone conversations.

Some modifications were made to the survey in 2001 (Appendix C). Some open-ended questions were modified for 2001 due to poor response in 2000. These questions were replaced by a list of options for which responses could easily be checked off by participants. Options included in the list were based on the responses received in 2000. In addition, farmers that participated in both 2000 and 2001 received a subset of demographic questions as it was not necessary to repeat some all of the questions for these farmers in 2001 (Appendix D).

FOLLOW-UP QUESTIONNAIRE. Another questionnaire instrument was used to follow up with farmers that had produced certifiable PFP fields in 2000, conducted in the late summer and early fall of 2001 (Appendix E). Questions were open-ended, and designed to elicit responses about problems with weed densities the year after PFP, future interest, and any other comments about PFP.

BASELINE SURVEY OF MANITOBA FARMERS. To provide a basis for comparing the results of the attitude scores of PFP participants to typical Manitoba farmers, a telephone questionnaire was conducted by Ipsos-Reid Corporation (Winnipeg, Manitoba) in February 2002 (Appendix F). A stratified random sample of 154 farmers, with proportions representing the population distribution in each Manitoba census agricultural region, was used. The questionnaire consisted of the same attitude questions used in the written questionnaire for PFP participants (Beus and Dunlap, 1991). A number of demographic questions were also included.

Researchers at Ipsos-Reid determined that a telephone survey would be the most appropriate format for this questionnaire because it minimizes the self-selection of respondents. Respondents to mailed surveys can read the survey before they agree to participate, while telephone respondents agree to participate before the questions are known (Joanna Karman, Ipsos-Reid Corp., pers. comm.). Respondents were restricted to farmers with more than 320 acres of seeded cropland. This is the standard restriction used by Ipsos-Reid to obtain samples of commercial farmers in Western Canada. The margin of error for this survey was +/- 8% at the 95% level of confidence. The refusal rate for the study was 30.3%, which is within the normal range of refusal rates for agricultural surveys conducted by Ipsos-Reid (25-35%; Chad Greenall, Ipsos-Reid Corp., pers. comm.).

Categorization of Fields and Farmers

Fields and farmers were categorized into three distinct groups, representing different levels of commitment to pesticide reduction in the year the PFP crop was attempted. Grouping categories for field-based and farm-based variables were comparable, but determined by different criteria because of the differing scale of observation for these variables. Fields were categorized into three groups: 1) non-certifiable PFP fields, 2) certifiable PFP fields but not in transition to organic certification, and 3) certifiable PFP fields in transition to organic production. Therefore the classification was not based on an objective determination of the "successfulness" of a field in terms of pest pressure. It was based solely on the farmer's ability to meet the requirements for PFP certification. Farmers were categorized into three groups comparable to the grouping for fields: 1) farmers with no certifiable PFP fields, 2) farmers with certifiable PFP fields whose farms were not in transition to organic, and 3) farmers with certifiable PFP fields whose farms were in transition to organic. It should be emphasized that the 'non-certifiable' designation does not imply typical 'conventional' fields or farmers; rather, the grouping is solely based on the meeting of PFP certification criteria. In fact, two fields in the 'non-PFP' group were actually in transition to organic but were not certifiable PFP because a residual herbicide had been used in previous years. The three categories can be considered ordinal as per Pretty (1998, p. 288) who described a proposal for reformation of the European Union Common Agricultural Policy which would include a several-tiered system of payments to farmers for farm practices ranging from basic practices (conventional production), to practices considered to be part of a transition to more sustainable agriculture, with organic production as the highest tier.

In the discussion of our study's results, the following terminology is used. Fields not certifiable as PFP are referred to as *non-certifiable fields*; fields certifiable as PFP that are not in transition to organic are referred to as *certifiable, non-transitional fields*; and fields certifiable as PFP that are in transition to organic are referred to as *certifiable, transitional fields*. For variables that are measured on a farm or farmer-basis, the three groups are referred to as *farmers with non-certifiable fields*, *farmers with certifiable fields, non-transitional farms*, and *farmers with certifiable fields, transitional farms*. When considered together, the non-certifiable fields and certifiable, non-transitional fields are referred to as *"conventional" fields*. Quotations are used around the word conventional to indicate that these fields do not necessarily represent typical conventional fields or farmers. In fact, some of the fields that were not certifiable were actually in transition to organic but were not certifiable as PFP because of the use of a residual herbicide in previous years, or because the crop was ploughed under due to weed pressure. When considered together, the certifiable, non-transitional fields and certifiable, transitional fields are called *certifiable fields*.

Categorization of Questionnaire Responses

Several variables were categorized to facilitate comparison between fields in these groups. Where possible, responses were classified into one of two categories for ease of presentation of results. Categories were selected to correspond with those used in sources of comparative information.

Reasons for selecting a field for PFP was assessed by asking respondents to choose one of a list of options. Responses were placed into one of four categories. Fields were classified as having had advance preparation for PFP if the farmer stated that any of the following was a reason for choosing the field: a competitive crop was selected for the PFP crop, the PFP crop followed a competitive forage stand, an effort had been made to prepare for low inputs in some other way, or that the field was relatively weed-free for a number of years prior to the PFP crop. If the only reason given for field selection was that the field was relatively weed-free at the beginning of the growing season, the field was classified as having no advance preparation for PFP. Farmers who stated that the field had been under-seeded to a crop that did not allow for herbicide application, or that they had missed the window for herbicide application were classified as "PFP by default". However, if a reason was given that also indicated advance preparation, such as preparation for transition to organic, that reason was used. Finally, the fields were classified as being in transition to organic or not. This series of options was considered to represent the continuum of increasing effort or interest in preparing for PFP, so the option furthest along the continuum (i.e. with the most effort) was chosen for classification if the farmer stated more than one reason for choosing the field.

Farmers were categorized as belonging to different types of agricultural groups depending on the nature of the organization. Sustainable agriculture groups included the Organic Producers Association of Manitoba (OPAM), the National Farmer's Union (NFU), zero-tillage groups such as the Manitoba Zero Till Research Farm (MZTRA), and local sustainable agriculture societies. General farm groups included Keystone Agricultural Producers (KAP) or Agricore. Commodity-based groups included the Manitoba Canola Growers Association (MCGA) or the Manitoba Cattle Producers Association (MCPA). Farmers were classified as belonging to 'other agricultural groups' if they belonged to groups such as the local drainage committee. Farmers could be classified as being affiliated with more than one group.

Farmers were categorized as having post-secondary education if they had completed a minimum of university diploma or degree.

Comparative Data

Data for comparison with study results was obtained from several sources. Statistics Canada provided demographic variables through the Census of Agriculture (Statistics Canada, 1997 and 2002). Where possible, recently released data from the 2001 Census of Agriculture was used for comparison. Otherwise, the 1996 Census was used. The Organic Producers' Association of Manitoba (OPAM) provided unpublished data regarding membership and acreage of organic crop production. Regional distribution of participants was assessed by comparison with the distribution of cropped acreage among Manitoba ecoregions (as indicated by Thomas et al., 1999a), and census agricultural regions in the 2001 Census of Agriculture (Statistics Canada, 2002). The latter was more useful for this purpose as it described the distribution on a smaller scale. Comparative data for many agronomic and demographic variables was obtained from the 1997 Manitoba Weed Survey (Thomas et al., 1998 and Thomas et al., 1999a). Some information was also obtained from a Canola Council of Canada study in which over 800 farmers in Western Canada were surveyed (Canola Council of Canada, 2000). Additionally, a random survey of Manitoba farmers was carried out by Ipsos Reid Corporation (described above) primarily for the purpose of providing a comparison for the Alternative-Conventional Agricultural Paradigm Scale (Beus and Dunlap, 1991), as well as several demographic variables.

Statistical Analysis

Prior to analysis, it was determined that observations would be combined across the 2 years of the study. The rationale for this approach is the inherent diversity of the fields and farmers involved in the project, which allows for the distinction of groups based on several criteria, including ecoregion, soil type, tillage system, rotation history, or year. Given the relatively small number of participants, and the exploratory nature of the study, it was impractical and unnecessary to separate observations based on each of these criteria. The resulting groups would be so small as to prohibit meaningful comparison. In addition, the variability resulting from the range in regions and management practices is likely to be as large as or larger than the variability associated with year effects. The maintenance of one data set from our purposive sampling method provided representation of a broad description of farmers and fields involved in PFP. We were therefore able to examine whether differences among fields or farmers implementing pesticide use reduction to varying degrees are robust across site-years and agronomic management practices. Similarly, Rydberg and Milberg (2000) argued that geographic differences were of less interest in a survey of weed flora on organic farms because such factors cannot be manipulated by farmers.

In the case of repeat participants over the two years, duplicate values for farmer-based demographic variables were removed, so each farm was only included once. For variables for which the farmer's response could vary from year to year, farmers who provided the same response both years were included (as a single observation), while those that provided different responses each year were eliminated from the dataset.

Statistical analysis was carried out using SAS (SAS Institute, North Carolina, USA). PROC GLM was used to perform analysis of variance (ANOVA) for comparisons of continuous numerical variables between groups. Group was the only source of variation included in the model.

Normality was tested using Shapiro-Wilk's W, and Bartlett's test was used to test for homogeneity of variances among groups. In several situations, distribution of data did not meet the assumption of normality, and transformations did not confer normality. In these cases, PROC NPAR1WAY was used to generate Mann-Whitney U tests (for 2-group tests) and Kruskal-Wallis tests (for tests among more than 2 groups). These tests are considered to be non-parametric equivalents of 2-sample t-tests and one-way ANOVA, respectively (Stokes et al., 2000). In cases where the outcome of a non-parametric test agrees with the outcome of ANOVA (i.e. significant or not significant at the $p<0.05$ level), the result of the ANOVA was presented. This was true in most cases with the exception of: average scores of personal or family health concerns as a reason for PFP, and comparison of farm size between study participants and the random sample of Manitoba farmers. For some variables, data could be transformed to meet normality. However, if results agreed with the outcome of ANOVA on the untransformed data, the results for the untransformed data were presented. This was the case for average farm size.

For variables analyzed using ANOVA, Fishers Protected LSD was used to separate means. For variables that required analysis with non-parametric methods, pair-wise comparisons of groups using the Mann-Whitney U test were carried out if the overall Kruskal-Wallis test was significant at the 0.05 level. For categorical variables, contingency tables were used to generate pairwise comparisons between groups when the overall chi-square test was significant ($p=0.05$).

PROC FREQ was used to generate contingency tables and chi-square statistics for comparisons of frequencies of categorical data. For tables with two groups and two response variables, Pearson's chi-square was used to test for the null hypothesis of no general association between treatment and response. For larger tables with three group categories and ordinal or binomial response categories, the Mantel-Haenszel chi-square was used to test for linear response (Stokes et al., 2000). Ordinal response variables with more than 2 categories could not be considered evenly spaced integer values, so standardized midranks were used (Stokes et al., 2000). If the response variable was not considered ordinal, Pearson's chi-square was used. This was the case for comparisons between the random sample of Manitoba farmers and farmers involved in the PFP study.

It was also the case for some questions to which there were more than two possible responses that could not be considered to be a linear progression. When zero counts were generated in a table, or if more than 20% of table cells had an expected value of less than 5, Fisher's exact test was used (Stokes et al., 2000).

Questions for which there was more than two possible responses, and responses were mutually exclusive, were analyzed using chi-square tests on the basis of the distribution of responses in each group rather than the proportion of responses for each individual response category. This occurred for responses to questions regarding farmers' approach to PFP during early-season crop development (Table 4-5), the reason the field was selected for PFP (Table 4-6), interest in attempting PFP in a regular rotation (Table 4-13), and length of time before PFP would be attempted on the same field (Table 4-14).

Despite the relatively large number of variables considered in the study, no adjustment was made for increasing risk of type I error. Multivariate Analysis of Variance (MANOVA) was not appropriate for use in this study given its inability to handle categorical and missing data. Due to the nature of the study, which depended on the ability of farmers to provide information, missing values were common for many variables. MANOVA requires a complete matrix of observations, and as such, could have only been performed on a small subset of the original data. An alternative to the MANOVA procedure, Bonferonni's adjustment (or Bonferonni's correction), was also not applied because of its very conservative nature, which prohibits adequate discussion of the outcome of this exploratory study. In a non-experimental study of this type, inferential methods are limited because of the observational nature of the study. Therefore, outcome of statistical tests should always be treated with caution in terms of implying cause and effect. Given the conservative context in which the study can be discussed, it was not necessary to use extremely conservative hypothesis testing procedures.

RESULTS AND DISCUSSION

Participation

Farmer response to requests for potential PFP fields was very good, considering that typically less than 1% of fields in annual cereal or oilseed crops are not sprayed with herbicide in Manitoba (Thomas et al., 1999a). A total of 71 farmers and 120 fields were included in the project in 2000 and 2001.

In 2000, 78 farmers expressed interest in participating in the project, and 47% (37) had fields included in the project. In 2000, 119 farmers expressed interest in participating, and 52% (62) had fields on which they attempted to grow a PFP crop. However, only 40 of these farmers were actually included in the project in 2001, due to a restriction of which crops were considered for the study (only wheat, oats, barley and flax in 2001).

A total of 81 fields belonging to 79 farmers offered in early spring 2001 were not included in the project. The primary reason for lack of inclusion (the reason for 44% of fields) was that the crop being grown was not one of the 4 crops targeted for the 2001 season (wheat, oats, barley or flax). The second most common reason (the reason for 33% of fields) was that the farmer decided to spray the field for weed pressure before a visit could be made to the field. Other reasons for lack of inclusion were past use of a residual herbicide on the field (12% of fields), distance from the research station (7% of fields) and the use of a seed treatment (5% of fields).

Thirty-five percent (13) of the participants in 2000 who were contacted in the spring of 2001 planned to grow a PFP crop in 2001. However, only 8 of these farmers had fields included in the project in 2001, for the reasons indicated above. Excluding participating fields in transition to organic production, only one farmer attempted PFP on the same field 2 years in a row; however, in the second year this field was sprayed for weed control and it did not achieve PFP certification.

Crops Offered for Participation

Fields seeded to a total of 16 crops were volunteered for the project. Only 11 crops were included because in 2001 we restricted which crops were being considered in the study (only wheat, oats, barley and flax in 2001) (Table 4-1). Primary interest by farmers was in spring and winter cereals (spring wheat, winter wheat, fall rye, barley, and oats), as well as flax. In 2000, all grain crops volunteered by farmers were included; in 2001, only spring wheat, oats, barley and flax were included. Soybean, buckwheat, hemp, and canola were included in 2000. In 2001, a small number of fababean, alfalfa seed, corn, peas, sunflower and various forage crop fields were volunteered but not included in the project due to the restriction regarding which crops were eligible in 2001.

Table 4-1. Number of fields volunteered for the on-farm research project and proportion certifiable as Pesticide Free Production (PFP) by crop.

Crop	Number included in project	Proportion certifiable
Spring wheat	36	67%
Oats	33	79%
Barley	20	65%
Flax	8	63%
Fall rye	8	100%
Winter wheat	6	17%
Canola	3	0%
Buckwheat	3	100%
Soybean	1	100%
Durum wheat	1	0%
Hemp	1	100%
All crops	120	68%

Regional Participation

Participants volunteered from virtually all agricultural regions of Manitoba (Table 4-2) (See Appendix H for maps of Manitoba ecoregions and census agricultural regions; Appendix M for map of participating fields). However, there were proportionally fewer participating fields from the highly productive south-central region of the province (adapted from Manitoba Crop Insurance Corporation, 2002), and proportionally more participating fields from regions that typically have higher levels of cattle and forage production (adapted from Statistics Canada, 2002), and reduced or zero-tillage (Thomas et al., 1999a). As compared to the distribution of cropped land in the 2001 Census of Agriculture, there were more participating fields from the south-western corner of the province (Census agricultural regions 1 and 2; 45% of participating fields), compared to the census distribution (22%, Statistics Canada, 2002). There were also more participating fields from the Interlake region (regions 11 and 12; 22% of participating fields) compared to the census distribution (11%). In contrast, there was less participation in the south-central area of the province (regions 7, 8 and 9; 16% of participants) compared to the census distribution (37%). The south-central area of

Manitoba is the most intensively farmed region of the province, as indicated by the proportion of farms applying agrichemicals (adapted from Statistics Canada, 2002). The regional distribution of participants in this study was consistent with the idea that higher yield potential increases the incentive for herbicide use (Pannel, 1990), and farmers from regions with lower yield potential would therefore be more likely to participate in PFP. Other studies have also found region to be an important consideration for the adoption and success of reduced pesticide use. Smolik et al. (1995) suggested that reduced-input systems may be more profitable in regions outside the U.S. Corn Belt. Marra and Kaval (2000) found that crop type and region were significant factors in determining the relative profitability of conventional versus organic production. Constance et al. (1995) found that region was a better predictor of support for pesticide reduction than individual farm characteristics. Rydberg and Milberg (2000) noted that organic farms in Sweden tend to be located in specific regions. Bellinder et al. (1994) found that cropping system, which is regionally determined, strongly influenced the effectiveness of European pesticide reduction strategies.

Table 4-2. Number and distribution of fields volunteered for the Pesticide Free Production (PFP) on-farm research project by ecoregion and census agricultural region[z]

Ecoregion or Census Agricultural Region	Distribution of Manitoba agricultural acreage	Number of project fields in each region	Proportion of project fields in each region
	Distribution of Manitoba ecoregions[y]		
Aspen Parkland	50%	67	56%
Lake Manitoba Plain	36%	29	24%
Interlake Plain	8%	21	18%
Mid-Boreal Uplands	1%	3	3%
Southwest Manitoba Uplands	1%	0	0%
Boreal Transition	4%	0	0%
Lake of the Woods	1%	0	0%
Total	100%	120	100%
	Distribution of Manitoba census agricultural regions[x]		
Region 1	11%	25	21%
Region 2	11%	29	24%
Region 3	10%	12	10%
Region 4	4%	0	0%
Region 5	4%	0	0%
Region 6	8%	7	6%
Region 7	14%	11	9%
Region 8	16%	2	2%
Region 9	7%	6	5%
Region 10	2%	1	1%
Region 11	5%	11	9%
Region 12	6%	14	12%
Total	100%	120	100%

[z]See Appendix F for maps of Manitoba ecoregions and census agricultural regions.
[y]Distribution of cropped acreage in spring cereals and oilseeds (Thomas et al., 1999a).
[x]Distribution of land in crops in the 2001 Census of Agriculture, adapted from Statistics Canada (2002).

PFP Certification

A total of 2368 ha of the land area volunteered for the project was certifiable as PFP. This represented 83% of the total land area volunteered for the project. Over the two years of the project, 68% of all fields included in the project were certifiable as PFP. The proportion of certifiable fields varied depending on the crop type (Table 4-1). No canola fields were certifiable, as PFP certification does not allow for the use of seed treated with a fungicide or insecticide. Ninety-five percent of canola growers use a seed treatment (Canola Council of Canada, 2000), and forgoing the insecticidal seed treatment in particular requires diligent scouting for flea beetles (*Phyllotreta cruciferae* Goeze and *Phyllotreta striolata* Fabricius) in case foliar insecticide application is required. Some farmers interested in attempting PFP canola indicated that they were not prepared to make the time commitment required to scout fields for potential insecticide treatment. A preventative seed treatment was seen as much more convenient by these farmers. This fact is likely to limit the success of PFP canola, although the elimination of a seed treatment may be more feasible during years when the flea beetle population is low and if practices such as trap crops are used to limit their impact (J. Gavloski, pers. comm.). Canola is a major crop in Manitoba, covering over 750 000 ha in 2001 (Statistics Canada, 2002). Despite this, only 4% of fields volunteered for the project in 2000 were canola fields. This suggests relatively low levels of interest in canola as a PFP crop on the part of farmers.

Only 17% of the winter wheat fields were certifiable, due to the application of fungicide to control leaf diseases. Winter wheat is an excellent candidate for elimination of in-crop herbicide because it competes well with weeds. The fact that Fusarium head blight (*Fusarium* spp.) (FHB) is usually avoided because winter wheat flowers earlier than spring wheat (Agriculture and Agri-Food Canada 2001a) adds to the potential of winter wheat as a PFP crop. However, current varieties grown in Manitoba are susceptible to leaf diseases. In 2000, less than 2% of the total wheat acreage in Manitoba was winter wheat (Agriculture and Agri-Food Canada, 2001a), although the acreage has increased in recent years (Fowler, 1997). The need for snow trapping to provide insulation for the crop tends to limit winter wheat to minimum and zero-tillage production areas. Given the small acreage that winter wheat covers in Manitoba, it is worth noting that 10% of fields offered for participation in 2000 were winter wheat. This indicates significant interest in winter wheat as a potential PFP crop. The first variety of winter wheat (UM 5089) with resistance to leaf spot diseases has been proposed for registration (Anonymous, 2002). This may improve the prospects for PFP winter wheat.

Other crops were more successful in terms of PFP certification. All fall rye and buckwheat fields included in the project were certifiable. These two crops are traditionally not sprayed with in-crop herbicide. Fall rye is an excellent competitor with weeds, partly because of its fall planting date. Buckwheat is usually seeded later than most other crops in this region due to frost sensitivity, and this may allow it to escape competition with early-emerging weeds. In addition, there are few in-crop herbicides registered for buckwheat and no registered seed treatments (Manitoba Agriculture and Food, 2001f). Sixty-three percent of flax fields were certifiable. This proportion can be considered relatively high as flax is not a good competitor with weeds. The high proportion of certifiable flax fields can be attributed in part to the fact that half of the flax fields were in transition to organic, or underseeded to forage species that did not allow for herbicide application. Three of the five farmers producing certifiable PFP flax rated their satisfaction with its production to be poor. This represented a higher proportion of farmers indicating low satisfaction with a certifiable PFP crop than was evident for farmers producing cereal crops. A high percentage of oat, spring wheat, and barley fields were also certifiable (79%, 67% and 65% respectively), indicating the potential of PFP to be successfully implemented in the production of these significant Western Canadian crops.

Questionnaire Response Rate

On a per-farmer basis, the questionnaire response rate from PFP participants was 96%. On a per-field basis, the response rate was slightly lower, at 95%, because a few farmers completed questionnaires for some, but not all, of the fields they included in the project.

Even after clarification was attempted via telephone, many surveys were missing some information. Many farmers either did not have complete field records, or had recently rented land for which they did not have complete field history. In addition, University of Manitoba ethical guidelines required a clause to be included in the survey indicating that respondents could refuse to answer any questions they preferred not to. As a result, variables differ in the number of observations available for analysis. In addition, because several farmers volunteered more than one field for the project, the number of observations for farm-based variables is less than those for field-based variables.

Reasons for Participant Interest in PFP

For all three groups of participants, the highest ranking reason for interest in PFP was the desire to reduce input costs, and there were no significant differences in the score values among groups (p=0.89) (Table 4-3). The high level of interest in reducing input costs across all groups can be attributed to the fact that many farmers in western Canada are currently in financial difficulty (Boyens, 2001). Farmers face uncertainty in terms of growing conditions and commodity prices, but can control costs by reducing input use. In 2000, pesticides represented 8% of total farm costs in Manitoba, and expenditure on pesticides had increased 25% since 1995 (Manitoba Agriculture and Food Program and Policy Analysis, 2001). Interest in organic production has shifted from its original social and environmental motivation to an economic motivation (Cacek and Langer, 1986), and the same incentive trend may be true for other reduced-input approaches such as PFP.

Farmers without certifiable fields had significantly higher interest in marketing opportunities than farmers with certifiable fields, non-transitional farms. This result suggests that 'conventional' farmers with certifiable PFP fields were less interested in PFP as a marketing strategy than farmers without certifiable fields. Marketing opportunities were ranked as the least important reason for interest in PFP by this group. In contrast, for farmers with non-certifiable fields, marketing opportunities ranked second, with interest in reducing input costs being the only reason of more interest. This may suggest that farmers who did not retain fields for certifiable PFP did so partly because of the lack of marketing opportunities for PFP grain at that point in time. It may also suggest that this group would be more likely to implement PFP if such opportunities were available. Marketing opportunities for PFP grain are currently improving, due to the recent addition of a marketing manager to the PFP Farmers' Co-op.

There were no significant differences in average scores in terms of interest in PFP as a means to reduce the risk of pesticide resistance (p=0.23). Interest in PFP for this reason tended to be less important than other reasons, particularly for farmers with certifiable fields. Herbicide resistant weeds can result in significant control costs for farmers. Such costs are estimated at $4 million (Can) annually in Western Canada. Rogers (1983) noted that adoption of new practices is often

Table 4-3. **Reasons for farmer interest in Pesticide Free Production (PFP). Means are followed by standard errors in parentheses.**

Group	Reducing input costs (n=66)[z]	Marketing opportunities (n=64)	Reducing risk of pesticide resistance (n=65)	Environmental concerns (n=65)	Personal or family health concerns (n=66)
	Average score[y]				
Farmers without certifiable fields	4.67 (0.13)	4.46 (0.22)*a*	4.07 (0.30)	3.53 (0.29)	3.93 (0.32)*a*
Farmers with certifiable fields, non-transitional farms	4.55 (0.14)	3.12 (0.23)*b*	3.53 (0.21)	3.97 (0.18)	3.98 (0.19)*a*
Farmers with certifiable fields, transitional farms	4.56 (0.21)	4.07 (0.19)*ab*	3.98 (0.24)	4.25 (0.19)	4.56 (0.18)*b*
p-value for group effect[x]	0.89	0.0003	0.23	0.11	0.03[w]

a - b Means followed by the same letter are not significantly different (P > 0.05) according to Fishers protected LSD.

[z]Number of observations within PFP groups for a particular variable.

[y]Ranges from 1-5; 5 indicates high interest.

[x]See Materials and Methods for details of statistical tests used.

[w]Kruskal-Wallis nonparametric test used.

triggered by problems with the existing production system. There is evidence that the occurrence of herbicide resistant weeds can trigger the adoption of reduced pesticide practices. For example, Sutherland (2001) found that adoption of IWM in Australia was related to the severity of herbicide resistant weed problems experienced by farmers. Thirty-three percent of farmers participating in our study in 2001 indicated that they had had herbicide resistant weeds on their farms. However, problems and costs associated with herbicide resistant weeds in Manitoba are not as severe as they are in Australia. This may explain the relatively low level of interest in PFP for this reason.

While interest in PFP because of environmental concerns was not significantly different among groups (p=0.11), there was an increasing level of interest in PFP for this reason as pesticide use among groups decreased. In particular, this was the least important reason for interest from farmers without certifiable fields. Concern about environmental pollution is consistently positively correlated with willingness to adopt pesticide reduction practices (Constance et al., 1995). Egri (1999) found that while concern about the environment is an important factor in determining interest in organic production, such concerns are often over-ridden by economic factors. The combination of lower average scores for environmental concern and higher scores for interest in marketing among farmers with non-certifiable fields may be an example of this phenomenon.

Interest in PFP because of health concerns, either on a personal or family level, was significantly different among groups. Interest based on this reason was significantly higher for farmers with certifiable fields, transitional farms than for either of the other two groups. Several farmers in this group commented that they had experienced negative health effects from exposure to pesticides in the past. Resulting interest in PFP for this reason is consistent with the idea that pesticide reduction is more likely when pesticide use has a direct negative impact on the farmer (Sutherland, 2001).

Participant Interest in Organic Production

Of the two groups that were not in transition to organic, just under 60% of farmers in each group stated that they had considered organic production (Table 4-4). This was similar to the proportion found in the random sample of Manitoba farmers (56%). There were no significant differences among participant groups and the random sample. Among farmers in the project, there was a diversity of viewpoints regarding the viability

Table 4-4. Demographic charcteristics of farmers attempting to produce Pesticide Free Production (PFP) crops

Group	Percentage of farmers						
	Who have considered organic production^{z}	Younger than 55	With net farm income over $25,000	With post-secondary education	Employed off-farm	Producing livestock	Who are certified seed growers
	(n=37)^{y}	(n=62)	(n=58)	(n=61)	(n=66)	(n=66)	(n=66)
Farmers without certifiable PFP fields	57.1	61.5	83.3	76.9	20.0	46.7	20.0
Farmers with certifiable fields, non-transitional farms	58.8	88.9	52.0	65.4	39.3	42.9	21.4
Farmers with certifiable fields, transitional farms	-	72.7	66.7	50.0	39.1	43.5	34.8
P-value for PFP participant group effect^{x}	1.00^{w}	0.12^{w}	0.61	0.10	0.29	0.87	0.26
Random sample of Manitoba farmers (n=154)^{v}	55.6	74.7	72.6	43.4	-	37.7	-
P-value for Manitoba farmers versus PFP groups^{u}	0.35^{w}	0.25	0.15	0.030	-	0.84	-

a - b Means followed by the same letter are not significantly different (P > 0.05) according to Fishers protected LSD.
^{z}Analysis does not include farmers already in transition to organic. Question was asked in 2001 only.
^{y}Number of observations within PFP groups for a particular variable.
^{x}P-value for Mantel-Haenszel chi-square (linear association). See Materials and Methods for details of statistical test used.
^{w}Fishers exact test was used due to small sample sizes.
^{v}Random sample of 154 Manitoba farmers conducted by Ipsos Reid Corp. (Winnipeg, MB).
^{u}Pearson chi-square for general association.

and attractiveness of organic production. Those already in transition to organic production saw PFP as a viable alternative market that would be beneficial to them during transition; however, several of these farmers commented that they thought the complete chemical elimination of organic production was preferable to PFP. Farmers did not express concern that PFP might 'compete' with organic. Several zero-tillage farmers (who were not in transition to organic) thought that the combination of zero-tillage and PFP could be considered more sustainable than organic production that relies on tillage for weed control. There were a few participants who were farming organically but were not certified organic farmers. They cited the cost of organic certification and marketing difficulties as disincentives to organic certification. A few other farmers were interested in organic production but cited difficulties in obtaining certification because they were interested in cycling in and out of organic production on a given field. This was not looked upon favourably by organic certification agencies. Another farmer had been practicing long-term, continuous pesticide-free production already, with the use of fertilizer. These farmers were interested in PFP as an alternative to the difficulties they saw with organic production, particularly if PFP certification was inexpensive and provided some premium marketing opportunities. For several farmers, PFP became a label for reduced-pesticide practices that they were already implementing but that did not meet the criteria for organic certification.

Of the 25 farmers in transition to organic production (35% of all participants), 44% indicated that they were planning to convert their whole farm to organic production. The rest were not planning to or were unsure. Organic certification guidelines now require that the entire farm be converted to organic production within a certain time frame (OPAM allows 10 years) (Lara Scott, OPAM, pers. comm.). Some farmers who are interested in organic production but may not want to convert their entire farm to organic may become more interested in intermediate strategies like PFP as this guideline is implemented.

Reason Fields were Selected for a PFP Attempt

Fields on which PFP was attempted were selected for various reasons. These reasons were grouped into 1 of 4 categories, based on the level of planning or commitment to a reduced-pesticide crop year (Table 4-5). It should be noted, however, that fields in transition to organic production did not necessarily receive more preparation for reduced-inputs than other fields that were not in transition to organic. Only the two 'conventional' groups of farmers were included in this analysis, as all those with certifiable, transitional fields chose to attempt PFP because they were already in transition to organic production.

Table 4-5. Reason field was selected for Pesticide Free Production (PFP) attempt (n=80)[z]

Group	PFP was by default[y]	No advance preparation indicated[x]	Prepared in advance for low inputs[w]	Field was in transition to organic[v]
	Percentage of fields			
Non-certifiable fields	3.1	25.0	62.5	9.4
Certifiable, non-transitional fields	18.8	10.4	70.8	0.0
P-value for group effect[u] = 0.0094				

[z]Excludes group of certifiable fields in transition to organic as all of these fields were selected because they were in transition.

[y]Field was underseeded to a forage species that did not allow for herbicide application, or window for herbicide application was missed.

[x]Only reason given was that the field was relatively weed-free at the beginning of the growing season.

[w]Producers noted that the field was relatively weed-free in years previous to PFP, or they were preparing specifically for low input production.

[v]Some non-certifiable fields were in transition to organic. These were not sprayed in-crop, but had a residual herbicide that made them ineligible.

[u]Fisher's exact test was used due to small sample sizes. Analysis was based on differences in distribution of reasons, rather than differences in the proportion of responses for individual reasons.

There were significant differences between the two groups with respect to the distribution of fields selected for PFP for these reasons (p=0.0094). Nineteen percent of certifiable, non-transitional fields were selected for PFP 'by default'; meaning that the window for herbicide application was missed, or the field was underseeded to a forage species that did not allow for herbicide application. However, it is probable that farmers chose relatively weed-free fields for a forage establishment year, as they would have been aware of the lack of herbicide options in this situation. Three percent of non-certifiable fields were indicated as being selected for this reason; however, these fields were deemed not certifiable due to the prior use of a residual herbicide. A higher proportion of non-certifiable fields (25%) versus certifiable, transitional fields (11%) were selected for a

PFP attempt without the farmer indicating any advance preparation for low inputs. Selection of fields for PFP on the basis of advance preparation for reduced-input crop production was the most common reason given for both groups, with over half of participants in each group indicating that this was why they selected fields for PFP. However, farmers with certifiable, non-transitional fields cited this reason more frequently (71%) than farmers with non-certifiable fields (63%). Given a general lack of rotational planning among farmers in this region (Canola Council of Canada, 2001; Fowler, 1997), it is noteworthy that such a high percentage of farmers in both groups indicated advance preparation for reduced inputs. Because the grouping criteria precluded the existence of fields in transition to organic in the certifiable, non-transitional group, no fields in this group are categorized as being chosen for this reason. Nine percent of non-certifiable fields were chosen because they were in transition to organic production. These non-certifiable fields that were in transition to organic were not certifiable because of the use of residual herbicides prior to the PFP attempt. These results suggest that farmers with certifiable fields were more likely than farmers without certifiable fields to have prepared in advance for reduced-pesticide use.

Level of Commitment to PFP During Early-Season Crop Development

Results suggest that farmers with certifiable fields had higher levels of commitment to achieving PFP certification than farmers without certifiable fields. There were significant differences among groups of farmers with respect to the distribution of commitment level to produce a PFP crop during the early stages of crop development ($p=<0.001$) (Table 4-6). None of the farmers with non-certifiable fields indicated that they planned not to spray the potential PFP field regardless of pest pressure. In contrast, 21% of farmers with certifiable, non-transitional fields and 85% of farmers with certifiable, transitional fields indicated this. Forty-three percent of the farmers with non-certifiable fields indicated that at this early stage of crop development, they thought they probably would apply pesticide to the field, while only 16% of farmers with certifiable, non-transitional fields and 8% of farmers with certifiable, transitional fields indicated this.

Table 4-6. Farmers' approach to Pesticide Free Production (PFP) during early-season crop development (n=32; question asked in 2001 only)

Group	Percentage of farmers indicating that their plans were to		
	Probably spray the crop	Probably not spray the crop	Not spray the crop regardless of pest pressure
Farmers without certifiable fields	42.9	57.1*ab*	0.0*a*
Farmers with certifiable fields, non-transitional farms	15.8	63.2*a*	21.1*a*
Farmers with certifiable fields, transitional farms	7.7	8.0*b*	84.6*b*
P-value for group effect^z = <0.001			

a-b Means followed by the same letter are not significantly different (P > 0.05).
^{z}Fisher's exact test was used due to small sample sizes. Analysis was based on differences in distribution of approaches, rather than proportion of responses for each approach.

Demographic Characteristics of Participants

AGE OF PARTICIPANTS. Age group was not significantly different among project participants, nor between participants and the random sample of Manitoba farmers (Table 4-4). However, 89% of farmers with certifiable fields but not in transition to organic were under 55, the highest proportion of the three groups. Farmers in transition to organic were older on average (73% under 55), as were the farmers without certifiable fields (62%). Within the random sample of Manitoba farmers, 75% of those surveyed were under 55. According to the 1996 Census of Agriculture, 69% of Manitoba farmers in 1996 were under 55 (Statistics Canada, 1997), but this proportion has most likely increased since 1996. The role of age in predicting environmental concern among farmers has generally been inconsistent (Constance et al., 1995).

NUMBER OF YEARS OF FARMING EXPERIENCE. The average number of years of farming experience was not significantly different among groups (p=0.11) (Table 4-7). However, there was a tendency for farmers with certifiable, non-transitional fields to have less years of farming experience than the other two groups. This trend is likely related to that found for age of farmers. Groups with a higher proportion of younger farmers also had a lower average number of years farming.

FARM INCOME. Farmers with certifiable fields, non-transitional farms had the lowest proportion of farms with net farm income over $25,000 (52% of farmers) (Table 4-4). Average net farm income in Manitoba was $21,815 in 2001 (Statistics Canada, 2002). A larger proportion of farmers without certifiable fields had net income above $25,000 (83%). However, these differences were not significant. This finding is inconsistent with the traditional technology adoption theory of the diffusion of innovations (Rogers, 1983), as higher income is often associated with higher levels of adoption of new technologies. However, critics have argued that 'environmental innovations' such as reduced pesticide use are a special case (e.g. Saltiel et al., 1994), such that traditional demographic predictors of adoption are less important. Farm income is generally not significantly associated with farmers' concern about the environment (Constance et al., 1995). Net farm income of project participants was not significantly different from that found in the random sample of Manitoba farmers.

EDUCATIONAL LEVEL. All PFP participant groups had higher proportions of post-secondary education than the random sample. Post secondary education was also more common for all three groups than that found for Manitoba farmers in the 1996 Census of Agriculture (36%) (Statistics Canada, 1997). There was also a significant difference between the proportion of farmers in each of the participant groups that had post-secondary education and the random sample of Manitoba farmers (43%) (p=0.03). This suggests that farmers attempting PFP tended to have higher levels of education than is typical in Manitoba. This finding is consistent with traditional technology adoption theory which predicts that farmers with more education will be more likely to adopt new innovations (Rogers, 1983). However, the same trend is not evident among the three PFP participant groups. There was a decreasing proportion of participants with post-secondary education as groups moved toward reducing their pesticide use (p=0.10) (Table 4-4). Farmers without certifiable fields had the highest proportion of post-secondary education (77%), while 65% of farmers with certifiable fields but not in transition to organic and 50% of farmers in transition had post-secondary education. Most comparisons between conventional and organic farmers do not show significant differences in educational level (Egri, 1999; Constance et al., 1995).

OFF-FARM EMPLOYMENT. There was a lower proportion of off-farm employment among farmers without certifiable fields (20%) than the other two groups (both 39%) (Table 4-4), but these differences were not significant. There is no consensus regarding the level of off-farm income and pesticide reduction (Constance et al., 1995). The higher proportion of off-farm work among certifiable groups may be related to the fact that they have the ability to experiment more with pesticide use reduction because they have alternate income. Supplemental income may also result from a spouse's off-farm income; however, this was not considered in the study. Farmers with off-farm employment may have less time to devote to farming, so PFP might occur by default because of a lack of time for weed control operations. This was suggested by a few farmers participating in the project who had full-time off-farm work. The fact that more non-certifiable farmers did not work off the farm might be explained by the fact that as their primary occupation, they are more concerned about long-term consequences like weed seed return, as well as the immediate costs associated with weed infestations. In contrast, it might have been expected that a farmer who did not work off the farm might have more opportunity to manage his or her system for successful PFP.

NUMBER OF PEOPLE INVOLVED IN FARM OPERATION. The number of people involved in the farm operation was not significantly different among groups (Table 4-7). It might have been expected that the more people involved in the farm operation, the more time there would be for management in order to achieve PFP. This explanation is similar to the one we offered for off-farm work levels and PFP adoption. However, farm size should also be considered in this assessment, as availability of time for managing the farm operation depends on the land base per person involved. There was a general trend toward less land farm operator as groups moved toward reduced pesticide use; however, differences among groups were not significant (Table 4-7).

FIELD AND FARM SIZE. Differences in field size among participant groups were not significant at the p=0.05 level, but because the level was only p=0.065, the trends in the data warrant discussion (Table 4-7). Field size for the entire group ranged from 3.2 ha to 130 ha. The largest difference in average field size was between the two groups of certifiable fields. Certifiable fields in transition to organic averaged 38.6 ha, while certifiable fields not in transition to organic averaged 25.5 ha. Average field size

Table 4-7. **Demographic and attitudinal characteristics of farms and farmers attempting to produce Pesticide Free Production (PFP) crops. Means are followed by standard errors in parentheses.**

Group	Average farm size (ha) (n=66)[y]	Average field size (ha) (n=120)[x]	Percentage of rented land per farm (n=66)	Percentage of fields rented rather than owned (n=114)[x]	Primary operator's attitude score[z] (n=61)
Farmers without certifiable PFP fields	668.5 (98.5)	31.3 (4.29)	17.6 (4.51)	5.6	88.0 (3.85)*a*
Farmers with certifiable fields, non-transitional farms	654.5 (87.8)	25.5 (2.30)	25.3 (4.18)	14.8	92.2 (1.79)*ab*
Farmers with certifiable fields, transitional farms	528.0 (79.0)	38.6 (6.09)	24.4 (5.67)	18.8	97.9 (2.55)*b*
P-value for PFP participant group effect[w]	0.51	0.065	0.55	0.40[v]	0.046
Random sample of Manitoba farmers[u]	495.2 (34.1)		-	-	88.9 (1.05)
P-value for Manitoba farmers versus PFP groups[w]	0.16	-	-	-	0.011
LSD for comparing Manitoba farmers with PFP groups	-	-	-	-	7.44

Table 4-7 continued.

Group	Number of people involved in farm operation (n=66)	Number of ha farmed per farm operator (n=66)	Number of years primary operator has been farming (n=65)
Farmers without certifiable PFP fields	2.60 (0.40)	283.2	27.3 (2.83)
Farmers with certifiable fields, non-transitional farms	2.64 (0.20)	270.8	22.6 (1.15)
Farmers with certifiable fields, transitional farms	2.09 (0.19)	235.0	26.9 (1.86)
P-value for PFP participant group effect[w]	0.19	0.65	0.11

a - b Means followed by the same letter are not significantly different (P > 0.05) according to Fishers protected LSD.

[z]Alternative-Conventional Agricultural Paradigm Scale; scores range from 24 to 120 with lower scores indicating adherence to a conventional paradigm (Beus and Dunlap, 1991).

[y]Number of observations within PFP groups for a particular variable.

[x]This is a field-scale variable, therefore grouping was based on certification and organic transition status of individual fields, not farmers.

[w]See Materials and Methods for details of statistical tests used.

[v]Fishers exact test was used due to small sample sizes.

[u]Random sample of 154 Manitoba farmers conducted by Ipsos Reid Corp. (Winnipeg, MB).

of non-certifiable fields was intermediate to both of these groups at 31.3 ha. Farmers growing certifiable PFP crops on fields which were not in transition to organic were more likely to attempt PFP on smaller fields than those with certifiable fields where commitment has been made to convert to organic production. If the two 'conventional' groups are considered (non-certifiable fields and certifiable fields not in transition to organic), it is apparent that smaller fields were more likely to achieve PFP certification, indicating that perhaps, where no long-term commitment to reduced pesticides has been made farmers are more likely to experiment with pesticide use reduction on smaller fields. Alternately, farmers may be more likely to remove larger fields from PFP attempts because of the greater risk involved. This is consistent with traditional technology adoption theory which suggests that during the initial stages of technology adoption, a new practice is likely to be implemented on a smaller scale than practices which are already accepted (Rogers, 1983).

Average field sizes for all three participant groups were somewhat larger than the 21 ha average field size for spring cereal and oilseed crops in Manitoba (Thomas et al., 1999a). The average field size for all three groups in the project was also larger than the average field size on organic farms on the Northern Great Plains (17.6 ha) (Entz et al., 2001). This indicates that while there may be some evidence that for fields not in transition to organic production, it is the smaller fields that tended to be retained for PFP certification, these fields are not small in the context of typical Manitoba farms. This is important to note because even at this early stage of implementation, PFP is being attempted on large fields, suggesting a willingness on the part of these farmers to experiment with pesticide use reduction on a relatively large scale.

Total farm size was not significantly different among participant groups (Table 4-7). However, the average size of farms with certifiable fields on farms in transition to organic was smaller than the other two groups. This is consistent with other comparative studies of organic farms (Stanhill, 1990). However, the role of farm size in the adoption of sustainable farming practices has been inconsistent in most comparative studies (Egri, 1999). There was no significant difference in farm size between the three participants groups and the random sample of Manitoba farmers. Average farm size for all three participant groups was larger than the average Manitoba farm size of 361 ha in 2001 as reported by Statistics Canada (2002). This suggests that PFP is of interest to farmers operating relatively large farms and is more evidence that Manitoba farmers are interested in implementing pesticide reduction on large, commercial-scale farms.

LAND TENURE. While the proportion of fields grown on rented land was not significantly different among groups, fewer fields were rented among the non-certifiable group (6% of this group, versus 15% of certifiable, non-transitional fields and 19% of certifiable, transitional fields) (Table 4-7). There were also no significant differences among groups in terms of the proportion of the farm that was rented (Table 4-7). This is inconsistent with the idea that increased land ownership may make a farmer more likely to implement more intensive management like that which would be required to achieve PFP. There is conflicting evidence over the role of this factor in leading to the adoption of sustainable farming practices (Saltiel et al., 1994). Tenancy (rather than ownership) has been found to be negatively correlated with adoption of soil conservation practices in some cases; however, economic pressures may override incentives for conservation associated with land ownership (Gertler, 1992).

LIVESTOCK PRODUCTION. There were no significant differences between groups in terms of the proportion that were producing livestock as part of the farm operation. Proportions ranged from 44 to 47% of farms per group (Table 4-4). There were no significant differences between PFP study participants and the random sample of Manitoba farmers (38%) (Table 4-4). The majority of farms producing livestock in all groups had beef cattle operations. Fifty-four percent of census farms in Manitoba have cattle (adapted from Statistics Canada, 2002). The higher level of cattle production in the census than in the random sample of Manitoba farmers may be due to the fact that cattle farms in the census are not necessarily significant field crop producing farms, a requirement for inclusion in both the PFP study and the random sample. Small and McCaughey (1999) found that 70% of Manitoba beef cattle farmers also produced cereals and oilseeds, which implies that approximately one-third of cattle farms are not significant producers of annual grain crops.

Integration of livestock into the farm operation can have significant implications for cropping system management and the potential for herbicide use reduction. The use of perennial forages, silage, or green feed in rotation can have significant weed management benefits. While the use of forages is usually related to the presence of livestock on-farm, other marketing arrangements may allow for the use of forages in rotation without livestock on-farm (e.g. high value hay for export). Farmers who depend more heavily on livestock for their farm income may be more likely to reduce pesticide use. A high level of dependence on farm income from crops (rather than livestock) has been shown to be negatively related to farmers' concern about the environment (Constance et al., 1995).

CERTIFIED SEED GROWERS. There were no significant differences in the proportion of farmers that were certified seed growers (Table 4-4). For both 'conventional' groups, this proportion was close to 20%; for farmers with certifiable fields, transition to organic farms, this level was 35%. There were 680 certified seed growers in Manitoba in 2002 (Iris Yuill, Manitoba Seed Growers Association, pers. comm.). This represents 3.6% of farms reporting cropped land in Manitoba. Certified seed growers are therefore over-represented in all three PFP participant groups compared to the provincial level.

Contamination tolerances for other cereal grains in cereal seed crops are very low, and volunteer crops that may cause contamination must be removed before the crop is inspected (Canadian Seed Growers Association, 2002). Therefore, weeds are particularly problematic in seed crops, and seed growers may also be more concerned about fields that are intended for certified seed production the year after PFP. However, some farmers involved in the project did select fields for PFP that were intended for use as seed production. A few farmers commented that they chose to terminate PFP attempts only because the crop was intended for seed. Based on the low tolerance for weeds in certified seed crops, farmers growing these crops may be more likely to use pesticides. Alternately, such farmers may be more likely to have the intensive crop management skills required to implement pesticide use reduction.

AFFILIATIONS WITH AGRICULTURAL ORGANIZATIONS. There were no significant differences among groups based on the proportion of farmers belonging to various categories of agricultural organizations (Table 4-8). Farmers without certifiable fields were less likely to belong to sustainable agriculture organizations and more likely to belong to general farm organizations than the other two groups. Approximately one quarter of the participants in each group did not belong to any agricultural organizations. Membership in different types of farm organizations may be representative of, or may influence, farmers' perceptions of acceptable farming practices. Comer et al. (1999)

Table 4-8. Affiliation of farmers attempting Pesticide Free Production (PFP) with different agricultural organizations (n=66)

Group	Percentage of farmers belonging to:				
	Sustainable agriculture groups[z]	General farm groups[y]	Commodity groups[x]	Other groups[w]	No agricultural groups
Farmers without certifiable fields	12.5	56.3	37.5	6.3	31.3
Farmers with certifiable fields, non-transitional farms	29.6	33.3	14.8	7.4	21.9
Farmers with certifiable fields, transitional farms	30.4	34.8	43.5	0.0	30.4
P-value[v]	0.38	0.28	0.07	0.46[u]	0.911

[z]Organic producer groups, zero-tillage groups, National Farmer's Union, or sustainable agriculture societies.

[y]Keystone Agricultural Producers or Agricore.

[x]e.g. canola, cattle, or seed producers associations.

[w]e.g. drainage committee.

[v]P-value for Pearson chi-square.

[u]Fishers exact test was used due to small sample sizes.

found significant differences between farmers following conventional or sustainable practices in terms of their affiliations with different agricultural groups.

Attitude Scores of Participants

There were significant differences in average attitude score among participant groups (Table 4-7). Farmers without certifiable fields had significantly lower average attitude scores than farmers with certifiable, transitional fields. This indicates adherence to a more 'conventional' paradigm among farmers without certifiable fields. Farmers with certifiable, non-transitional fields had an average attitude score intermediate to, but not significantly different from, both other groups. The average attitude score of the random sample of Manitoba farmers was significantly lower than the average score of farmers with certifiable, transitional fields (Table 4-7). However, the average score of the random sample was not significantly different from either of the 'conventional' groups of participants. This suggests that while a somewhat more 'alternative' attitude was found among farmers achieving certifiable PFP, participating farmers within the two 'conventional' groups had attitude scores typical of Manitoba farmers.

Attitude differences are important in determining behaviour of farmers in terms of adopting sustainable farming practices (MacRae, 1990). Constance et al. (1995) found that attitudinal variables were more important than demographic variables in predicting support for pesticide use reduction. However, other factors, particularly economic ones, may override pro-environmental attitudes in terms of adoption of sustainable practices (Egri, 1999; Fairweather, 1999). Constance et al. (1995) found that farmers who supported pesticide reduction and those neutral on the issue were similar in most aspects except for their perception of the economic impact of pesticide reduction would cause. While it has sometimes been assumed that there is a discrete split in the farm population in terms of support for low-input practices, Lasley et al. (1990) found that such attitudes were normally distributed among farmers. Constance et al. (1995) also found that farmers are less polarized in their attitudes about pesticide reduction than previously thought. Beus and Dunlap (1991) and Comer et al. (1999) found that the attitude instrument used in our study (with modifications in the case of Comer et al.) discriminated between farmers from groups known to subscribe to conventional or alternative paradigms. Beus and Dunlap (1991) found that all known alternative agriculture groups had average scores of 90 or over on this scale, while a random sample of farmers in Washington State had an average score of 80.9. Average scores for all PFP participant groups and the random sample of Manitoba farmers were over 88, suggesting that attitudes among North American farmers have moved more toward the alternative paradigm in the decade since the attitude instrument was first used, or that attitudes vary by region.

Management Practices for PFP

Farmers were asked two questions to draw out the distinctiveness of management for PFP compared to conventional production (Table 4-9). There was a significant difference among groups (p=0.02) in response to the question "did you manage your PFP field any differently than your conventional fields?" Twenty-nine percent of farmers with certifiable fields, non-transitional farms, and 36% of the farmers with certifiable fields, transitional farms responded positively to this question. Results were not significantly different between these two groups. In contrast, none of the farmers without certifiable fields indicated that they managed their fields differently from their conventional fields. This proportion was significantly different from that found for both certifiable groups. Specific differences in management practices among farmers with certifiable PFP fields included the use of post-emergent harrowing, hand-weeding, pre-seed weed control with glyphosate, increased seeding rates, compost tea applications, mowing weed patches, or the use of forages or green manure in rotation. These results suggest that farmers that purposely managed fields to achieve PFP were more likely to achieve PFP certification.

There were no differences among participant groups regarding farmers' statements regarding their use of non-chemical pest management techniques (~20% for all groups) (Table 4-9). It is interesting to note that farmers often were using techniques that academics would classify as cultural or non-chemical management (e.g. high seeding rates), but that they did not necessarily mention the use of these practices as non-chemical pest management techniques. As a result, there was a discrepancy between the actual use of such practices and the reporting or identification of these as 'non-chemical' practices. The current convention of using pesticides as a direct pest control method may mean that the use of indirect control methods such as increased seeding rates are not readily identified as useful. Thomas et al. (1999a) found that Manitoba farmers were uninterested in non-chemical weed control unless such practices could be easily

Table 4-9 Management of fields on which Pesticide Free Production (PFP) was attempted

Group	Percentage of farmers stating that			
	They have grown a PFP crop in the past	They used different management for PFP[z]	They used non-chemical pest control techniques	They expect to increase future pesticide use[y]
	(n=65)[x]	(n=64)	(n=63)	(n=30)[w]
Farmers without certifiable PFP fields	25.0*a*	0.0*a*	20.0	-
Farmers with certifiable fields, non-transitional farms	53.6*a*	29.4*b*	23.1	6.0
Farmers with certifiable fields, transitional farms	66.7*b*	36.4*b*	18.2	0.0
P-value[v]	0.02	0.02	0.92[u]	1.00[u]

a - b Means followed by the same letter are not significantly different (P > 0.05) according to Fishers protected LSD.
[z]Different management than for their conventional fields.
[y]On the certifiable PFP field, as a result of having grown a PFP crop.
[x]Number of observations within PFP groups for a particular variable.
[w]Small sample size because question asked of producers only in 2001.
[v]P-value for Mantel-Haenszel chi-square (linear association). See Materials and Methods for details of statistical test used.
[u]Fishers exact test was used due to small sample sizes.

implemented. Despite low reporting of use of non-chemical pest management practices, farmers did display knowledge of a wide range of these practices when asked to indicate what methods would be most useful for producing future PFP crops (see Chapter 3).

Previous 'PFP' Production

There was a significant difference in the proportion of farmers who stated they had grown a PFP-type crop (i.e. forgoing in-crop pesticide) prior to attempting a PFP crop as part of this project (Table 4-9) ($p=0.02$). Twenty-five percent of farmers with non-certifiable fields had previously produced a crop without in-crop pesticide, while 54% of those with certifiable, non-transitional fields, and 67% of those in transition to organic had. Farmers with certifiable fields on transitional farms were significantly different from both other groups; however, responses from farmers in the other two groups were not significantly different from each other. Results suggest that farmers who were using fewer pesticides more commonly had prior experience with a pesticide-free crop. Rogers (1983) recognized that trial of a new practice is crucial to its full adoption. If a farmer has had favourable experience with a practice in the past, he or she would be expected to be more likely to implement it in the future. The high level of past experience with pesticide reduction among farmers making the commitment to organic production supports this idea.

Future Pesticide Use

Very few farmers stated that they thought they might have to increase pesticide use as a consequence of PFP (Table 4-9). Only 6% of those whose fields were not in transition and 0% of those whose fields were in transition expected to increase their pesticide use as a result of implementing PFP. These proportions were not significantly different from each other.

Perception of PFP as an Acceptable Practice

As groups moved toward reducing pesticide use, the proportion of farmers stating that they thought PFP was a practice acceptable to most farmers increased (Table 4-10). However, differences between groups were not significant. This trend is consistent with the idea that farmers are more willing to implement a practice when they perceive that the concept is accepted by the farming community around them (Saltiel et al., 1994; Bultena

Table 4-10. Farmers' perceptions of Pesticide Free Production (PFP) and weed densities

Group	Percentage of farmers stating that:		
	PFP was financially beneficial (n=53)[z]	PFP is acceptable to the majority of farmers (n=63)	They are more tolerant to weeds than most farmers (n=38)[y]
Farmers without certifiable fields	-	30.8	28.6
Farmers with certifiable fields, farms not in transition to organic	90.3	35.7	30.0
Farmers with certifiable fields, transition to organic farms	90.9	40.9	54.6
P-value[x]	1.00[w]	0.54	0.36[w]

[z]Number of observations within PFP groups for a particular variable.

[y]Small sample size because question asked of producers only in 2001.

[x]P-value for Mantel-Haenszel chi-square (linear association). See Materials and Methods for details of statistical tests used.

[w]Fishers exact test was used due to small sample sizes.

and Hoiberg, 1983). Constance et al. (1995) argued that support for reduced pesticide practices is more related to regional and community context than to individual farm characteristics. Approximately one-third of farmers in each group indicated that PFP was a generally acceptable practice.

Financial Outcome of PFP

Over 90% of farmers with certifiable fields stated that PFP was financially beneficial compared to growing the crop conventionally (Table 4-10). Because markets for PFP grain were not yet established when this study was conducted, all farmers responding positively to this question indicated that financial benefits were due to reductions in input costs. Some farmers noted that the financial benefits were only possible because of the specific situation they were in. For example, some farmers indicated that the year after PFP, they chose a crop that allowed for good weed control. Others specifically chose a relatively weed-free field for PFP, minimizing weed problems. Some farmers stated that the financial outcome of producing a PFP crop was likely the same as if they had applied herbicide due to the trade-off between input costs and yields. Swanton et al. (2002) found that average gross returns for a rotation including a winter wheat crop without in-crop weed control was no different than other weed control treatments. The perception of the economic outcome of reduced pesticide use is a critical factor in its adoption (Constance et al., 1995). Therefore, positive perceptions of the financial viability of PFP lend support to the idea that PFP has the potential to be widely adopted by Manitoba farmers.

Tolerance to Weed Densities

As the level of pesticide reduction among groups increased, the proportion of farmers stating that they were more tolerant to weed pressure (than they would expect other farmers to be) increased (Table 4-10), but differences among groups were not significant. Over half of farmers with certifiable fields, transitional farms said they were more tolerant weed pressure, while 30% of those with certifiable fields, non-transitional farms and 29% of those without certifiable fields agreed with this statement.

Satisfaction with Certifiable PFP

Farmers with certifiable fields were asked to rate their satisfaction with growing a PFP crop as good, fair or poor (Table 4-11). While other factors besides the lack of pesticide use can contribute to satisfaction levels, such responses do give an overall general impression of how satisfied farmers were with implementing PFP. Satisfaction was lower for fields in transition to organic (50% good, 36% fair, 14% poor). Fields not in transition to organic were rated better in terms of satisfaction (74% good, 19% fair, 8% poor). In addition, no farmers with certifiable fields in 2000 surveyed after the 2001 season indicated that they had any regrets about leaving the field unsprayed in 2000. These results may be an indication of the selectivity of farmers in choosing fields for certifiable PFP. If farmers retained only those fields that were appropriate for PFP in terms of weed densities, high levels of satisfaction would be more likely.

Table 4-11. Farmer satisfaction with producing a certifiable Pesticide Free Production (PFP) crop (n=81)

Group	Good	Fair	Poor
	Percentage of fields		
Farmers with certifiable fields, farms not in transition to organic	73.6	18.9	7.6
Farmers with certifiable fields, transition to organic farms	50.0	35.7	14.3
P-value for group effect[z] = 0.04			

[z]P-value for Mantel-Haenszel chi-square (linear association). Analysis was based on differences in distribution of satisfaction categories, rather than differences in proportion of responses for individual satisfaction categories.

Interest in Attempting PFP in the Future

Interest in PFP for the future was focussed on spring and winter cereals; however, virtually every major crop in this region was suggested for future PFP attempts (Table 4-12). There was no significant difference in interest in pursuing regular PFP in future crop rotations between those that had grown a certifiable crop and those who had not (Table 4-13). Responses from farmers in transition to organic were complicated by the fact that if they were planning to fully implement organic production, then PFP as a transitional mechanism or marketing strategy will not be implemented after organic certification is obtained. As a result, future interest in PFP in this group may appear relatively low, even though these farmers are committed to pesticide reduction.

Table 4-12. Preferred crops for future Pesticide Free Production (PFP)[z]

Crop	Percent of participants suggesting
Oats	58%
Barley	48%
Spring wheat	40%
Winter wheat	28%
Fall rye	27%
Alfalfa	25%
Flax	18%
Canola	9%
Peas	7%
Buckwheat	4%
Hemp	3%
Fababean	3%
Triticale	1%
Sunflower	1%
Sorghum Sudan-grass	1%
Corn	2%

[z]As suggested by all participating farmers.

Table 4-13. Response of farmers to the question: 'would you try Pesticide Free Production (PFP) in a regular crop rotation?' (n=63)

Group	Yes, without a premium	Yes, but only with a premium	No or unsure
	Percentage		
Farmers without certifiable fields	40.0	40.0	20.0
Farmers with certifiable fields, non-transitional farms	59.3	33.3	7.4
Farmers with certifiable fields, transitional farms	66.7	23.8	9.5
P-value for group effect = 0.50[z]			

[z]P-value for Mantel-Haenszel chi-square (linear association). Analysis was based on differences in distribution of responses, rather than differences in proportion of responses for individual categories.

Marketing Premiums Required by Participants. Sixty-seven percent of farmers with certifiable fields, transitional farms stated that they would try to implement PFP regularly, even without a premium for the PFP crop (Table 4-13). A further 24% stated that they would try PFP regularly but only if a premium existed. Ten percent were unsure or said they would not try it again. Sixty percent of farmers with certifiable fields, non-transitional farms, and 40% of farmers without certifiable fields stated that they would try PFP again even without a premium for PFP. If a premium was guaranteed, a further 33% of farmers with certifiable fields, transitional farms and 40% of farmers without certifiable fields would try PFP in a regular crop rotation. Twenty percent of those without certifiable fields were unsure or said they would not try it in a regular rotation. These results suggest that the level of commitment to future PFP was lower among farmers without certifiable fields.

Participants were asked what marketing premium would be required for them to consider implementing PFP on a regular basis. Data for 2001 only was used here because of the lack of response to an open-ended question on this topic in 2000. When pooled over all three participant groups, farmers suggested that price premiums in the range of 20% above conventional grain prices for wheat, oats, barley, and flax would be required. The average premium required for flax was only slightly higher than that for the three spring cereal crops. This is surprising, because flax would be expected to be a more difficult PFP crop to grow due to its poor competitiveness with weeds. However, fewer farmers were willing to accept low premiums for flax (premiums less than 10%) than for cereals. Forty-five percent of farmers with certifiable fields, non-transitional farms suggested a 10% premium or less for PFP cereal crops. In contrast, only 17% of farmers without certifiable fields and 11% of farmers with certifiable fields, transitional farms suggested this relatively low level of premium for PFP cereal crops. For farmers without certifiable fields, the suggestion of relatively high premiums than may be an indication of their high level of interest in marketing as a reason for PFP, whereas those with certifiable fields on non-transitional farms may require less compensation because of high interest in PFP for other reasons. For farmers with certifiable fields on transitional farms the indication of requirement for high premiums may reflect the expectations of high premiums for organic production. Interest in organic production for economic rather than the traditional environmental and social reasons has been increasing (Cacek and Langer, 1986), so significant organic premiums are likely to be important for many organic farmers. Marketing opportunities for PFP-identified grain at a price premium are expected for all PFP certifiable grain produced in 2002 (Brenda Tjaden Lepp, pers. comm.). A recently completed survey regarding consumer interest in PFP food products indicated the existence of a sizeable group willing to pay premiums in the range of 1-10% for such products, and a smaller niche group of consumers that are willing to pay premiums between 10-20% (Magnussen, 2002). Whether or not such retail-level premiums will allow for adequate farm-level premiums will likely depend on the capture of value by grain handlers and processors.

FUTURE INTENTIONS FOR PFP. When asked how long they would wait until attempting PFP on a field which had previously had a PFP attempt, farmers without certifiable fields were most likely to be unsure (75%) (Table 4-14). More than half of farmers with certifiable fields, non-transitional farms indicated that they would try PFP on the same field within 3 years. However, 44% of farmers in this group were unsure of when they might attempt PFP in the future. Not surprisingly, most farmers with certifiable fields, transitional farms indicated that they would try PFP on the same field next year (75%) because PFP would be implemented as part of the requirements for organic transition. The proportion of farmers indicating interest in trying PFP again increased with increasing amounts time since the previous PFP attempt. Similar trends were evident when farmers were asked how long they would wait until trying PFP on a different field than the field they attempted PFP on; however, farmers in all groups were more likely to indicate that they would sooner implement PFP on a different field than on the same field as PFP had previously been attempted.

Many farmers in Western Canada typically do not follow a planned rotation, and advance planning for regular PFP would be very unusual for many farmers. The Canola Council of Canada (2000) found that only 41% of canola growers in Western Canada (n=881) indicated that they followed a planned rotation. In the Prairie ecozone, which encompasses most of Manitoba's ecoregions, this value was 60%. Fowler (1997) indicated that many winter wheat farmers tend not to follow planned rotations.

Table 4-14. Response of producers to the question: "How long would you wait until you try Pesticide Free Production (PFP) on the same field as you tried PFP this year?" (n=38)[z]

Group	Next year	In 2 years	In 3 or more years	Unsure
	Percentage of farmers			
Farmers without certifiable fields	12.5	12.5	0.0	75.0
Farmers with certifiable fields, non-transitional farms	12.5	18.8	25.0	44.0
Farmers with certifiable fields, transitional farms	75.0	8.3	0.0	16.7
P-value for group effect = 0.0012[y]				

[z]2001 responses only included because of ambiguity in responses to an open-ended form of question in 2000.

[y]Fisher's exact test was used due to small sample sizes. Analysis was based on differences in distribution of responses, rather than differences in proportion of responses for individual categories.

PARTICIPANT COMMENTS REGARDING FUTURE INTEREST IN PFP. Farmers in transition to organic thought that PFP could be a good market for their transitional crops. Some farmers were interested in producing PFP forage and feed grain, and winter cereals were cited as being especially appropriate for PFP. Some farmers suggested that their implementation of PFP in the future would depend very much on their rotations as well as marketing. A number of farmers indicated that they would adopt a 'wait and see' approach to decisions regarding implementing PFP in the future. These farmers planned only to implement PFP on fields with low weed densities. These same farmers did not indicate that they would actively try to make PFP happen through advance planning. Other participants suggested that they were trying to reduce their agrichemical input use regardless of whether or not it fit within PFP guidelines, but they were interested in networking with others with similar interests and thought that PFP might be useful in this regard. Farmers did not express awareness of other non-organic eco-label frameworks currently in use in Manitoba, so PFP was likely their first encounter with a pesticide use reduction strategy intermediate to conventional and organic production. (See Appendix G for a summary of comments from participants)

Participants who had certifiable fields in 2000 and were surveyed the following summer (n=23), cited a number of barriers to PFP adoption. The availability of a marketing premium (61%) as an incentive to make up for potential yield loss and risk, and to be rewarded for making an effort not to use pesticides, was the most commonly cited barrier. High weed densities forcing farmers to apply herbicides were cited by 30% of these farmers. The restriction regarding use of residual herbicides for PFP certification was cited by 17% of farmers. Barriers mentioned by less than 10% of farmers included: the issue of 'coffee shop talk' and overcoming the pervasive mindset of reliance on chemicals and expectations of weed-free fields; the need for identity preserved (IP) separation of PFP grain; problems of weed seed return; the management skill required for PFP; and lower crop yields. Again, several farmers cited the difficulty in 'finding a clean field', implying that they would not alter management to achieve PFP.

These same farmers were also asked if they had attempted PFP again for a second year on any part of their farm. Fifty-seven percent said that they had. Those that did not grow a PFP crop cited the following reasons: weed densities were too high (30% of those surveyed), a residual herbicide was used on the intended field (9%), or they used a seed treatment (4%).

Interest in future PFP may be related to pre-existing attitudes among farmers where some are more interested in reducing chemical use and input costs. Alternately, one successful year of PFP may reinforce the commitment of some farmers to try PFP in the future. This would be consistent with the traditional model of technology adoption that predicts that a practice is more likely to be adopted if it has been attempted previously (Rogers, 1983).

Summary

While some studies have shown differences in demographic variables among farmers practicing reduced-input agricultural and their conventional counterparts, others have shown few differences between these groups (Saltiel et al., 1999; de Buck et al., 2001; Lockeretz et al., 1981). In this study, groups categorized on the basis of implementation level of PFP displayed few significant differences in demographic variables. The general lack of demographic differences indicates that farmers who were interested in and successfully implementing PFP were typical for Manitoba, suggesting that PFP may be practiced by typical Manitoba farmers. The groups did differ in terms of level of education. PFP participant groups had higher levels of education than was typical for Manitoba farmers.

The PFP groups differed in terms of average attitude scores. Farmers with certifiable fields, transitional farms had a higher average attitude score than the two 'conventional' PFP groups. The attitude scores of the 'conventional' PFP groups were typical for Manitoba farmers. The average attitude score for the PFP group in transition to organic was higher than is typical for Manitoba farmers. This suggests that attitudes are important in determining adoption of organic production, but that farmers interested in PFP are not different from typical Manitoba farmers in their attitudes. Perception of PFP as an acceptable practice and higher tolerance to weed densities tended to be associated with the certifiable PFP groups. Across all PFP groups, the primary reason for interest in PFP was reducing input costs. However, there were some significant differences among groups in reasons for interest in PFP. Farmers without certifiable fields were more interested in PFP for marketing reasons and less interested in PFP for personal health reasons. Overall, there were more similarities in the ranking of reasons for interest in PFP among the two groups of farmers with certifiable fields in comparison to the group of farmers without certifiable PFP fields. Interest in all reasons was highest in the group with certifiable fields, transitional farms. These findings are consistent with the idea that attitude variables are important for the successful adoption of environmental innovations (Beus and Dunlap, 1991; MacRae, 1990). In particular, the results of our study support the finding by Constance et al. (1995) that attitudinal variables may be more important than demographic variables in explaining variation in the adoption of pesticide use reduction.

Farmers with certifiable PFP fields tended to have higher levels of prior experience with reduced pesticide crop production, and tended to show more evidence of active preparation for low inputs in their selection of fields for PFP than did farmers without certifiable fields. The former also tended to have lower levels of uncertainty about future plans and were more likely to say that they managed their PFP field differently from conventional fields. Results suggest that active planning for reduced pesticide use tended to increase the likelihood of achieving PFP certification. This supports the argument that regular reduction or elimination of herbicide use requires alteration of the cropping system in order to reduce weed densities (Van Acker et al., 2002).

Satisfaction with the outcome of certifiable PFP was high among groups with certifiable fields and few farmers indicated that they expected to increase future pesticide use as a result of producing a certifiable PFP crop. In general, future interest in PFP was high among all participants. However, despite this generally high interest, many farmers were unsure when they would implement PFP again. A general tendency of Manitoba farmers to remain flexible in their future cropping plans is likely responsible for this. In addition, future implementation of PFP may depend on marketing opportunities. This was noted in particular by farmers who did not have certifiable PFP fields. Future interest in reducing pesticide use may result in adoption of other reduced-pesticide frameworks besides PFP, as some farmers expressed interest in reducing input use regardless of the specific guidelines of PFP.

CHAPTER 5

GENERAL DISCUSSION

Nature of PFP Crops, Farms, and Farmers

Given the intermediate nature of PFP, we expected that there would be agronomic differences in the nature of crops, farms, and farmers involved in PFP implementation as compared to either conventional or organic farms and farmers. However, farmers implementing successful PFP, particularly those not in transition to organic production, tended to be similar to typical Manitoba farmers in many ways. Of particular note is the finding that some agronomic characteristics that are typically cited as being negatively affected by reductions in pesticide use were not significantly different among certifiable PFP fields and non-certifiable fields. Crop yields as a percentage of regional and varietal averages were not significantly different among groups. Weed densities tended to be higher in certifiable fields than non-certifiable fields, but the vast majority of farmers with certifiable fields did not experience increased costs associated with rising weed densities the year after certifiable PFP. Very few farmers indicated that they had any regrets about producing a PFP crop. General satisfaction with certifiable PFP crops was high, and the financial outcome of producing a certifiable PFP crop was positive for over 90% of participants. These findings contradict a general attitude that pesticides are always required to achieve acceptable crop yields and farm income. This study provides evidence that, when farmers choose appropriate fields, pesticide use can be reduced without serious adverse consequences.

An important question arising from this study is whether or not there is a typical profile for PFP farmers. Of particular interest in this assessment is the difference between 'conventional' farmers who had certifiable and non-certifiable fields, as it is farmers who are not in transition to organic that are targeted by an intermediate approach such as PFP. There were few significant demographic differences between these two groups, and few indications that farmers with certifiable fields differed from what is typical in Manitoba. This indicates that there is not a profile of successful PFP farmers that is obviously different from typical Manitoba farmers.

There was some evidence of differences in demographic characteristics of participants that are worth noting. All farmers involved in the project tended to have higher levels of education than is typical of Manitoba farmers; however, farmers with non-certifiable fields tended to have higher levels of education that farmers with certifiable, non-transitional fields, who in turn had higher levels than farmers with certifiable, transitional fields. Therefore, the finding that higher levels of education are a characteristic of farmers implementing successful PFP is not completely straightforward. Perhaps there is a trade-off between higher levels of education leading to more awareness of environmental and economic concerns with pesticide use, and the nature of agricultural education to promote an input-intensive model of farming. A higher proportion of 'conventional' farmers with certifiable fields were under 55, suggesting that younger farmers may be more interested in PFP. 'Conventional' farmers with certifiable fields also tended to rent more land, have less net farm income, have less years of farming experience, and were more likely to be employed off-farm. These factors are arguably related to age, as younger farmers are less likely to have built up as much equity in the farm as older farmers.

Some reasons for interest in PFP were significantly different among groups, suggesting that some attitudinal factors may be important in the adoption of PFP. In particular, farmers who implemented certifiable PFP tended to be less interested in marketing opportunities and more interested in environmental and health issues. There was also a trend toward the perception of PFP as an acceptable practice and tolerance to weed densities among 'conventional' farmers with certifiable fields. However, farmers with 'conventional' farms were not significantly different from the random sample of farmers in Manitoba, in terms of attitude score. However, scores among farmers with certifiable PFP fields tended to be higher than other groups. This suggests that 'conventional' farmers implementing PFP are well within the range of mainstream farmers in terms of attitude scores, but have some tendency to be more concerned about reducing reliance on external inputs for reasons other than immediate marketing opportunities.

Farmers participating in the project tended to be from regions that traditionally have lower grain yields, less history of agrichemical use, more livestock and forage production, and higher levels of reduced tillage. Region affects historical crop yield potential and past level of agrichemical use, and may also be related to local social acceptability of pesticide use reduction (Constance et al., 1995). Therefore, regional location may be important in determining interest in PFP.

Farmers participating in the project tended to be as diversified or more so in their operations as is typical in Manitoba. For example, farmers tended to have higher levels of forage in the participating field's rotation history, were more likely to be using reduced tillage, were growing more winter cereals, or were growing more certified seed crops than typical Manitoba farmers.

Farmers had a tendency to minimize the risk associated with PFP attempts. Many farmers commented that the ability to choose whether or not to pursue PFP based on specific yearly conditions was an important advantage of the concept, particularly in contrast to the long-term commitment required for organic certification. Risk minimization was evident in terms of the lower weed densities and smaller sizes of 'conventional' fields that were PFP certifiable. There also appeared to be a tendency of farmers to choose relatively more marginal land for attempting PFP. 'Conventional' farmers with certifiable fields also tended to be more likely to have some form of advance preparation for a PFP crop or past experience with pesticide use reduction, both of which would minimize the perceived risk of PFP implementation.

While there were few significant differences among groups, a number of factors may have contributed to determining how successful PFP attempts were among 'conventional' farmers. These included farm location, level of diversification, farmer interest in reducing risk and input costs, educational level, and perhaps age and attitudes. However, most agronomic and demographic characteristics of farmers and fields involved in this study were typical of Manitoba. de Buck et al. (2001) also found few differences between farmers implementing IAFS (similar to IPM) and conventional farmers. Trends in demographic and attitudinal variables suggest some factors that may be related to successful implementation of PFP, but farmers implementing PFP can still be considered 'mainstream'. This is a critical finding as it suggests that there is the ability of PFP or other intermediate strategies to be implemented by a large segment of the farm population. In this way, PFP has the potential to have a significant impact by providing a framework for pesticide use reduction.

Management Practices for PFP Implementation

In this study, specific practices that showed promise for aiding in the implementation of reduced pesticide use included seeding date manipulation (particularly delayed seeding), use of forages and increased seeding rates. While many farmers did not specifically identify the use of non-chemical weed management practices for PFP even if they were currently using such practices, farmers as a group did provide a list of 25 management practices that they would find useful for implementing PFP. The lack of identification of current practices as non-chemical methods suggests on the one hand, a lack of valorization of existing knowledge among farmers with respect to crop management for pesticide use reduction. On the other hand, it suggests an awareness of many practices that could be implemented for pesticide use reduction was evident. It is crucial that existing farmer knowledge surrounding pesticide use reduction strategies is recognized and valued by the broader agricultural community, including farmers, academics, and extension workers. It is also important that exchanges of such information are facilitated among farmers to ensure that existing knowledge is not lost as the farm population becomes older and smaller. However, care should be taken to emphasize that simple substitution of only one or a few alternative management practices for herbicide use may not lead to satisfactory results. Similarly, what is successful on one farm may not be appropriate for another. Combinations of approaches, in the context of individual farm situations, should be highlighted.

Some management practices that have been shown to be effective in reducing weed pressure were rarely used or infrequently suggested as important practices for PFP. For example, there was a general lack of interest in chaff collection or intercropping for weed management. The lack of interest in such management practices may be because they require capital outlay for new equipment, are more difficult to implement than other practices, or because of a general lack of appreciation of the value or acceptability of such practices by farmers.

The results of this study support the idea that reductions in pesticide use will be most successful if farmers actively prepare for reduced-input crop production. However, there has been a tendency in the literature surrounding IPM to simply observe pest levels and base pesticide reduction decisions on those real-time observations rather than to manage cropping systems to allow for pesticide use reductions. Some authors have found that simply applying ET-based decision making to an existing cropping system does not necessarily result in reliable reductions in herbicide use (Yee and Ferguson, 1996; Proven et al., 1991). In this study, farmers did show selectivity in retaining or aborting PFP attempts based on weed densities and yield potential within specific fields, although this did not appear to be based on strict use of academically determined ET's. The lack of use of objectively defined ET's is not surprising, as several authors have found that adoption of such ET's among farmers is low (National Research Council, 1989; Czapar et al., 1997; Canola Council of Canada, 2000). There is of course value in the selective choice of fields for PFP attempts, and in this sense economic thresholds and decision support systems are important tools. Such methods need to be user-friendly and should explicitly value and make use of farmers' experience. But given the site-specific nature, complexity, and low adoption of these tools, a simpler and more reliable means to achieve pesticide use reduction is to alter farm management.

Use of independent crop scouts may be valuable for identifying opportunities for reductions in, and more efficient use of, crop inputs. Petrzelka et al. (1997) found that the returns from hiring independent crop consultants was approximately 4:1. In this study, only 10% of farmers were using independent crop consultants, although this is likely relatively high for Manitoba. Getting unbiased advice on opportunities and management for pesticide use reduction from sales agronomists can be difficult, as their affiliation with crop input companies necessitates the promotion of specific products (Van Acker and Martens, 2000). Sharing the costs of independent consultants among a group of farmers may be more affordable. Such an approach is currently being used in Quebec with good success (Agroenvironmental Advisory Clubs) (Clubs Conseils en Agroenvironment, 2001). The Quebec government supports this initiative, and other provincial governments should consider providing such support, given the environmental and economic benefits of such unbiased advice. This would be more proactive way of promoting economically viable farming than the current approach of providing emergency financial aid to farmers.

Future Prospects and Challenges for PFP Adoption

The results of this study demonstrated high levels of satisfaction among farmers with certifiable PFP crops both in financial terms and impact on weed populations. Future adoption of PFP will be supported or hindered depending on various developments surrounding economic factors, new pesticides, plant breeding, government policies, and agronomic research.

Recently, the federal government has initiated a process to develop a national Agriculture Policy Framework (APF). One of the major 'pillars' of this framework is environmental stewardship. This may lead to requirements for farmers to implement environmental farm plans, which have thus far been implemented voluntarily in Ontario and the Atlantic Provinces. The practice of PFP or other reduced-pesticide use frameworks may help farmers demonstrate pro-active attempts to ensure environmental stewardship and minimize the transition to compliance with environmental farm plans. In addition to its environmental focus, PFP may fit with the requirements of some of the other 'pillars' of the framework, including risk reduction (by reducing input costs), food safety, and an overall branding of Canadian products as high quality. PFP may therefore receive more interest and support from government sources in the future (Brenda Tjaden Lepp, pers. comm.).

The Fusarium head blight (FHB) problem in Western Canada suggests that if a reliable, cost-effective fungicide with a relatively wide window of application is found to control this disease, the potential for PFP certification for cereals may decline dramatically. An exception to this might be winter wheat, which typically avoids severe FHB pressure. Severity of FHB is increasing in wheat, barley, and oats. FHB was found in 96% and 84% of spring wheat fields in 2000 and 2001, respectively (Agriculture and Agri-Food Canada, 2001 and 2002). The implications for end-use quality and yield loss due to this disease are very significant. Currently, only two products are registered for suppression of FHB, Folicur® (tebuconazole) and Bravo® (Chlorothalonil) and the effectiveness of these treatments varies. This means that use of fungicides for FHB control is currently not as widespread as a more effective product might be.

Genetic resistance to FHB in cereal varieties could make PFP a more likely possibility for cereals. The development of genetic resistance to significant diseases would increase the likelihood of PFP adoption in general. Breeding may also play a role in terms of weed management via the production of varieties that are more competitive with weeds. However, how such competitiveness is conferred is not well understood (Paul Watson, pers. comm.) and has received relatively little research attention thus far. In general, breeding of plants to be more productive at lower input levels would be advantageous for PFP and other reduced-input approaches. Plant breeding has traditionally depended on large-scale modification of the crop's environment through the use of inputs. Breeding for plant adaptability to adverse conditions would be advantageous in allowing for reduced crop input use (Boyer, 1983)

Some argue that in times of economic crisis, farmers tend to increase input use, farm more land, and farm marginal land in order to overcome narrowing profit margins (Parrott and Marsden, 2002). In our study, poor economic conditions were the primary motivation driving farmers to reduce inputs via PFP. Therefore, if prices for major crops in Western Canada increase, there may be less incentive among farmers to reduce input use. Increases in the cost of inputs have however traditionally captured all gains in crop values achieved through higher crop yields or prices. An additional economic consideration is that PFP is designed to occupy a middle ground in terms of marketing between organic and conventional food items. If organic products become cheaper to consumers, for example, through increased supply, then PFP may not have a niche to fill between organic and conventional supplies. Currently, prices for organic private-label items are only slightly higher than non-organic items in retail outlets such as Superstore. Similarly, if organic premiums for farmers are eroded by increased supply or increased capture of value by the marketing and processing chain, there may be less possibility of a premium for an intermediate strategy like PFP, and subsequently less farmer interest in PFP. While farmers with certifiable fields tended to be interested in implementing PFP even without a marketing premium, there is little doubt that the availability of premium prices would encourage more farmers to attempt and achieve PFP.

The specific guidelines for PFP were developed so that it would be accessible to a wide range of farmers as well a successful marketing strategy. In this regard, the certification process for PFP is an important consideration. In particular, the ability of a farmers' marketing co-op to own the PFP trademark and control the use of the term is critical to developing market premiums for PFP (Brenda Tjaden Lepp, pers. comm.). Disillusionment with organic certification, in terms of cost of certification as well as the unreliability of buyers of certified organic grain, was evident among several farmers participating in this study. While strict guidelines are necessary for consumer confidence in PFP-labelled products, it should be recognized that increasing regulation would make PFP certification more costly and less accessible to farmers.

Region was shown to be an important factor in terms of interest in PFP, but not necessarily in the proportional success in achieving PFP certification. There may be greater potential for PFP in areas of Western Canada other than Manitoba. Alberta and Saskatchewan have a higher proportion of fields with reduced herbicide use than Manitoba. Three and six percent of cereal fields are not sprayed with herbicides in Alberta and Saskatchewan, respectively, while in Manitoba this proportion is under 1% (Thomas et al., 1999b, Thomas et al., 1999a, Thomas et al., 1999c). This may in part be due to drier conditions west of Manitoba, which may decrease weed and disease pressure. Alternately, it may be more challenging for farmers in regions with higher yield potential, higher historical use of pesticides, higher disease and weed pressure, and less forage production to implement PFP, because the social acceptability of pesticide use reduction may be lower in these regions than in other regions. A related consideration is the tendency of farmers to place great value on high yields or grades to the extent that lower yielding, but more profitable and less risky production systems may not be considered. This is likely to be particularly important in regions with high yield potential for grain crops. In particular, the limited interest in PFP from the Red River Valley region of Manitoba indicates the influence of region (Appendix M).

The limitations associated with PFP canola deserve consideration as it is a significant crop in Manitoba, covering over 750 000 ha in 2001 (Statistics Canada, 2002). In particular, an increase in cost or loss of registration of insecticidal seed treatments may make PFP canola more feasible.

Specific characteristics of some crops may make them more appropriate for PFP marketing. For example, flax has been linked with particular health benefits. Products containing PFP certified flax might provide even greater appeal as a marketing strategy promoting healthy food products (Brenda Tjaden Lepp, PFP Marketing Manager, pers. comm.).

There may be potential for PFP crops that were not explored in this study. Forage and feed crops may have a role in the production of 'natural' meat products (e.g. the Healthy Grain initiative in Quebec; Pierre Lachance, pers. comm.). A great challenge lies in applying PFP to crops that are less amenable than cereals are to pesticide use reduction. Examples of these crops include canola, pulses, sunflower, and potatoes. Management of the cropping system and knowledge of pest biology to allow for PFP is likely to be especially important for these crops.

There may be tension between PFP and promoters of organic or conventional production. Any production system that challenges the status quo may imply that other systems have negative attributes. This may lead to some backlash. However, PFP is not likely to generate the same level of hostility among conventional agriculturalists as does organic production. Nevertheless, by trying to provide an intermediate approach between organic and conventional production, PFP may invite criticism from those involved in promoting more radical changes to the conventional model of crop production. There have been few indications of such tension so far, perhaps because of the limited implementation of PFP. In particular, response to PFP at an organic farmers' conference was positive (personal observation). The positive response to PFP on the part of organic agriculturalists appears to be related to a recognition of pesticide use reduction as a continuum, as well as to the marketing opportunities PFP may offer. The current lack of marketing opportunities for crops produced during the transition to organic production may act as a barrier to increased certified organic production. The existence of PFP to provide such opportunities may draw more farmers to implement organic production. This has been the experience of the Healthy Grain initiative in Quebec, an intermediate pesticide reduction strategy which regularly has participating farmers leave the program because they have decided to convert fully to certified organic production (Pierre Lachance, pers. comm.). Negative response to PFP seems to have been greater from supporters of conventional agriculture than from supporters of organic agriculture. There has been significant coverage of the PFP initiative in the mainstream media, but some commentary on PFP in the mainstream agricultural media has been negative.

The most pressing constraint in the adoption of PFP may be the general lack of advance management or planning for reduced inputs among farmers. Our results suggest that many farmers interested in PFP were not planning to alter their production system to achieve PFP. Instead of expecting or hoping to 'get lucky' with a situation that allows for pesticide reduction, farmers can increase the likelihood of successful pesticide reduction by instituting practices that result in more robust cropping systems (Van Acker et al., 2002).

PFP in the Context of Sustainable Agriculture

It is important to consider the overall sustainability of a cropping system that includes PFP crops. One important question in this regard is whether or not PFP actually results in a reduction of pesticide use. Bostrom and Fogelfors (2002b) found that, in a continuous spring cereal rotation, excluding herbicide every 2 years with no other control measures was detrimental compared to applying half rates every year. This was because resulting weed densities were 43% to 178% higher in the exclusion situation, even though the same amount of pesticide was applied. But they are careful to point out that this does not mean that a less regular or less planned exclusion of herbicides will be as detrimental. Given a general lack of advance crop production planning on the part of many farmers, it seems unlikely that farmers would implement a schedule of pesticide use reduction. Instead, appropriate selection of fields on an annual basis is more likely. Lawson (1994) reported similar findings that suggested the annual elimination of herbicide use based on ET's did not result in long-term herbicide reduction compared to the application of half the recommended herbicide rate every year. This was because ET's were exceeded over 80% of the time, and the outcome in terms of economic considerations as well as weed seedbank and seedling densities was less favourable when ET's were used. However, results from our study indicate that farmers did not experience problems with weed densities the year following PFP and do not expect to increase future pesticide use as a result of growing a certifiable PFP crop. Only moderate increases in weed densities, and management to ensure competitiveness of the cropping system, may be responsible for the minimal impact of residual weed densities in our study. This outcome has been suggested by Légerè et al. (1996), Bostrom and Fogelfors (2002a), and Buhler (1999b).

Another important consideration is whether or not agronomic practices used to substitute for pesticide use have negative environmental implications. For example, the production of certified seed may require more intensive pesticide use than farm saved seed. Certified seed is promoted as important for the production of a clean, competitive crop; however, certified seed may not be necessary if farmers ensure that farm-save seed is cleaned of weed seeds, and has a large average seed size as well as good germination and vigour. The use of stubble burning to reduce disease pressure is another non-chemical pest management practice that has a negative impact on the environment by reducing organic matter return to the soil. However, this practice has largely been discredited as an effective method of disease control.

A more important substitution of a non-chemical practice for pesticide use is the replacement of herbicide use with tillage. This study demonstrated the existence of a trade-off between the use of herbicides and tillage. This trade-off is crucial to the discussion of long-term sustainability of pesticide use reduction. The environmental implications of tillage in terms of erosion and depletion of organic matter are significant; therefore a substitution of tillage for herbicide use is not environmentally benign. The use of indices to quantify tillage and herbicide use would be useful in determining the significance of this trade-off. However, no such index was used in this study because there are no widely accepted (or published) indices, and there is a need for further information on those that are available. Thomas and Leeson (2001) discuss the options and difficulties for developing such indices and found that different indices ranked the same production systems differently. However, they also demonstrated that some high input systems use high levels of both tillage and herbicide, so herbicide use does not necessarily substitute for tillage but may be used in addition to it. It was found that a reduced-input, diversified annual and perennial cropping system had the least overall use of inputs (herbicide + tillage) compared to high input or organic systems. Holm et al. (2002) found that net returns for a low herbicide, zero-tillage system in Saskatchewan were similar to zero-tillage systems using higher levels of herbicides, and both zero-tillage systems had higher net returns than tilled systems. Kuepper (2001) and Lockeretz et al. (1981) indicated high support for soil conservation among organic farmers; however, comparative studies of organic and conventional agriculture tend not to directly address this concern. In particular, European literature is generally more focussed on issues of biodiversity and soil fertility than soil conservation (e.g. Mäder et al., 2002). While it is possible to farm organically while implementing excellent soil conservation practices (Kuepper, 2001), and many organic farmers do so, this study supports the idea that an intermediate strategy like PFP may lead to higher actual use of reduced tillage than true organic production.

The long-term sustainability of PFP can also be addressed by considering its impact on the economic viability of farms. Farmers involved in this study were generally satisfied financially with the outcome of PFP, regardless of the current lack of a premium. This may be due to appropriate field selection for PFP. Financial risk associated with crop production is a critical consideration for farmers, especially given the current low level of government subsidies in Canada and high level in the US and EU. Input reduction is a means to reduce risk, as there is less capital outlay required to produce a crop. This may be achieved through diversification to create a cropping system that is robust against pests. Not all diversification is as effective in promoting input use reduction. 'Diversification' that results in the addition of a crop with similar lifecycle characteristics and pests to current crops will not make the cropping system significantly more robust. In addition, not all diversification is appropriate, given the scale, equipment, and skills of a given farm operation. Olson and Francis (1995) argue that diversification must be complementary to the rest of the farm. Diversification of existing crop production practices is possible and may be more complementary than diversifying into entirely new crop types. For example, forage production can be diversified through the use of new forage species (particularly by increasing the use of forages other than alfalfa, which is dominant in this region), self-seeding annual legume species, or annual forages (Entz et al., 2002). Subsistence farmers, who have limited reliance on agrichemical inputs, use a range of risk reduction strategies such as staggered planting, intercropping, and the growing of multiple varieties to ensure complete crop failure does not occur (Parrott and Marsden, 2002). These risk- and input-reduction strategies may also be worth considering in Western Canada.

The trend toward specialization of farms had led to a specialization of skills amongst individual farmers. In order to capitalize on the benefits of diversification, new, co-operative arrangements between farmers may be necessary. The production of forages without livestock on a given farm may be made possible by arranging buyers and equipment sharing among neighbouring farms. However, given the current decline in significance of co-operative ventures among Western Canadian farmers, there may be limited support for co-operative activities.

Several authors have argued that sustainable agriculture is a process and that rigid rules to achieve it are counter to the inherent need for flexibility in dealing with biological systems (El-Swaify, 2000; Schaller, 1990; Rigby and Caceres, 2001). Specific regulations have a very important role to play as part of a certification system leading to consumer confidence in, and successful marketing of, PFP products. In addition, the flexible nature of PFP may lead to uncertainty over volumes of certifiable grain produced, which can seriously limit the pursuit of marketing opportunities (Brenda Tjaden Lepp, pers. comm.). However, it was apparent during the course of the project that many farmers were interested in reducing pesticide use whether or not they met PFP guidelines. This demonstrates the existence of a group of farmers who are approaching pesticide reduction from a diversity of approaches. In the development of a strategy such as PFP, it is important to ensure that promotion of the concept does not discourage farmers' innovations with respect to other pesticide reduction frameworks. Some farmers have reacted to intermediate strategies by implying that such approaches are promoted as excessively inventive or ground-breaking, when farmers see the guidelines as a no different from their own rational decision-making processes (de Buck et al., 2000). As a food product marketing strategy, it may be important to promote PFP as a new and innovative concept. However, it is important that PFP or other strategies like it do not alienate farmers by overshadowing their existing pesticide use reduction approaches or implying that the new approach is the singularly superior approach to pesticide use reduction. Instead, PFP can act as a validation of the approaches that some farmers are already using by bringing increased attention to, and support for, such strategies. On the other hand, PFP can demonstrate to farmers who have not implemented significant pesticide use reduction that the guidelines for such a program can be relatively simple and attainable. PFP should be considered a success if farmers become more aware of opportunities for reducing input use, and if media attention helps to shift attitudes among farmers in this regard.

PFP is a particular way of approaching IPM and encouraging its adoption on farms. The recent movement away from traditional technology adoption theory suggests that re-invention of innovations is a positive development and may make them more likely to be retained in the long-term. There is already some evidence of re-invention of PFP. Some of these adaptations of PFP guidelines existed prior to farmers' introduction to PFP. These farmers used PFP as a label for their existing pesticide use reduction activities. Other examples of re-invention of the concept include the use of seed treatments, in-crop fungicides, or residual herbicides while continuing to eliminate in-crop pesticide use. Some farmers are also instituting reductions in fertilizer use in addition to PFP attempts.

The Value and Challenges of Participatory Research

The exploration of participatory research in this study was a valuable one. Many authors have called for a diversification of approaches to sustainable agriculture, particularly by using interdisciplinary approaches. The integration of agronomy with other disciplines, particularly social science disciplines, broadens the perspective in which pesticide reduction is considered, and is a more realistic approach to agricultural development.

Participatory research in agriculture is on the increase. The importance of farmers' perceptions is being recognized and more common in agronomic research (e.g. Liebig and Doran, 1996). However, agronomic research that directly involves farmers is still relatively rare. Farmer decision-making is complex, but it is the way in which crop production decisions are really made. It therefore is a critically important context for any agronomic research. Parrott and Marsden (2002) argue that there are many synergies that arise when farmer and researcher expertise are combined.

As an educational opportunity, participatory, on farm research is particularly valuable for students without a farm background, as it results in exposure to a wide range of farm types as well as rural culture. This is particularly important as the Canadian population becomes increasingly urbanized and the proportion of students with urban backgrounds pursuing agricultural education increases. It also highlights the educational benefits that would be generated if universities were more involved in extension activities than they currently are.

The exploration of PFP via a participatory strategy was valuable for both researchers and farmers. Participation in this study resulted in more opportunity for participants to be aware of the outcome of other farmers' attempts to implement PFP, than if pesticide use reduction was pursued outside of a specific project. Rogers (1983) suggests that such 'observation' may contribute to the likelihood that a practice will be fully adopted. For researchers, it provided an opportunity to assess the potential of PFP without a time lag of several years of testing on experimental stations. The collaboration of farmers and researchers has also led to the continuation of PFP beyond the confines of the on-farm research project. The interest generated by the on-farm research project has recently resulted in an increasingly active farmers' co-op and associated marketing opportunities.

There are also challenges that arise in conducting participatory research. For researchers with no background in social sciences, a shift to this type of research can be intimidating and frustrating. Working with farmers can be unpredictable, as they can withdraw from the project at any time. For example, relying on farmer-provided information in this study led to challenges in terms of ensuring that fields met regulations for inclusion in the project. Some farmers volunteered for the project indicating that they met all the requirements for PFP, but later examination of records showed that a residual herbicide or seed treatment had been used, disqualifying the field for certification. It is therefore advisable to involve more farmers in a project than are required for analysis. Another issue that arose was the tendency for misunderstanding between farmers and researchers in terms of the specific regulations surrounding PFP. Several farmers interpreted 'pesticides' to mean only insecticides, and therefore thought they were practicing PFP even though they used herbicides. This highlights the need for researchers to be aware of differences in academic and everyday language.

The nature of PFP as a yearly opt-in or opt-out concept meant that there were high levels of uncertainty beginning the project, in terms of how many would volunteer, from which regions, and what proportion of fields would achieve PFP certification. As it happened, the outcome resulted in an adequate number of fields and farmers in each group for statistical analysis. However, analysis would have had to be different if the majority of fields were certifiable, or not certifiable, as the number of farmers in each group may not have been large enough to allow for statistical comparisons between groups. Relying on farmers to volunteer for this project also posed challenges. Some farmers waited until late in the growing season to volunteer for the project. This, combined with logistical difficulties associated with the regional distribution of participants meant that exact timings for weed density counts, biomass assessments, or any other time-sensitive agronomic data would have been difficult. Another challenge in terms of analysis was the high frequency missing information resulting from relying on farmers' records. This may preclude the possibility of using multivariate or other techniques that require a complete matrix of data to be available for analysis. Indeed, this was a major consideration in determining how to analyze information in this study. A high degree of flexibility in the approach to analysis was required.

Several authors have argued that participatory research should be qualified as to its degree, in order to avoid superficial use of the term (Pretty, 1995; Rocheleau, 1994). While this study involved farmers more actively than has traditionally been common in this topic area, there is much room for increasing the participatory nature of agronomic research. This study did have guidance from the farmer steering committee responsible for PFP research; however, many farmers participating in the project did not directly participate in the guiding of the project. A more truly participatory study would include farmers in the analysis and discussion of results, and would have provided more opportunity for interaction between farmers involved in the study. An even further progression of farmer participation in research would be for farmers to initiate and conduct their own research, as suggested by Pretty (1995) and demonstrated by Exner et al. (1996).

Future Research

While the rhetoric of sustainability is common among governmental and other funding agencies, in practice it can be difficult to obtain funding for projects such as this one. Currently, public funding is often dependent on obtaining matching funds from industry sources. Studies with no apparent value to agro-industrial interests will not attract` funds from both industry and matching funds from governments. There has been a general trend toward reduced public funding for agricultural research (Parrot and Marsden, 2002). Given limited funds for agricultural research, requirements for matching industry funds should be removed in order to focus public dollars on research that is truly in the public interest. Research regarding reduced pesticide use is, by its nature, of public interest because the externalities associated with pesticide use affect the general public. In addition, Gerlter (1992) suggests that given a farm crisis that shows no signs of abating, attitudes about shifting to alternative agriculture may be more supportive than in the past. Therefore, research regarding pesticide use reduction may have the potential to be more widely adopted among farmers than previously thought possible.

While research regarding economic thresholds and decision-support systems is valuable in determining which fields are best suited to pesticide use reduction in a given year, it is apparent that without such academically-derived guidelines, the majority of farmers in this project were satisfied with their own decision-making abilities regarding pesticide use. While it may be argued that the existence of the on-farm research project may have encouraged farmers to retain fields for PFP to see what the results would be, farmers were explicitly told that the goal of the project was simply to observe their crop production decisions and not to influence them. A more pressing need than decision support systems is for research and extension that demonstrates ways in which cropping systems can be managed to allow for regular reductions in pesticide use. It is also crucial that combinations of non-chemical pest management practices are explored as it is a combination of strategies that will be required to successfully and consistently reduce farmers' reliance on pesticides. Most alternative practices, even direct ones such as mechanical weed control, do not have the high efficacy of herbicides. The expectation that substitution of simple, single cultural practices for pesticide use to be as effective as chemical control is probably unreasonable in most cases. In this study, assessment of non-chemical management practices focussed primarily on the use of single management practices. A more realistic approach to assessing on-farm use of non-chemical practices would be to directly assess the package of practices in use on a particular farm. This would involve a more thorough understanding of the management of individual farm operations. The use of paired farms located in the same region but with different management practices or philosophies (as used by du Croix-Sissons et al. (2000) and Liebig and Doran (1999b)) may be useful in this regard. It would also be useful to observe the practices of farmers interested in PFP over a longer period of time in order to assess the frequency with which PFP is implemented on the same field and to what degree its use is rotated throughout the farm. This would add to an assessment of the ability of PFP to reduce long-term pesticide use over large areas of cropland.

It would also be advantageous to explore reduced-input strategies other than PFP, particularly ones that fill in the gaps between existing strategies and move away from strictly defined frameworks that limit creativity in developing strategies for economically and environmentally sustainable agriculture. This study has shown the potential of a simple pesticide reduction framework to generate interest from farmers, while at the same time, interest in PFP-labelled food products has increased (Magnussen, 2002). It is likely that any widespread, easily marketed pesticide use reduction strategy needs to be simple for both farmers and consumers, and rigorously certified. This approach has the potential to make a large impact in terms of pesticide use reduction on a much larger number of farms and fields than has previously occurred. However, it is also important to support the generation and dissemination of farmers' knowledge regarding methods for reducing overall dependency on pesticides, regardless of a particular framework. Farmers independently, or in groups, should be encouraged to undertake their own site-specific investigations into methods that allow for reduced pesticide use. More research that documents and facilitates farmers' investigations into these methods would be useful. This approach would integrate research and extension and provide a way to encourage, value, and disseminate farmers' knowledge of cropping systems management that can allow for reductions in input use.

In pest management disciplines, and in weed science in particular, there is a need for basic research to increase knowledge about the ecology and biology of pests. In particular, longer-term studies with more detailed examination of weed population dynamics would add credibility to this study's finding that residual weed populations in fields selected by farmers for PFP were not detrimental.

In this study, deciding on the appropriate use of controls and obtaining comparative data was a challenge. The availability of Census of Agriculture data and the Weed Survey Series, particularly management information, was extremely valuable. It would have been difficult to undertake an assessment of PFP in the context of what is typical in Manitoba without this information. However, depending on the timing, such information may not always be current. Both the Census of Agriculture and the Weed Surveys are conducted approximately every 5 years. Any less frequent availability of comparative information could seriously restrict the ability of studies like this to situate farmers' practices in the context of typical practices. An up-to date record of what comparative data is available would be useful for future research of this sort. Such a compilation might also promote the standardization of data collection and reporting, so that comparisons across studies are made easier. However, this may become less likely as the publicly funded institutions that would likely undertake such a compilation are threatened with reduced funding.

Conclusions

Approaches to pesticide reduction that are intermediate to conventional and organic cropping systems have been described as a 'third way', a 'stepping stone' to organic production, or a 'halfway house' between the two concepts. There is currently a proliferation of such intermediate strategies (Kane et al., 2000), of which the most widely known is IPM. Given the increasing gap between organic and conventional production in terms of organic certification requirements, there will likely be increasing interest in developing intermediate strategies that are of interest to farmers and which meet consumer demand for food produced with reduced use of agrichemicals.

This study demonstrated the ability of Manitoba farmers to eliminate pesticides from crops for a full growing season. A high proportion of farmers interested in reducing their pesticide use were able to do so. Results indicated that farmers who choose fields for pesticide reduction can produce crops with satisfactory yields, grades, residual weed densities, and financial outcomes. This provides evidence that pesticide use is not always necessary for agronomically and economically sound farming. The study also demonstrated the ability of an intermediate strategy like PFP to co-exist with conventional soil conservation practices, and potentially provide an integration of reduced tillage and reduced pesticide use. The participatory nature of the study was valuable in that it allowed for a broader assessment of the issues associated with pesticide use reduction beyond those that could be measured on an experimental station. It also proved to be a valuable learning experience for researchers. The administration of an on-farm research project by university researchers also likely increased the media attention surrounding PFP and led to greater awareness of the concept among farmers and greater dissemination of research results. There is also evidence of the continued use of PFP beyond the scope of this project.

From a marketing perspective, the challenge of an intermediate pesticide use reduction strategy is to develop a concept that is easily implemented by farmers and which meets the desires of consumers in as simple a manner as possible. Complexity and inconsistency in the implementation of IPM is cited as being responsible for the lack of widespread adoption of IPM principles (de Buck et al., 2001; Kogan, 1998). This also leads to confusion on the part of consumers in terms of its meaning and value. A concept like PFP is based on IPM principles but with more straightforward guidelines for both farmers and consumers. This means that there is less opportunity for inconsistency in the implementation of PFP or misunderstanding of PFP as a marketing strategy. PFP shows potential to be successfully adopted by mainstream farmers in Manitoba and therefore deserves further exploration in terms of cropping systems management and marketing strategies that may improve its success.

Without a marketing outlet however, there is less need for strictly defined pesticide use reduction strategies. Many farmers involved in the PFP project were interested in a range of input reduction strategies that do not fit with any particular label. These farmers are adopting systems to suit their specific (often economic) needs and then sell their production into mainstream markets. This situation is also beneficial as it leads farmers to knowledge-based farming that is more economically and environmentally sustainable.

Exposure to PFP may also lead farmers recognize the potential of intermediate strategies and to develop other intermediate crop production and marketing frameworks. Regardless of the future significance of PFP marketing opportunities, PFP should be considered a success if it contributes to the process of moving toward pesticide use reduction. If farmers interested in PFP are drawn to consider, discuss, and continue to experiment with knowledge-based farming in order to reduce pesticide use, then PFP will have contributed to improving the sustainability of agriculture in Western Canada.

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APPENDIX A

Herbicide Use Restrictions for Certified Pesticide Free Production

Herbicides that can be applied as a preemergent burnoff: Amitrol 240 (when used at rates recommended for preemergent burnoff), glyphosate products, Gramoxone, Pardner.

Herbicides that can be applied in the fall prior to a PFP crop: 2,4-D, MCPA, Rustler, plus those listed above.

Herbicides that can be applied in the year prior to a PFP crop: 2,4-DB, Achieve 80DG, Achieve Extra Gold, Assure II, Avenge, Banvel II (< 0.25 L/ac applied prior to September 1 of the previous year), Basagran, Buctril M, Champion Extra, Champion Plus, Compas, Dichlorprop + 2,4-D, Dual II, DyVel, DyVel DS, Eptam, Eradicane, Express Pack, Freedom Gold, Frontier, Frontline, Fusion, Gramoxone, Harmony Total, Hoegrass II/284, Horizon/Horizon BTM, Kerb, Laddock, Laser DF, Liberty, Linuron, MCPB + MCPA, Mecoprop, Pardner, Pea Pack, Pinnacle, Poast Ultra, PrePass, Puma, Puma Super Refine Extra, Reglone/Reward, Select, Sencor/Evict, Stampede EDF, Target/Sward, Thumper, Triumph Plus, Venture, plus those listed above.

Herbicides that can be applied no less than 2 years prior to a PFP crop: Absolute, Accent, Accord, Assert, Atrazine, Attain, Avadex, Curtail, Eclipse, Edge, Everest, Flaxmax Ultra, Fortress, K2, Lontrel, Muster, Muster Gold/II, Odyssey, Prestige, Prevail, Primextra Light, Prism, Pursuit, Reflex, Simazine, Spectrum, Sundance, trifluralin products, Trophy, Ultim, Velpar.

Herbicides that can be applied no less than 4 years prior to a PFP crop: Ally, Amber.

APPENDIX B

Post-Harvest Questionnaire

Part A. Agronomic questions:

1. a. What PFP crop did you grow or attempt to grow this year?____________________
   b. Which variety?____________________________
   c. What is the legal land description of the field?__________________________
   d. Did you use a seed treatment? ☐ **Yes** ☐ **No**

2. a. Were you able to leave the crop unsprayed for the entire season? ☐ **Yes** ☐ **No**

   IF YES:

   b. How satisfied were you with your attempt at producing a PFP crop?

   ☐ Good ☐ Fair ☐ Poor

   IF NO:

   c. What weed/disease/insect pest(s) required control(s)?____________________

   d. What product(s) did you spray on the field to control the problem?__________
   ____

3. What was the source of your seed for the PFP field?

   ☐ Home grown - cleaned ☐ Home grown - not cleaned ☐ Certified seed

4. Which implement did you use to seed the PFP crop?__________________________
   ____
   ____

5. What type and width of opener did you use to seed the PFP crop?________________
   ____
   ____

6. When did you seed the PFP crop? Month__________ Day______________

7. What seeding rate did you use? _______________bu/ac OR _________lbs/ac

8. What depth did you seed the crop?___________________ inches

9. What row spacing did you use?_____________________inches

10. What size was the PFP field? ____________acres

11. Is the land that the PFP crop was grown on: (check one)

☐ owned OR

☐ rented

12. a. Is the PFP field in transition to certified organic? ☐ **Yes** ☐ **No**

<u>IF YES</u>:

b. How many years has the field been in transition (including this year, 2000)?

_________years

13. What was the estimated yield of the PFP field?___________bu/ac OR ________lbs/ac

14. What was the grade of seed harvested from the PFP field?_____________________________

Field History

15. What crop rotation and chemicals (insecticides, fungicides, or herbicides) have you used in this field in the past 5 years?

Year	Crop	Planting date	Chemical 1	Chemical 2	Chemical 3	Chemical 4
1999						
1998						
1997						
1996						
1995						

16. What do you plan to do with this field next year?

- ☐ Another PFP crop
- ☐ Conventionally grown crop
- ☐ Use a cleanup crop for pest problems that became apparent
- ☐ Field is in transition to organic
- ☐ Other____

____

____

Herbicide use history

17. This year (2000), did you use a pre-emergent or pre-plant herbicide on your PFP field?

☐ Yes ☐ No

IF YES, please complete the following:

Name of herbicide				
Rate	☐ **Recommended**	☐ **Higher**	☐ **Lower**	
Level of control	☐ **Excellent**	☐**Good**	☐**Fair**	☐**Poor**

18. Last year (1999), did you use a pre-harvest herbicide on your PFP field?

☐ Yes ☐ No

IF YES, please complete the following:

Name of herbicide				
Rate	☐ **Recommended**	☐ **Higher**	☐ **Lower**	
Level of control	☐ **Excellent**	☐**Good**	☐**Fair**	☐**Poor**

19. Did you use a herbicide on your PFP field after harvest in 1999 (last year)?

☐ Yes ☐ No

IF YES, please complete the following:

Name of herbicide				
Rate	☐ **Recommended**	☐ **Higher**	☐ **Lower**	
Level of control	☐ **Excellent**	☐**Good**	☐**Fair**	☐**Poor**

Tillage practices

20. a. How would you categorize the tillage system on your PFP field?

□ Zero □ Minimum □ Conventional

b. How many years have you been using this tillage system on this field?

__________years

21. Did you till the PFP field after harvest in 1999 (year prior to PFP crop)?

□ **Yes** □ **No**

IF YES: please specify the implements and number of times used

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

(Please be as specific as possible regarding the implement design.)

22. Did you till the PFP field before seeding in the spring of 2000 (this year)?

□ **Yes** □ **No**

IF YES: please specify the implements and number of times used

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

(Please be as specific as possible regarding the implement design.)

23. Did you till the PFP field this fall (2000) after harvest?

□ **Yes** □ **No**

IF YES: please specify the implements and number of times used

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

Implement________________________________Number of times used_________

(Please be as specific as possible regarding the implement design.)

Fertilizer practices

24. Did you apply fertilizer in the fall of 1999 (after harvest last year)?

□ **Yes** □ **No**

IF YES: answer part A or B below - A if you know the actual amount of each nutrient applied, and B if you know the formulation and rate of the product

Part A	**1st application**	**2nd application**
Nitrogen (lb/ac)		
Phosphate (lb/ac)		
Potassium (lb/ac)		
Sulphur (lb/ac)		
Placement (e.g. broadcast, deep or surface banded, injected)		

OR:

Part B	**1st application**	**2nd application**
Formulation (e.g. 21-0-0-24)		
Rate of product applied (e.g. 20lb/ac)		
Placement (e.g. broadcast, deep or surface banded, injected)		

Fertilizer practices continued

25. Did you apply fertilizer before seeding in 2000? □ **Yes** □ **No**

IF YES: answer part A or B below - A if you know the actual amount of each nutrient applied, and B if you know the formulation and rate of the product.

Part A	**1st application**	**2nd application**
Nitrogen (lb/ac)		
Phosphate (lb/ac)		
Potassium (lb/ac)		
Sulphur (lb/ac)		
Placement (e.g. broadcast, deep or surface banded, injected)		

OR:

Part B	**1st application**	**2nd application**
Formulation (e.g. 21-0-0-24)		
Rate of product applied (e.g. 20lb/ac)		
Placement (e.g. broadcast, deep or surface banded, injected)		

Fertilizer practices continued

26. Did you apply fertilizer at seeding in 2000? ☐ Yes ☐ No

IF YES: answer part A or B below - A if you know the actual amount of each nutrient applied, and B if you know the formulation and rate of the product.

Part A	**1st application**	**2nd application**
Nitrogen (lb/ac)		
Phosphate (lb/ac)		
Potassium (lb/ac)		
Sulphur (lb/ac)		
Placement (e.g. with seed, side banded, midrow banded)		

OR:

Part B	**1st application**	**2nd application**
Formulation (e.g. 21-0-0-24)		
Rate of product applied (e.g. 20lb/ac)		
Placement (e.g. with seed, side banded, midrow banded)		

Harvest practices

For the crop grown previously to the PFP crop (that is, the crop grown on the same field in 1999), please provide details about harvest practices.

27. a. Was the crop swathed? ☐ **Yes** ☐ **No**

IF YES:

b. Crop stage at swathing____

c. Date of swathing____

d. Date of harvest: Month________ Day________

IF NO:

e. Date of direct harvest: Month________ Day________

f. Crop stage at time of direct harvest________________________________

28. Was the field burned after harvest last year, or this spring before seeding?
☐ **Yes** ☐ **No**

29. a. Have you used a chaff cart as part of your harvesting procedures on the PFP field?
☐ **Yes** ☐ **No**
b. IF YES, for how many years? ________ years

Part B. Demographic Information

The following questions are designed to provide some information about your farm operation in order to determine what factors besides agronomic practices might influence the success of pesticide-free crop production. The results will be helpful in determining which producers are most likely to be interested in PFP and whether or not this system has the potential to be widely adopted. All information will be kept confidential.

1. How many acres do you farm?
   a. ___________owned acres farmed
   b. ___________rented acres farmed
   If land rented varies from year to year, please provide an average.

2. Which of the following crops do you grow on a regular basis? (Check all that apply)

   □ Fall rye □ Alfalfa □ Winter wheat □ Barley
   □ Spring wheat □ Oats □ Flax □ Peas □ Canola
   □ Other (s): ____

3. a. Do you raise livestock? □ **Yes** □ **No**
   b. If yes, please specify the type of animal raised and number of animals_________
   ____
   ____

4. a. Is any part of your farm currently in transition to organic certification?

   □ **Yes** □ **No**

   IF YES:
   b. How many acres of your farm are currently certified?____________
   c. What many acres of your farm are in transition?________________
   d. Why have you decided to convert to organic?___________________
   ____
   e. Do you plan to convert your entire farm to certified organic?
   □ Yes □ No

5. a. Do you normally scout your fields to determine if herbicide/pesticide application is required? ☐ **Yes** ☐ **No**

IF YES:

b. Do you: ☐ scout your fields personally?
☐ use a scout from a dealership?
☐ use a hired (independent) crop scout

6. Have you ever taken a crop scouting course? ☐ **Yes** ☐ **No**

7. Are you a certified seed grower? ☐ **Yes** ☐ **No**

8. How many years have you been farming? __________ years

9. How many years has your family been farming? __________ years

10. a. Do the you work off the farm? ☐ **Yes** ☐ **No**

b. If yes, is the work: ☐ seasonal full time
☐ seasonal part time (how many hours per week? _______)
☐ full time year round
☐ part time year round (how many hours per week? _______)

11. Do you belong to any producer groups or community organizations? Please list:____
____
____
____

12. How many people are involved in your farming operation?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 or more

13. How likely is it that your farm will remain within your family for the foreseeable future?
☐ Very likely ☐ Somewhat likely ☐ Not likely

Experience with PFP

The following questions are about the experience with PFP you had this year and your opinions on what could improve it.

14. Why are you interested in Pesticide Free Production?

Please **circle** the number that shows how important each of the following is to you, with 1 as not important at all and 5 as very important.

Marketing opportunities	1 2 3 4 5
Concerned about the environment	1 2 3 4 5
Reducing herbicide resistance in weeds	1 2 3 4 5
Reducing input costs	1 2 3 4 5
Reducing my own and my family's exposure to pesticides	1 2 3 4 5
Other (please specify)	1 2 3 4 5

15. a. Would you try PFP again? □ **Yes** □ **No**

b. IF YES: How long would you wait before trying PFP again on the same field as this year?__________ years

16. Would you plan to incorporate PFP crops into a regular rotation?

□ Yes, but only if a marketing premium was available

□ Yes, I would consider it even without a premium

□ No

17. Why would/would't you try PFP again?______________________________

____

____

____

____

____

18. What crop would you use if you were to attempt PFP again?

☐ Fall rye ☐ Alfalfa ☐ Winter wheat ☐ Barley

☐ Spring wheat ☐ Oats ☐ Flax ☐ Peas ☐ Canola

☐ Other (s): ______________________________

19. a. Have you grown a PFP crop prior to 2000? ☐ **Yes** ☐ **No**

b. If yes, what crop did you grow?______________________________

c. If yes, what level of success did you have?

☐ Good ☐ Fair ☐ Poor

20. a. If you were able to produce a PFP crop this year, were you able to find a market for it as a PFP crop? ☐ **Yes** ☐ **No**

b. Where you able to obtain a premium for the PFP grain? ☐ **Yes** ☐ **No**

21. a. Do you think you came out ahead financially by producing a PFP crop rather than producing the crop with the use of pesticides? ☐ **Yes** ☐ **No**

IF YES: was it because of ☐ reduced input costs

☐ marketing premium

☐ both

22. What marketing premium do you think is necessary to make PFP a concept you could implement on a regular basis?

Crop__________________ Premium______________________

Crop__________________ Premium______________________

Crop__________________ Premium______________________

23. New concepts can often be frustrating to put into practice. Did you find that there was a time during the season that you regretted your decision to try PFP?

☐ **Yes** ☐ **No**

Why?____

____

____

24. Why did you choose to try PFP on this field this year?

- ☐ I knew it had been a clean field in past years
- ☐ It looked clean this spring
- ☐ I had been actively preparing the field for a low-input system
- ☐ The spray window was missed
- ☐ Other____

25. a. Did you manage your PFP field differently from conventional fields (apart from not spraying it)? ☐ **Yes** ☐ **No**

IF YES: what were the differences? Please explain:

26. Did you use any non-chemical pest management techniques for the PFP crop?

☐ **Yes** ☐ **No**

IF YES, please list them:

27. If you were to plan to produce a PFP crop in the future, what management strategies would you use?

28. Do you think PFP is an idea that is acceptable to the majority of farmers?

☐ **Yes** ☐ **No**

29. Can you suggest anything that would help you adopt a rotation that included PFP crops?

Opinions of the current agricultural system

30. Listed below are several pairs of contrasting views regarding North American agriculture.

For each pair please indicate which one of the two views you most agree with - the one in the left hand column, or the one in the right-hand column - by circling the appropriate number on the line between them.

1 - strongly agree with view in left-hand column
2 - mildly agree with view in left-hand column
3 - undecided/neutral
4 - mildly agree with view in right-hand column
5 - strongly agree with view in right-hand column

Meeting North American food needs with fewer and fewer farmers is a positive outcome of technological progress.	1 2 3 4 5	Meeting North American food needs with fewer and fewer farmers is a negative outcome of our free market system.
Farmland should be farmed so as to protect the long-term productive capacity of the land, even if this means lower production and profits.	1 2 3 4 5	Farmland should be farmed so as to maximize annual profits, even if this threatens the long-term productive capacity of the land.
High energy use makes North American agriculture vulnerable and should be greatly reduced.	1 2 3 4 5	Large inputs of energy into agriculture should be continued as long as it is profitable to do so.
The primary goal of farmers should be to maximize the productivity, efficiency, and profitability of their farms.	1 2 3 4 5	The primary goal of farmers should be to improve the quality of their products and to enhance the longterm condition of their farms.
The amount of farmland owned by an individual or corporation should NOT be limited, even if the ownership of land becomes much more concentrated than at present.	1 2 3 4 5	The amount of farmland owned by an individual or corporation should be limited in order to encourage land ownership by as many people as possible.
Agricultural scientists and policy-makers should recognize that there are limits to what nature can provide and adjust their expectations accordingly.	1 2 3 4 5	Agricultural scientists and policy-makers should expand efforts to develop biotechnologies and other innovations in order to increase food supplies.
Good farming depends mainly on personal experience and knowledge of the land.	1 2 3 4 5	Good farming depends mainly on applying the findings of modern agricultural science.
The future success of North	1 2 3 4 5	Healthy rural communities are

American agriculture will NOT be affected if rural communities continue to decline.		absolutely essential for North American agriculture's future success.
Small to medium sized farms can best serve North America's agricultural needs.	1 2 3 4 5	Large to very large farms can best serve North America's agricultural needs.
Farm traditions and culture are outdated and of little use in modern agriculture.	1 2 3 4 5	Farm traditions and culture help maintain respect for the land and are essential for good farming.
Farming is first and foremost a business like any other.	1 2 3 4 5	Farming is first of all a way of life and second a business.
Farmers should use primarily natural fertilizers and production methods such as manure, crop rotations, compost, and biological control.	1 2 3 4 5	Farmers should use primarily synthetic fertilizers and pesticides in order to maintain adequate levels of production.
Most people should live in cities and leave farming to those who do it best.	1 2 3 4 5	Many more people should live on farms and in rural areas than do at present.
Modern agriculture is a major cause of ecological problems and must be greatly modified to become ecologically sound.	1 2 3 4 5	Modern agriculture is a minor cause of ecological problems and needs only to be fine-tuned periodically in order to be ecologically sound.
Farmers should only farm as much land as they can personally care for.	1 2 3 4 5	Farmers should farm as much land as they profitably can.
Farms should be specialized in one or at most a few crops.	1 2 3 4 5	Farmers should be diversified and include a large variety of crops.
Soil and water are the source of all life and should therefore be strictly conserved.	1 2 3 4 5	Soil and water are the basic factors of production and should be used so as to maximize production.
Farmers should purchase most of their goods and services just as other consumers do.	1 2 3 4 5	Farmers should produce as many of their own goods and services as possible.
The key to agriculture's future success lies in learning to imitate natural ecosystems and farm in harmony with nature.	1 2 3 4 5	The key to agriculture's future success lies in the continued development of advanced technologies that will overcome nature's limits.
Most farms should specialize in either crops or livestock.	1 2 3 4 5	Most farms should include both crops and livestock.
Production, processing, and marketing of agricultural products is best done at local and regional levels.	1 2 3 4 5	Production, processing, and marketing of agricultural products is best done at national and international levels.
The successful farmer is one who earns enough from farming to enjoy	1 2 3 4 5	The successful farmer is one who truly enjoys farming even if it provides only

an above average standard of living.		a below average standard of living.
Technology should be used to make farm labour more rewarding and enjoyable, but not to replace it.	1 2 3 4 5	Farm labour should be replaced whenever possible by more efficient machines and other technologies.
The abundance and relatively low prices of food in North America are evidence that North American agriculture is the most successful in the world.	1 2 3 4 5	High energy use, soil erosion, water pollution, etc. are evidence that North American agriculture is not nearly as successful as many believe it to be.

31. What is your highest educational level?
    - ☐ Elementary
    - ☐ High school
    - ☐ University/College Diploma
    - ☐ University Degree
    - ☐ Graduate (Masters)
    - ☐ Post-graduate (Ph.D.)

32. What is your current age?

    ☐ under 35 ☐ 35-54 ☐ over 55

33. What is your <u>average NET annual</u> farm income?

    ☐ Under $25,000 ☐ $25,000-50,000 ☐ $50,000-75,000
    ☐ $75,000-100,000 ☐ over $100,000

34. Do you have any other comments about Pesticide Free Production?______________

APPENDIX C

Changes Made to the Post-Harvest Questionnaire in 2001.

Part 1: Agronomic information

1 b. What was the intended end use? Feed, malt, etc____________________

Added after question 6:

Was the crop underseeded to another crop? ☐ **Yes** ☐ **No**

IF YES: Which crop? ______________

Date seeded: Month_______________ Day __________

Addition to question 12:

a. Is the PFP field **certified** organic? ☐ **Yes** ☐ **No**

b. Is the PFP field in **transition to** certified organic? ☐ **Yes** ☐ **No**

IF YES: This year, the field was:

☐ In year 1 of transition

☐ In year 2 of transition

☐ In year 3 of transition

☐ In transition for more than 3 years

Added after question 14:

What is the estimated dockage of the PFP crop?____________________

Changes to question 15:

What crop rotation and pesticides (insecticides, fungicides, or herbicides) have you used in this field in the past 5 years?

Year	Crop	Variety	Planting date	Chemical 1	Chemical 2	Chemical 3	Chemical 4
2000							
31999							
1998							
1997							
1996							

Added after question 16:

Do you plan to grow another PFP crop next year, on a different field? □ **Yes** □ **No**

Added after question 26:

Did you apply fertilizer after seeding in 2001 (this spring)? ☐ **Yes** ☐ **No**

IF YES: answer part A or B below - A if you know the actual amount of each nutrient applied, and B if you know the formulation and rate of the product.

Part A	**1st application**	**2nd application**
Nitrogen (lb/ac)		
Phosphate (lb/ac)		
Potassium (lb/ac)		
Sulphur (lb/ac)		
Placement		

OR:

Part B	**1st application**	**2nd application**
Formulation (e.g. 21-0-0-24)		
Rate of product applied (e.g. 20lb/ac)		
Placement		

Part 2: Demographic information

Added after question 2:

Which of the following crops did you grow **this year**?

☐ Fall rye ☐ Alfalfa ☐ Winter wheat ☐ Barley
☐ Spring wheat ☐ Oats ☐ Flax ☐ Peas ☐ Canola
☐ Other (s): ____________________

Changes to question 14:

a. Have you ever considered converting any part of your farm to organic production?

☐ **Yes** ☐ **No**

IF YES, continue on to part b. IF NO, go to question 6.

b. Is any part of your farm currently in transition to organic certification?

☐ **Yes** ☐ **No**

IF YES:

c. How many acres of your farm are currently certified?__________ ac

d. How many acres of your farm are in transition?__________ ac

e. Why have you decided to convert to organic?__________

____

____

f. Do you plan to convert your entire farm to organic? ☐ **Yes** ☐ **No**

Changes to question 15:

Would you try PFP again? ☐ **Yes** ☐ **No**

IF YES: How long would you wait before trying PFP again on the **same field** as

☐ next year ☐ in 2 years ☐ in 3 years
☐ in 4 years ☐ in more than 4 years ☐ Unsure

IF YES: How long would you wait before trying PFP on **another field**?

☐ next year ☐ in 2 years ☐ in 3 years
☐ in 4 years ☐ in more than 4 years ☐ Unsure

Changes to question 22:

What marketing premium do you think is necessary to make PFP a concept you could implement on a regular basis? Please **check the box** of the premium you think is necessary to receive for PFP crops.

Crop	0-5%	6-10%	11-15%	15-20%	21-25%	26-30%	Over 30%
Spring wheat							
Canola							
Barley							
Oats							
Flax							

Added after question 24:

Would you tend to describe yourself as an early adopter of new agricultural technologies?

☐ Yes ☐ Somewhat ☐ No

Changes to question 27:

If you were to plan to produce a PFP crop in the future, what management strategies would you use? Check any that apply:

☐ Would **NOT** plan in advance for a PFP crop
☐ Late seeding
☐ Increased seeding rates
☐ Early seeding
☐ Narrow row spacing
☐ Pre-emergent glyphosate
☐ Post emergent (in crop) harrowing
☐ Post harvest glyphosate previous year
☐ Spray or mow weed patches
☐ Low soil disturbance
☐ Incorporate livestock into the farm system
☐ Use rotation to manage pest problems
☐ Use forages in rotation
☐ Use alfalfa in rotation
☐ Use summerfallow
☐ Band fertilizer rather than broadcast
☐ Fertilize the crop well
☐ Spray field well in previous years
☐ Chaff collection
☐ Grow a companion crop for pest/weed suppression
☐ Select competitive crops or varieties for pest/weed suppression
☐ Other:____

Which of these practices would you say are the most important to produce a PFP crop?

1. ______________________________
2. ______________________________
3. ______________________________

Added after question 27:

When you **decided this spring** to try to grow a PFP crop, did you think that:

☐ You probably would have to spray the crop

☐ You probably would **NOT** have to spray the crop

☐ You would leave the crop unsprayed regardless of the pest/weed pressure

☐Other:____

____

Do you think that you will have to increase your pesticide use in future years as a result of having grown a PFP crop this year? ☐ **Yes** ☐ **No**

Compared to other farmers in your area, are you:

☐ More tolerant of weeds in your fields

☐ No different in your tolerance of weeds in your fields

☐ Less tolerant of weeds in your fields

Added after question 28:

35. Have you ever had herbicide resistant weeds on you farm? ☐ **Yes** ☐ **No**

IF YES: Weed__________________Resistant to:____________________

APPENDIX D

Questions omitted from the post-harvest survey for farmers who were repeat participants in 2001

Part 2: Demographic questions

1. How many acres do you farm?
   a. ___________owned acres farmed
   b. ___________rented acres farmed
   If land rented varies from year to year, please provide an average.

2. Which of the following crops do you grow **on a regular basis**? (Check all that apply)
   ☐ Fall rye ☐ Alfalfa ☐ Winter wheat ☐ Barley
   ☐ Spring wheat ☐ Oats ☐ Flax ☐ Peas ☐ Canola
   ☐ Other (s): ____

4. a. Do you raise livestock? ☐ **Yes** ☐ **No**
   b. If yes, please specify the type of animal raised and number of animals____
   ____

5. a. Have you ever considered converting any part of your farm to organic production?
   ☐ **Yes** ☐ **No**
   IF YES, continue on to part b. IF NO, go to question 6.
   b. Is any part of your farm currently in transition to organic certification?
   ☐ **Yes** ☐ **No**

   IF YES:
   c. How many acres of your farm are currently certified?_____________ac
   d. How many acres of your farm are in transition?__________________ac
   e. Why have you decided to convert to organic?____________________
   ____
   ____
   f. Do you plan to convert your entire farm to organic? ☐ **Yes** ☐ **No**

6. Do you normally scout your fields to determine if herbicide/pesticide application is required? ☐ **Yes** ☐ **No**

IF YES:

Do you: ☐ scout your fields personally?
☐ use a scout from a dealership?
☐ use a hired (independent) crop scout

7. Have you ever taken a crop scouting course? ☐ **Yes** ☐ **No**

8. Are you a certified seed grower? ☐ **Yes** ☐ **No**

9. How many years have you been farming? __________ years

10. How many years has your family been farming? __________ years

11. a. Do you work off the farm? ☐ **Yes** ☐ **No**
    b. If yes, is the work: ☐ seasonal full time
    ☐ seasonal part time (how many hours per week? _______)
    ☐ full time year round
    ☐ part time year round (how many hours per week? _______)

12. Do you belong to any producer groups or community organizations? Please list:____
____
____
____

13. How many people are involved in your farming operation?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 or more

14. How likely is it that your farm will remain within your family for the foreseeable future?
☐ Very likely ☐ Somewhat likely ☐ Not likely

19. What crop would you use if you were to attempt PFP again?
☐ Fall rye ☐ Alfalfa ☐ Winter wheat ☐ Barley
☐ Spring wheat ☐ Oats ☐ Flax ☐ Peas ☐ Canola
☐ Other (s): ________________________________

20. a. Have you grown a PFP crop prior to 2001? ☐ **Yes** ☐ **No**
    b. If yes, what crop did you grow?________________________________
    c. If yes, what level of success did you have?

☐ Good ☐ Fair ☐ Poor

21. a. If you were able to produce a PFP crop this year, were you able to find a market for it as a PFP crop? ☐ **Yes** ☐ **No**
b. Where you able to obtain a premium for the PFP grain? ☐ **Yes** ☐ **No**

34. Do you think PFP is an idea that is acceptable to the majority of farmers?
☐ **Yes** ☐ **No**

37. Listed below are several pairs of contrasting views regarding North American agriculture.

For each pair please indicate which one of the two views you most agree with - the one in the left hand column, or the one in the right-hand column - by circling the appropriate number on the line between them.

1 - strongly agree with view in left-hand column
2 - mildly agree with view in left-hand column
3 - undecided/neutral
4 - mildly agree with view in right-hand column
5 - strongly agree with view in right-hand column

Meeting North American food needs with fewer and fewer farmers is a positive outcome of technological progress.	1 2 3 4 5	Meeting North American food needs with fewer and fewer farmers is a negative outcome of our free market system.
Farmland should be farmed so as to protect the long-term productive capacity of the land, even if this means lower production and profits.	1 2 3 4 5	Farmland should be farmed so as to maximize annual profits, even if this threatens the long-term productive capacity of the land.
High energy use makes North American agriculture vulnerable and should be greatly reduced.	1 2 3 4 5	Large inputs of energy into agriculture should be continued as long as it is profitable to do so.
The primary goal of farmers should be to maximize the productivity, efficiency, and profitability of their farms.	1 2 3 4 5	The primary goal of farmers should be to improve the quality of their products and to enhance the longterm condition of their farms.
The amount of farmland owned by an individual or corporation should NOT be limited, even if the ownership of land becomes much more concentrated than at present.	1 2 3 4 5	The amount of farmland owned by an individual or corporation should be limited in order to encourage land ownership by as many people as possible.
Agricultural scientists and policy-makers should recognize that there are limits to what nature can provide	1 2 3 4 5	Agricultural scientists and policy-makers should expand efforts to develop biotechnologies and other

and adjust their expectations accordingly.		innovations in order to increase food supplies.
Good farming depends mainly on personal experience and knowledge of the land.	1 2 3 4 5	Good farming depends mainly on applying the findings of modern agricultural science.
The future success of North American agriculture will NOT be affected if rural communities continue to decline.	1 2 3 4 5	Healthy rural communities are absolutely essential for North American agriculture's future success.
Small to medium sized farms can best serve North America's agricultural needs.	1 2 3 4 5	Large to very large farms can best serve North America's agricultural needs.
Farm traditions and culture are outdated and of little use in modern agriculture.	1 2 3 4 5	Farm traditions and culture help maintain respect for the land and are essential for good farming.
Farming is first and foremost a business like any other.	1 2 3 4 5	Farming is first of all a way of life and second a business.
Farmers should use primarily natural fertilizers and production methods such as manure, crop rotations, compost, and biological control.	1 2 3 4 5	Farmers should use primarily synthetic fertilizers and pesticides in order to maintain adequate levels of production.
Most people should live in cities and leave farming to those who do it best.	1 2 3 4 5	Many more people should live on farms and in rural areas than do at present.
Modern agriculture is a major cause of ecological problems and must be greatly modified to become ecologically sound.	1 2 3 4 5	Modern agriculture is a minor cause of ecological problems and needs only to be fine-tuned periodically in order to be ecologically sound.
Farmers should only farm as much land as they can personally care for.	1 2 3 4 5	Farmers should farm as much land as they profitably can.
Farms should be specialized in one or at most a few crops.	1 2 3 4 5	Farmers should be diversified and include a large variety of crops.
Soil and water are the source of all life and should therefore be strictly conserved.	1 2 3 4 5	Soil and water are the basic factors of production and should be used so as to maximize production.
Farmers should purchase most of their goods and services just as other consumers do.	1 2 3 4 5	Farmers should produce as many of their own goods and services as possible.
The key to agriculture's future success lies in learning to imitate natural ecosystems and farm in harmony with nature.	1 2 3 4 5	The key to agriculture's future success lies in the continued development of advanced technologies that will overcome nature's limits.
Most farms should specialize in		Most farms should include both crops

either crops or livestock.	1 2 3 4 5	and livestock.
Production, processing, and marketing of agricultural products is best done at local and regional levels.	1 2 3 4 5	Production, processing, and marketing of agricultural products is best done at national and international levels.
The successful farmer is one who earns enough from farming to enjoy an above average standard of living.	1 2 3 4 5	The successful farmer is one who truly enjoys farming even if it provides only a below average standard of living.
Technology should be used to make farm labour more rewarding and enjoyable, but not to replace it.	1 2 3 4 5	Farm labour should be replaced whenever possible by more efficient machines and other technologies.
The abundance and relatively low prices of food in North America are evidence that North American agriculture is the most successful in the world.	1 2 3 4 5	High energy use, soil erosion, water pollution, etc. are evidence that North American agriculture is not nearly as successful as many believe it to be.

38. What is your highest educational level?
- ☐ Elementary
- ☐ High school
- ☐ University/College Diploma
- ☐ University Degree
- ☐ Graduate (Masters)
- ☐ Post-graduate (Ph.D.)

39. What is your current age?

☐ under 35 ☐ 35-54 ☐ over 55

40. What is your <u>average NET annual</u> farm income?

☐ Under $25,000 ☐ $25,000-50,000 ☐ $50,000-75,000
☐ $75,000-100,000 ☐ over $100,000

41. Do you have any other comments about Pesticide Free Production?____

APPENDIX E

Follow-up Questionnaire - Farmers with Certifiable PFP Fields Who Participated in 2000.

Name: **Date:**

1. In the field that was PFP last year, what was the weed density like last year (2000, the PFP year)?

☐ none ☐ light ☐ average ☐ heavy ☐ very heavy

2. In the field that was PFP last year, what has the weed density been like this year (2001)?

☐ none ☐ light ☐ average ☐ heavy ☐ very heavy

3. Do you think the weed/pest pressure is higher than it would have been if you had sprayed last year?

4. If yes: Do you think you have to spend more time and/or money controlling an increased pest pressure this year?

5. Do you still think you came out ahead financially with a PFP crop now that you've seen the pest pressure this year? (all farmers with certifiable fields noted that they came out ahead financially in the 2000 post-harvest survey)

6. Do you regret your decision not to spray this field last year? Why or why not?

7. What do you think is the greatest hurdle/impediment to implementing PFP?

8. Did you try to grow a PFP crop this year? If you are not trying PFP this year, why not?

9. Are you still interested in PFP for future years? If no, why not?

APPENDIX F

Baseline Survey of Manitoba Farmers by Ipsos-Reid Corp. (February 2002)

Interviewer:________________________ **Argid (from sample):**____________________

Town:______________________________ **Census Division:**______________________

2001 Producer Comparison Study

Project Number: 1432-06

Draft 5

January 22, 2002

Hello, this is __________ calling from Ipsos-Reid, formerly the Angus Reid Group. We are asking growers if they would participate in a survey concerning their attitudes and opinions about North American agriculture. This study is being sponsored by the University of Manitoba as a project for a student and should only take about 12 to 15 minutes of your time.

SCR-1) Do you make most of the management decisions for the farm?

Yes	Continue to Q.SCR-2
Shared	Continue to Q.SCR-2
No	Ask to speak to that person and repeat intro
Not available	Arrange callback
Not a Farm household	Thank and Terminate

SCR-2) Is now a convenient time to complete this survey?

Yes	Continue to Q.SCR-3
No	Arrange callback

Thank you, please be advised that you have the right to withdraw from this study at any time and or refrain from answering any of the questions. This study has been reviewed and approved by the University of Manitoba, Joint-Faculty Research Ethics Board, and any complaint regarding the procedure may be reported to the Human Ethics Secretariat at 474-7122.

SCR-3) Now to begin the survey. How many acres of seeded cropland did you have this year, that is, in 2001? Please include all seeded acres, that is, those owned, sharecropped, rented, or leased. (INTERVIEWER NOTE: IF GREATER THAN 6,000 CONFIRM AMOUNT WITH RESPONDENT)

____________________________________Acres.

(IF LESS THAN 320 ACRES THANK AND TERMINATE BY SAYING "I'm sorry. We have filled our quota for growers with your size of farm. Thank you for your time.")

Section 1: Opinions of the current agricultural system

1. Next I am going to read you several pairs of contrasting views regarding North American agriculture. For each pair please tell me which of the two views you agree with the most. If you are neutral or not sure please let me know.

INTERVIEWER: READ 1ST STATEMENT ON LEFT, THEN STATEMENT ON RIGHT, THERE IS NO NEED TO ROTATE OR RANDOMIZE.
Which of these views do you agree with the most.

AFTER RESPONDENT HAS SELECTED A STATEMENT ASK, "And do you strongly or mildly agree with this statement.

THEN CIRCLE THE APPROPRIATE NUMBER ON THE LINE BETWEEN THEM USING THE FOLLOWING LEGEND.

1 - strongly agree with view in left-hand column
2 - mildly agree with view in left-hand column
3 – Neutral/undecided/don't know
4 - mildly agree with view in right-hand column
5 - strongly agree with view in right-hand column

Meeting North American food needs with fewer and fewer farmers is a positive outcome of technological progress.	1 2 3 4 5	Meeting North American food needs with fewer and fewer farmers is a negative outcome of our free market system.
Farmland should be farmed so as to protect the long-term productive capacity of the land, even if this means lower production and profits.	1 2 3 4 5	Farmland should be farmed so as to maximize annual profits, even if this threatens the long-term productive capacity of the land.
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The primary goal of farmers should be to maximize the productivity, efficiency, and profitability of their farms.	1 2 3 4 5	The primary goal of farmers should be to improve the quality of their products and to enhance the longterm condition of their farms.
The amount of farmland owned by an individual or corporation should NOT be limited, even if the ownership of land becomes much more concentrated than at present.	1 2 3 4 5	The amount of farmland owned by an individual or corporation should be limited in order to encourage land ownership by as many people as possible.

Agricultural scientists and policy-makers should recognize that there are limits to what nature can provide and adjust their expectations accordingly.	1 2 3 4 5	Agricultural scientists and policy-makers should expand efforts to develop biotechnologies and other innovations in order to increase food supplies.
Good farming depends mainly on personal experience and knowledge of the land.	1 2 3 4 5	Good farming depends mainly on applying the findings of modern agricultural science.
The future success of North American agriculture will NOT be affected if rural communities continue to decline.	1 2 3 4 5	Healthy rural communities are absolutely essential for North American agriculture's future success.
Small to medium sized farms can best serve North America's agricultural needs.	1 2 3 4 5	Large to very large farms can best serve North America's agricultural needs.

(INTERVIEWER READ: "There are a few more to go.")

Farm traditions and culture are outdated and of little use in modern agriculture.	1 2 3 4 5	Farm traditions and culture help maintain respect for the land and are essential for good farming.
Farming is first and foremost a business like any other.	1 2 3 4 5	Farming is first of all a way of life and second a business.
Farmers should use primarily natural fertilizers and production methods such as manure, crop rotations, compost, and biological control.	1 2 3 4 5	Farmers should use primarily synthetic fertilizers and pesticides in order to maintain adequate levels of production.
Most people should live in cities and leave farming to those who do it best.	1 2 3 4 5	Many more people should live on farms and in rural areas than do at present.
Modern agriculture is a major cause of ecological problems and must be greatly modified to become ecologically sound.	1 2 3 4 5	Modern agriculture is a minor cause of ecological problems and needs only to be fine-tuned periodically in order to be ecologically sound.
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Farms should be specialized in one or at most a few crops.	1 2 3 4 5	Farmers should be diversified and include a large variety of crops.
Soil and water are the source of all life and should therefore be strictly conserved.	1 2 3 4 5	Soil and water are the basic factors of production and should be used so as to maximize production.

Farmers should purchase most of their goods and services just as other consumers do.	1 2 3 4 5	Farmers should produce as many of their own goods and services as possible.

(INTERVIEWER READ: "We just have a few more to go now.")

The key to agriculture's future success lies in learning to imitate natural ecosystems and farm in harmony with nature.	1 2 3 4 5	The key to agriculture's future success lies in the continued development of advanced technologies that will overcome nature's limits.
Most farms should specialize in either crops or livestock.	1 2 3 4 5	Most farms should include both crops and livestock.
Production, processing, and marketing of agricultural products is best done at local and regional levels.	1 2 3 4 5	Production, processing, and marketing of agricultural products is best done at national and international levels.
The successful farmer is one who earns enough from farming to enjoy an above average standard of living.	1 2 3 4 5	The successful farmer is one who truly enjoys farming even if it provides only a below average standard of living.
Technology should be used to make farm labour more rewarding and enjoyable, but not to replace it.	1 2 3 4 5	Farm labour should be replaced whenever possible by more efficient machines and other technologies.
The abundance and relatively low prices of food in North America are evidence that North American agriculture is the most successful in the world.	1 2 3 4 5	High energy use, soil erosion, water pollution, etc. are evidence that North American agriculture is not nearly as successful as many believe it to be.

Section 2: Demographics

Finally, I would like to ask you a few questions for classification purposes. These are used to group your responses with responses from other producers.

2A) Now thinking about the crops you grow. Which of the following crops do you grow on a **regular basis**. Do you grow.....? (READ LIST, RECORD ALL THAT APPLY)

Σ	Spring Wheat
Σ	Winter Wheat
Σ	Barley
Σ	Canola
Σ	Oats
Σ	Field Peas
Σ	Chick Peas
Σ	Lentils
Σ	Dry Beans
Σ	Flax or linola
Σ	Alfalfa
Σ	Potatoes
Σ	Sunflowers
Σ	Other Crops (please specify)

2B) Now thinking about the crops you grew **last year, that is in 2001**. Did you grow.....? (READ LIST, RECORD ALL THAT APPLY)

Σ	Spring Wheat
Σ	Winter Wheat
Σ	Barley
Σ	Canola
Σ	Oats
Σ	Field Peas
Σ	Chick Peas
Σ	Lentils
Σ	Dry Beans
Σ	Flax or linola
Σ	Alfalfa
Σ	Potatoes
Σ	Sunflowers
Σ	Other Crops (please specify)

3A) Now switching to thinking about specific crops. Have you **ever** grown Liberty Link Canola? (DO NOT READ LIST)

Σ	Yes
Σ	No
Σ	DK/REF

3B) Have you **<u>ever</u>** grown Roundup Ready Canola? (DO NOT READ LIST)

Σ	Yes
Σ	No
Σ	DK/REF

3C) New developments are underway that could see a wheat variety that is tolerant to Roundup herbicide coming to the marketplace. This new wheat has been commonly referred to as Roundup Ready Wheat. If this wheat was available locally and at a reasonable price, how likely would you be to try Roundup Ready Wheat? Would you be....(READ LIST)

Σ	Very likely
Σ	Somewhat likely
Σ	Somewhat unlikely
Σ	Very unlikely
Σ	DK/REF (DO NOT READ)

4A) Do you raise livestock? (DO NOT READ LIST)

Σ	Yes
Σ	No
Σ	DK/REF

(IF YES CONTINUE, IF NO OR DK/REF SKIP TO QUESTION 5)

4B) Which of the following livestock operations do you have on your farm (READ LIST, RECORD ALL THAT APPLY)? (INTERVIEWER: IF YES ASK "Approximately how many animals do you have in that operation?

	Operation	Number of Animals
Σ	Cattle	
Σ	Hogs	
Σ	Poultry	
Σ	Sheep	
Σ	Any other Livestock (Please Specify)	
Σ		
Σ		

5) Currently is any part of your farm being used for organic production?

Σ	Yes
Σ	No
Σ	DK/REF

IF YES SKIP TO 7, OTHERWISE CONTINUE

6) Have you ever considered converting any part of your farm to organic production?

Σ	Yes
Σ	No
Σ	DK/REF

7) What is the highest level of education you completed? Please stop me when I reach your category. (READ LIST, RECORD ONLY ONE RESPONSE)

Σ	Elementary school
Σ	High school
Σ	University/College Diploma
Σ	University Degree (Bachelors)
Σ	Graduate Degree (Masters)
Σ	Post-graduate Degree (Ph.D.)
Σ	DK/REF (DO NOT READ)

8) Which of the following age categories do you fall into (READ LIST, RECORD ONLY ONE RESPONSE)?

Σ	under 35
Σ	35-54
Σ	over 55
Σ	DK/REF (DO NOT READ)

9) Which of the following categories describes your average NET annual farm income? Please stop me when I reach your category. (READ LIST, RECORD ONLY ONE RESPONSE)

Σ	Under $25,000
Σ	$25,000-50,000
Σ	$50,000-75,000
Σ	$75,000-100,000
Σ	over $100,000
Σ	DK/REF (DO NOT READ)

On behalf of Ipsos-Reid and myself thank you for your time. Good night.

APPENDIX G

Summary of Comments Made by PFP Project Participants

Comments and suggestions about how to improve the implementation of PFP and future directions for PFP and pesticide use reduction:

- A land set aside program which would pay producers to use green manure and rotate fields for several years in forage would help in PFP implementation.
- Use of alfalfa and zero-tillage (common comment)
- Poor grain prices and high input costs will continue to make PFP attractive
- Farmers need to be encouraged to try PFP and learn from their mistakes.
- Grow winter crops, fall seeded canola
- Improve disease control in winter wheat
- Use of forage crops and livestock
- More information about intercropping
- Marketing will be challenging, but premiums must be attractive, especially for non-competitive crops
- Premiums would make PFP into less of an ad-hoc attempt, and farmers would put more effort into making it happen.
- Educate to create demand for PFP products at consumer level
- Demand will grow as consumers realize the impact of pesticides, and realize that the premium goes to farmers.
- Growing PFP crops is not as difficult as marketing will be
- It would be nice if marketing also spun off some local processing initiatives.
- PFP marketing would be easier in a dual marketing system (i.e. no CWB for wheat and barley)
- Change the rules: so that you can use fungicides for leaf disease in winter wheat and seed treatments in canola.
- PFP may be a stepping stone to organic, but there are concerns about the level of tillage required in organic production.
- PFP is the logical evolution of zero-till and organic.
- PFP may be more sustainable than true organic because fertilizer is allowed.
- PFP may persuade farmers to change their mindset and values about relying on pesticides
- Prefers the idea of being permanently pesticide free but still use fertilizer.
- The marketing aspect will ultimately lead to PFP's success or failure – too many agronomically driven projects (eg. hemp) that were not based on a market.
- Increasing seeding rates and using forages will help
- The concept is good, nice to see the University doing something like this
- If the price goes up for PFP crops farmers will grow them
- PFP will be a wait-and-see approach depending on spring conditions
- 'I am a firm believer that we as farmers need to demonstrate that pesticide application is not just a routine, and that we can "miss" a year to help reduce our overall reliance on chemicals. However, farming entirely without pesticides is not practical for the vast majority of farmers (at present). Hopefully we can use our experience with PFP to sharpen our other pest control skills.'
- 'I am trying to develop a low input system whereby I grow an average yielding crop with the lowest possible cost - I am hoping that being part of PFP, I will pick up

some new ideas about this.' Doesn't think a certificate is as important as the learning & networking opportunity

- 'I think this is a better way to produce food for our people, since we overproduce anyway, production is not problem.'
- 'It's going to be the future way to farm because input costs are slowly going beyond the level that farmers can afford'
- Try to clean up the field for PFP by using spring cultivation to stimulate weeds and then grow Roundup Ready canola, spraying Roundup twice.
- He is considering a "natural" beef marketing plan with PFP feed barley
- He interested in organic but would rather rotate in and out of it
- He thinks it's true that often increased weed densities can often be controlled by the normal spray program, if it is a wet year, and you can't spray, such a situation could get out of control so you have to be careful.
- 'Not spraying when low/no weed populations exist has always been part of our cropping system'
- More markets for forages/alfalfa allowing for an easier rotation with grain and oilseed crops would help PFP implementation
- No suggestions, just farm as you see fit for a given year.
- More research of crops that compete with or suppress weeds and insects, availability of crops not affected by diseases that affect current crops
- minimizing disturbance and never using more than 40lb/ac of N to reduce weed problems (even if yields are lower with less fertilizer)
- The questionnaire was very useful to get him thinking about his management practices.
- All his seed is home grown and cleaned - he challenges the need for certified seed if you clean you own properly.
- A premium is required because in order to prepare for a PFP crop, I have to grow crops in rotation that aren't as profitable, so the premium has to offset that.
- Use of annual forages as well as perennial.
- Premium is required to compensate for reduced yields and potential cleanup costs the following year.
- Grow forages so weeds don't go to seed with the cutting regime.
- We always try to produce with the least amount of chemicals.
- Uses reduced rates of estaprop regularly (20% reduction) - because he is familiar with how this product works; would like to learn more about reduced rates
- Time is a big consideration – now that I work off the farm, there is less time to spray so PFP fits in well.
- PFP after a forage crop is the most suitable time for weed management

Comments regarding whether or not participants would try PFP again

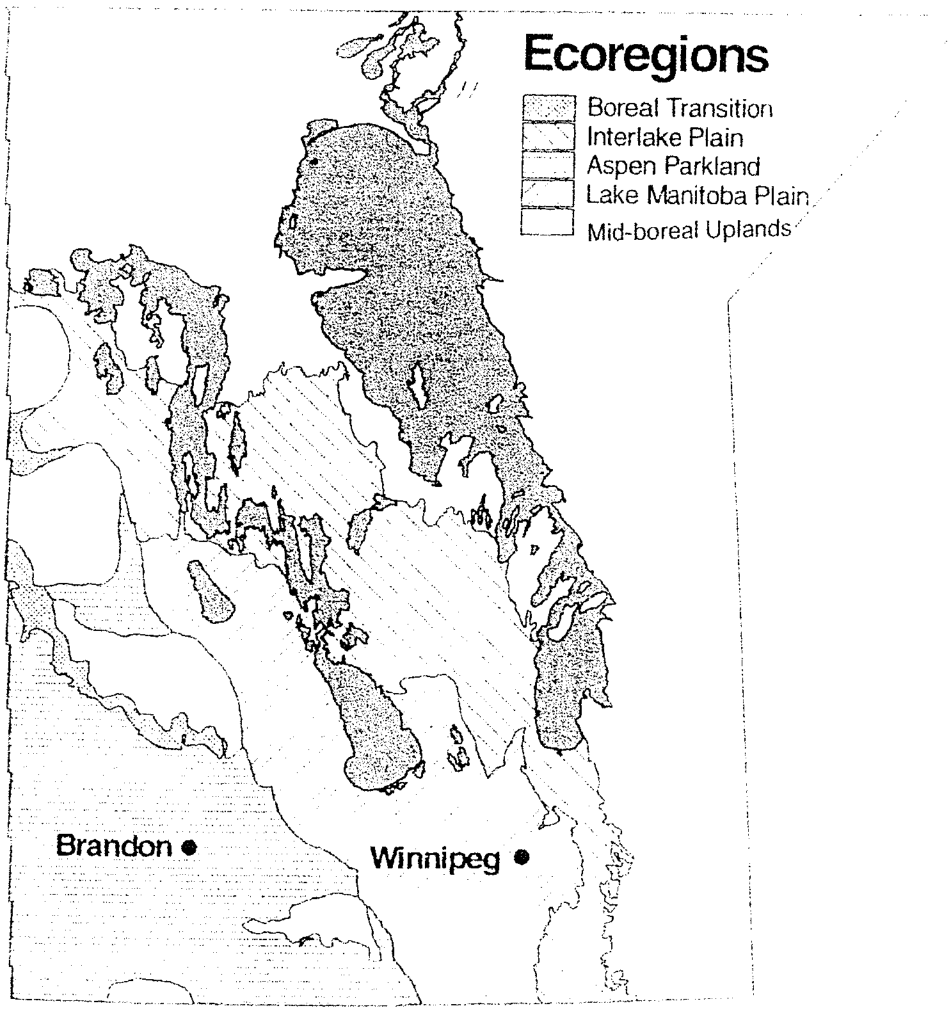
- No, because researchers experiment at our expense
- Because of being in transition to organic
- Because I like to experiment and change, improve the viability of the family farm
- To delay herbicide resistance and develop an integrated approach to weed control
- To keep costs down and hopefully find marketing opportunities
- Want to try it with winter wheat during years when a fungicide is not needed.
- Environmental reasons – reduce the amount of poison being dumped on the earth
- To reduce input costs (very common comment).

- I would try it again if I can find a clean field
- No, because I think organic provides better opportunities for reducing pesticide use and gaining consumer acceptance of the product.
- It's a good fit with perennial forages and livestock production
- Reducing input costs is important, with marketing as a bonus
- High input farming is unsustainable.
- You should only spray when weed populations warrant it.
- To reduce dependency on the chemical companies that monopolize agriculture
- Because I'm thinking about organic production
- Great opportunity to reduce costs and still have a good income if crop choice is right.
- I would follow several years of forage with Roundup Ready canola, which would then allow for 1 or 2 years of PFP.
- To gain experience growing crops without pesticides
- To expand my knowledge and preserve soil and wildlife
- It would work when you use diverse management practices.
- We want to do anything to prevent use of chemicals and fertilizers
- We plan to underseed more land to forage species in 2002 and that may be the reason to apply a PFP crop
- Future interest will depend on weed infestation
- Want to reduce costs and chance of resistance
- I am trying to work out a system that enables me to reduce input costs
- I have been doing this practice off and on for the past 15 years. I always believed in why spend money on spray if it didn't need it
- I think it gives me a much better understanding about natural weed control and weed response to chemicals, for example, in the development of resistance.
- PFP is more sustainable than the current system
- I would do it again because of the cost savings and that it's a lot healthier without the chemicals
- If I believed I had a field that was free enough of weeds I would try PFP again
- it has to be economically viable - it cannot be a novelty.
- Want to cut down on chemical use on our farm.
- My experience to date with PFP has been OK, and we are experimenting with organic production, so PFP may become redundant
- Reducing input costs is the key to farming in these times.
- I'm trying to reduce my exposure to chemicals
- there should be more to farming than operating big equipment and being a chemical applicator - that's what is left of mainstream North American farming - there is a challenge to take a more integrated approach to weed and pest control
- We should experiment with how to grow it to be ready in case a processor wants PFP grain
- I'd like less chemical cost and a better price for my grain
- I want to experiment to see if it could be viable on our farm
- There is less pesticide to leach into soil and ground water
- With our rotation, PFP should work, so we will try it again.
- I'm not scared to try new things on a small acreage but I don't like to waste money on testing technological advances for someone else's benefit

APPENDIX H

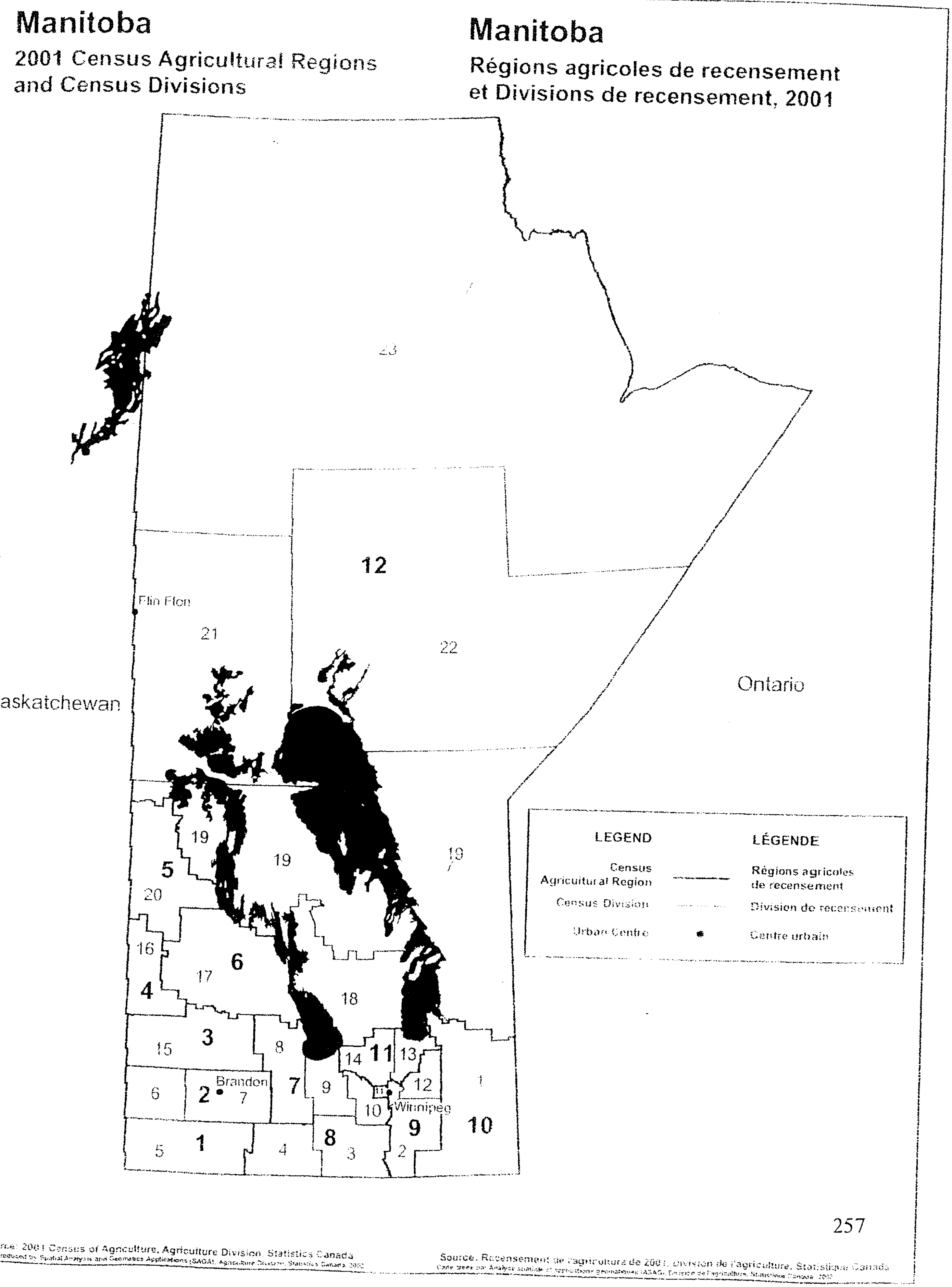
Maps of Manitoba Ecoregions and Census Districts

Figure 5-1. Map of ecoregions in Manitoba



MAP 1 Figure 5-2. Map of census agricultural regions in Manitoba

CARTE 1



APPENDIX I

Description of Manitoba Ecoregions

Ecozones are the most general level in the ecological land classification system (Smith et al., 1998). Ecoregions are subdivisions of an ecozone, with a unique combination of climate, natural vegetation, and soils.

The northern and eastern limit of arable land in Manitoba is located in the Interlake Plain Ecoregion, which lies in the Boreal Plains Ecozone. Native vegetation is dominated by trembling aspen and balsam poplar. The ecozone is broadly ridged, with glacial till and lacustrine deposits underlain by Paleozoic limestone. Predominant soils are Dark Gray Chernozems, with local areas of peaty Gleysols and Mesisols. About 40% of the region is farmed.

The Lake Manitoba Plain Ecoregion lies to the south and west of the Interlake Plain Ecoregion and is part of the Prairies Ecozone. It is transitional between boreal forest and aspen parkland. Native vegetation is dominated by trembling aspen, bur oak, and fescue grasslands. The ecoregion is underlain by limestone, and has broadly ridged glacial till in the north and smooth lacustrine deposits in the south. The predominant soil is a Black Chernozem, with local pockets of Gleysol. Annual crop production is less prevalent in the north of this ecoregion due to topography and stoniness.

The Mid-Boreal Upland Ecoregion is part of the Boreal Plains Ecozone. This area is dominated by trembling aspen, balsam poplar, white and black spruce, and balsam fir. This ecoregion consists of kettled to dissected deep glacial till, lacustrine and fluvioglacial deposits overlaying Cretaceous shales. Predominant soils are Gray Luvisols, with local areas of peaty Gleysols, Mesisols, and Dystric Brunisols. Agriculture is predominant only in southern parts of the ecoregion.

The Aspen Parkland Ecoregion in the Prairies Ecozone is a transitional area between the grasslands in the south and the forest ecosystems in the north, and it has a transitional grassland ecoclimate. Native vegetation is mostly gone, but would have been dominated by trembling aspen, oak, and fescue grasslands. The ecoregion is underlain by Cretaceous shale, and is undulatin to kettled to hummocky to ridged, with glacial till, lacustrine, and fluvioglacial deposits. This region is a highly productive agricultural area.

Source: Thomas et al. (1999a)

APPENDIX J

Weather Data for Winnipeg and Brandon, MB

Table 5-1. Average daily mean temperature and total monthly precipitation for Winnipeg and Brandon, Manitoba in 2000, 2001, and climate normals[z]

		Brandon, MB		Winnipeg, MB	
		Average daily temperature (°C)	Total precipitation (mm)	Average daily temperature (°C)	Total precipitation (mm)
Apr.	2000	4.1	4.1	6.6	3.6
	2001	4.5	17.2	7.0	21.3
	Climate Normal	3.5	31	4.0	29.6
May	2000	11.1	53.0	12.9	72.1
	2001	12.7	55.0	13.6	115.3
	Climate Normal	11.4	52.7	12.0	58.8
June	2000	13.5	61.0	15.8	259.6
	2001	15.2	122.0	17.6	97.6
	Climate Normal	16.1	74.4	17.0	89.5
July	2000	18.8	118.0	21.0	101.6
	2001	19.6	38.0	21.5	282.4
	Climate Normal	18.4	75.8	19.5	70.6
Aug.	2000	17.7	59.0	19.9	109.7
	2001	19.2	22.0	21.0	35.6
	Climate Normal	17.5	69.2	18.5	75.1
Sept.	2000	11.5	43.0	12.5	62.0
	2001	12.8	23.0	14.5	13.2
	Climate Normal	11.4	50.1	12.3	52.3
Oct.	2000	5.6	29.0	7.4	7.6
	2001	3.4	12.0	5.1	11.9
	Climate Normal	4.4	27.7	5.3	36.0
Nov.	2000	-8.3	83.1	-3.5	73.9
	2001	0.3	6.4	1.2	4.6
	Climate Normal	-6.1	17.7	-5.3	25.0

[z]Source for climate normals (1971-2000): Meteorological Service of Canada. Source for 2000 and 2001 Winnipeg data: University of Manitoba Point weather station. Source for 2000 and 2001 Brandon data: Agriculture and AgriFood Canada Brandon Research Centre.

APPENDIX K

Spearman Correlation Coefficients for Continuous Variables

Table 5-2. Significant Spearman Correlation Coefficients for Continuous Agronomic and Demographic Variables

variable 1	variable 2	Spearman coefficient	p-value	N
number of crops grown regularly	proportion of rented land	0.49	<0.0001	116
number of crops grown regularly	farm size	0.38	<0.0001	116
number of years farming	farm size	0.34	0.000	117
field size	farm size	0.30	0.001	117
number of crops grown regularly	yield as % of 1 yr prov yield	0.31	0.001	108
number of people farming	proportion of rented land	-0.27	0.004	114
number of years farming	attitude score	-0.22	0.022	109
number of people farming	attitude score	0.22	0.024	106
yield as % of 1 yr prov yield	weed density by ecoregion	-0.21	0.031	109
yield as % of 1 yr risk area yield	proportion of rented land	0.21	0.031	101
number of people farming	weed density	-0.20	0.032	114
field size	weed density	-0.20	0.033	119
yield as % of 1 yr prov yield	farm size	0.20	0.036	109
yield as % of 1 yr risk area yield	weed density	-0.21	0.039	101
number of years farming	yield as % of 1 yr prov yield	0.18	0.064	109
number of years farming	yield as % of 1 yr prov yield	-0.18	0.064	109
number of people farming	weed density	-0.17	0.068	114
number of people farming	farm size	-0.17	0.068	114

APPENDIX L

Grade Distribution of Manitoba Crops in 2000 and 2001

Table 5-3. Grade Distribution of Manitoba Crops in 2000 and 2001

		Grade						
Crop	Year	malt	1	2	3	4	feed + sample	Number of observations
Red spring wheat	2000	n/a	22%	63%	10%	0%	4%	35423
Red spring wheat	2001	n/a	39%	57%	2%	0%	2%	29800
Red spring wheat	Average	n/a	31%	60%	6%	0%	3%	65223
oats	2000	n/a	21%	34%	32%	8%	4%	8895
oats	2001	n/a	16%	37%	32%	11%	3%	6580
oats	Average	n/a	18%	36%	32%	9%	4%	15475
barley	2000	4%	85%	9%	n/a	n/a	2%	12352
barley	2001	3%	84%	11%	n/a	n/a	2%	8935
barley	Average	3%	85%	10%	n/a	n/a	2%	21287
flax	2000	n/a	88%	9%	2%	0%	0%	3713
flax	2001	n/a	98%	1%	0%	0%	0%	3684
flax	Average	n/a	93%	5%	1%	0%	0%	7397

Source: Manitoba Crop Insurance Corporation

Figure 5-3. Map of Participants in the PFP On-Farm Research Project in 2001 and 2002