Demographic Influences on Willingness to Pay for Cold Tolerance Technology

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Abstract

New technologies in agriculture have the potential to increase production levels, reduce risk, and improve profits for farm operators. However, in order for this to take place the technologies must appeal to producers, creating enough interest that they decide to invest in them. Gauging the level of interest in a technology and the types of producers who will be interested in trying it are important steps in technology development. Cereal crops such as wheat are important to agriculture in Canada in terms of both acreage and revenue. Researchers in Canada are currently attempting to develop more cold tolerant cereal crops to reduce the risk of frost damage and increase the area available to produce these crops. A producer survey including questions on past adoption behavior, attitudinal characteristics, and demographics as well as a set of dichotomous choice questions on new varieties was conducted and analyzed using a regression and willingness to pay calculations. Demographics were the focus during these activities. It was determined that producers from areas experiencing frost regularly with high incomes and large land bases had a higher propensity to adopt and higher willingness to pay for this technology.

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Recent technological improvements in agriculture have greatly improved yield and output and reduced the labor required by the industry. Technologies in machinery, biotechnology, and precision agriculture, along with many other fields, have greatly improved efficiency and increased food availability. However, before these technologies can benefit either society or the agricultural community, producers must decide to make use of them. There are numerous factors that interact to determine whether a particular producer or segment of producers will incorporate a technology into their operation. Knowledge of these factors is very useful to those developing new technologies and trying to predict demand levels and effects on industry. Some categories of influencing factors include farm manager demographics, industry conditions, risk factors, and macroeconomic and policy issues.

In an undergraduate study at the University of Alberta, the likelihood of adoption and willingness to pay for more frost tolerant wheat varieties was examined. Researchers from University of Saskatchewan, University of Alberta, and other partnering organizations are working to improve the low temperature tolerance of cereal crops commonly grown in Western Canada (Genome Prairie 2006). This could reduce risk of crop failure or poor crop quality for many producers. It could also expand cereal crop production to areas currently considered marginal or non-agricultural land (Genome Prairie 2006).

With many fluctuations in climate conditions, cold tolerant cereal grain technology has great potential in Alberta. Short growing seasons, unpredictable weather, and limited rotations make the benefits offered by more cold tolerance varieties significant. In 2005, wheat was the field crop accounting for the highest acreage and the highest farm receipts in Alberta, at 6.6 million acres and $787 million in receipts (Alberta Agriculture and Food 2006). This accounts for over one third of Alberta crop receipts (Alberta Agriculture and Food 2006). This is why current research is strongly focused on wheat.

If a crop experiences frost damage during the normal growing season or because the crop requires a very long growing season, producers can suffer economic losses. For example, a frost early in the year can completely destroy a crop, while later frosts can reduce the yield and grade of the end product. Frost can result in wrinkled kernels, higher green seed content, or grain that spoils easily. This is why many crop breeders focus on increasing frost tolerance and decreasing days to maturity. If the crop takes fewer days to reach harvest, the risk of frost exposure is lower.

Adoption of more frost tolerant cereals could expand rotational options for producers on the edge of wheat growing areas, and it could increase the amount of food produced on the limited agricultural land base. More frost tolerant varieties can be seen as a risk management tool for wheat producers, as they reduce the risk of lower quality and yield, both of which are very costly problems. As these new cold tolerant varieties are developed and move towards commercialization, information on the number and type of producers who may be willing to invest in this technology can be used in focusing upcoming development and marketing efforts.

Objectives

The goal of this project was to gauge the level of demand and willingness to pay for increased tolerance to inclement temperatures, either through higher frost tolerance of the plants or through decreased days to maturity. By determining the number and type of cereal producers interested in frost tolerant varieties, decisions on production levels, pricing, and promotion can be made more effectively.

Previous Work

There has been previous research and discussion on the factors that influence farmers and other business operators to adopt new technology. Although these studies did not directly examine improvements in low temperature tolerance in cereal crops, the methods and findings of other researchers provided a basis for this project's hypothesis and a point of reference when evaluating the findings.

Karshenas and Stoneman (1993) looked at technology adoption in an industrial, rather than agricultural, setting. They examined the cost benefit equilibrium that must be reached before a firm manager makes the decision to invest in new technology. They reported that the decision to adopt new technologies came sooner for larger firms and for those expanding rapidly. This conclusion is closely related to the idea of economies of scale. This idea is not as important for cold tolerant varieties as it is for other technologies, as seed can be bought in small lots and the initial investment required to try the seed is not large. This may lead to a higher propensity to adopt, even by smaller firms, than would be seen for a technology requiring a large capital outlay.

Koundouri, Nauges, and Tzouvelekas looked at adoption of more efficient irrigation technology in Greece (2006). In this case, observed behavior was used rather than stated choice (Koundouri, Nauges, and Tzouvelekas 2006). Younger, more educated farm operators were more likely to make use of the new technology. It was also noted that those with smaller operations but more profit per unit of land than average were more likely to adopt (Koundouri, Nauges, and Tzouvelekas 2006). This could be because the use of irrigation equipment is labor intensive and time consuming, so it is more appropriate for small, intensive operations. Operations in geographic areas with worse environmental conditions were more likely to make use of the technology (Koundouri, Nauges, and Tzouvelekas 2006). Producers in areas that frequently experience drought were more likely to make the investment in irrigation technology, as the marginal benefit was higher for them (Koundouri, Nauges, and Tzouvelekas 2006).

Saha, Love and Schwart examined the characteristics of dairy producers adopting the use of bovine growth hormone in the United States (1994). Early adopters were characterized as being younger and from larger operations (Saha, Love and Schwart 1994). Higher education levels and larger dairy herds also had a significant positive impact on the degree to which the technology was adopted.

After considering the nature of the technology being studied and the findings of past research, it was hypothesized that younger, larger, more educated farmers would be more likely to adopt this cold tolerant new technology. Those with higher income levels were also expected to have a higher propensity to adopt the new technology. It was also expected that those from marginal agricultural areas with more variable weather would have a higher interest in the new technology. It was expected that willingness to pay would rise with the increased level of frost tolerance or decreased days to maturity.

Methods

In order to determine willingness to pay for new varieties with improved resistance to cold temperatures, a research project with a number of stages was designed. First, a written survey was designed to gather primary information from Alberta producers. The survey included sections on previous adoption behaviors, past experiences with frost damage, and factors influencing the decision to adopt a new technology or variety. Both yes or no questions and attitudinal scales were used in the survey. The attitudinal questions focused on risk aversion and innovation levels of the participant. Demographic characteristics were also measured. The final section of the survey asked participants to choose between their existing wheat variety and one with improved frost tolerance and or decreased days to maturity. The three attributes altered in this dichotomous choice section were increase in seed cost, decrease in days to maturity, and degrees increase in frost tolerance. There were 16 dichotomous choice questions in total, and each participant was asked to answer 8 of these choices. Every combination of traits was used except for those with no improvement in either time to maturity or frost tolerance. The variations used were a 0, 2, or 4 day decrease in days to maturity; an increase in frost tolerance of 0, 2, or 4 degrees Celcius, and an increase in seed cost of 25 or 50 percent. A sample of these questions is included in the Appendix.

After gaining human ethics approval from the University of Alberta Agriculture, Forestry and Home Economics Research Ethics board, the survey was administered in person at agricultural meetings and trade shows. 104 people filled out the survey, but 4 left the majority of the questions blank so they were removed prior to analysis. The majority of the 100-person sample filled out the survey at the Farm and Ranch Tradeshow held in Edmonton, Alberta, Canada in late March 2007. Other sources were attendees at a Canola Club Root Meeting near Stony Plain Alberta and farms in the Vulcan area of Southern Alberta. This would be considered a convenience sample, as it was drawn from those who volunteered to participant and who were gathered in a common place.

After gathering the raw data, the data was analyzed with descriptive statistics and regression techniques to determine statistically significant relationships between the decision to adopt a new variety, choice characteristics and demographics. Excel and the software program TSP were used to accomplish this. Once the logit equation was estimated, standard procedures for logit stated choice models were used to calculate willingness to pay for each of the desirable attributes, decreased days to maturity and increased degrees of frost tolerance were calculated for different types of respondents.

Finally, the findings of this study were compared to the results of similar studies on technology adoption in agriculture. The ways in which the findings were either validated or confirmed by the work of others were explored.

Results

Demographics

The survey responses showed that there are more farmers in older age categories, as shown in figure 1. The survey sample contained older farm operators than would be representative of Alberta. According to the census, half of all farmers fall between the ages of 35 and 54 years (Statistics Canada 2001). In this sample, nearly half of all respondents were over 51 years of age. This may have impacted the results of our analysis, as age may be related to adoption behaviors and attitudes towards technology. One explanation for the difference between the census and our data could be that older farmers are more likely to attend the extension events at which the survey was administered.

The average farm income level of respondents to the survey differed greatly from the Alberta data, as displayed in figure 2. While most farmers reported a net income of less than $25 000 on the census, over half of cold tolerance survey respondents placed themselves in the over $50 000 annual net income category (Statistics Canada 2001). This could be because farm operators with more income are more likely to attend extension events.

The mean education level of survey respondents was college or technical school. The full distribution of responses is shown in figure 3. The survey sample contained people with a higher education level (on average) than the general farm population (Statistics Canada 2001). In particular, there was a higher proportion of university educated people in the sample (Statistics Canada 2001).

Figure 4 illustrates that the farm sizes reported by respondents to the survey were larger than the provincial average (Statistics Canada 2001). This could be because the survey focused on large-scale grain farmers rather than smaller livestock farms or hobby farms. Small farmers often have off-farm jobs and this may have decreased the likelihood of attendance at events where the survey was performed.

Past Behavior and Experiences

The pie chart in figure 5 shows that frost damage is a consideration for the vast majority of producers in the sample. A closer examination of the data reveals that the majority of frost damage is experienced late in the season. These numbers indicate that crop damage due to low temperatures is a commonly experienced problem, so there should be a market for more cold tolerant varieties. At the most basic level of analysis, the dichotomous choice variety questions revealed that 39 percent of respondents indicated that they would be interested in a new variety with some type of improvement in frost tolerance characteristics, even though this came along with a seed price increase.

Logistic Stated Choice Results

The regression, detailed in table 1, was developed using Time Series Processor (TSP) software. Demographic factors were used as independent variables in the regression. A logit model was used. This allows for both choice-specific and chooser-specific variables to be used as explanatory variables (Hull and Cummins, 2005).

A result of one indicates a decision to stay with the existing variety while a result of two indicates a decision to invest in a new, more cold tolerant variety. The equation form is as indicated below. The numbers to be used in this formula are in table 1.

$$\text{Probability (choose new variety)} = \frac{e^{\alpha_1+\alpha_2 X_2+\ldots+\alpha_k X_k}}{1+e^{\alpha_1+\alpha_2 X_2+\ldots+\alpha_k X_k}}$$

x= variety or respondent characteristic α= estimated logit coefficients

The first variables in the equation include seed cost (SC), frost tolerance (FT), decrease in days to maturity (DD), and a status quo or constant variable (SQ). These were the choice specific variables, which varied depending on the survey version and the new variety being examined. Demographic (chooser-specific) variables included were farm size in acres (SIZEA2), age in years (AGE2), education level (EDUCATION2), income level (INCOME2), region (REGION2), and frequency of frost damage experience (HOWOFTEN2). These demographics were not interacted with the seed characteristics before addition to the model. Examining the coefficient on each of these variables gives insight into the type of people more likely to invest in cold tolerant cereal seed, in this case the new variety. The scaled r-squared of .180615 indicates that this model has just over 18 percent more explanatory power than a model containing only a constant term (Hall and Cummins, 2005).

The coefficient on seed cost is negative, indicating that utility gained from the new variety drops as the seed price increases. This follows the general law of demand and was not a surprising result. Both increased degrees of frost tolerance and decreased days to maturity had positive coefficients, indicating that the likelihood of purchasing a new variety increases as tolerance to cold temperatures increases or as the variety matures faster. These things both increase the risk reduction value of the product, so they increase the value of the seed and therefore propensity to adopt and willingness to pay. Each of these first three variables in table 1, SC, FC, and DD, is statistically significant at the five percent level.

Farm size has a statistically significant positive coefficient. Operators of larger farms are more likely to adopt the new varieties. This could be because large farms are faced with more risk that they would like to mitigate, because they are less diversified, because they are often the operator's only source of income, or because they have a larger budget for investment in new technologies. This follows the findings of Karshenas and Stoneman (1993), but it is in contradiction to the findings of Koundouri, Nauges and Tzouvelekas (2006). The introduction of a new wheat variety does not require the labor and management resources demanded by the irrigation systems examined in the Kondouri, Nauges and Tzouvelekas study, so this could explain the differing results (2006). Larger farms can adopt more cold tolerant seed without adding extra work to their operation.

There was a negative coefficient on the age variable, but this coefficient was not statistically significant at the five percent level. The negative sign follows in line with findings in other studies such as the one by Saha, Love, and Schwart (1994) that younger operators are more likely to try new things, but the data from this project does not strongly support this conclusion.

One of the results from this analysis that contradicts past findings is in the effects of education. The negative coefficient (Table 1) indicates that as education level rises, the utility created by adoption and the likelihood of adoption decreases. Past work by Koundouri, Nauges and Tzouvelekas and many others indicates the opposite; in general those with more education are more apt to adopt new technology (2006). The reasoning behind this finding is unclear, but it could be because those with varying education levels did not systematically differ from one another in other ways. Income, often closely related to education, did have the expected sign on its coefficient.

Region is one of the more interesting variables in this equation. The coding on the survey was as shown in the map in figure 6, with 1 being the furthest north region, the Peace. There are great variations in weather and temperature throughout Alberta, and there is a greater risk of frost in the more northern regions. Thus, the negative coefficient on the region variable is logical, as it means that those in the lower numbered areas are more interested in frost tolerance and decreased days to maturity as a result of their location. The Northwest, region 2, is more mountainous and forested than region 3, the Northeast, so this follows along the correct gradient. The coefficient on this variable was not significant at the five percent level, but it was significant at the ten percent level, and seemed like an important finding although it had a fairly high P value. The map included in figure 6 indicates the regions and the percentage of respondents from each region. The remaining three percent of respondents were from other provinces or did not indicate the area in which they farm.

The variable measuring frequency of frost damage (HOWOFTEN2) follows a similar pattern to that shown in region. The categories for this variable were 1) every year 2) every 2-3 years 3)Every 4-10 years 4)Less than every 10 years. There was a statistically significant, negative coefficient on this variable. This indicates that respondents who experience regular frost damage are more likely to invest in more resilient varieties in order to minimize losses experienced on these occasions.

Willingness to Pay

After estimating the logit model, it was possible to calculate the willingness to pay for the variety improvement of greater frost tolerance and earlier maturity. First, values for a representative respondent were chosen based upon mean demographic values from the survey. This respondent farmed 2885 acres, was between 41 and 50 years of age, had a college or technical school education, and made $50 001- $100 000 per year in net income. They were from the Northeast region and experienced frost damage every 4 to 10 years. It was determined that the willingness to pay for increased degrees of frost tolerance, decreased days to maturity, and a combination of the two were all just slightly negative in this case. From there, the focus shifted to those who experienced frost damage on a regular basis, as this will be the target market for these varieties.

Results of the analysis are shown in figure 8. The percent increase in seed cost that producers were willing to pay was just slightly higher for increased degrees of frost tolerance than it was for decreased days to maturity. Large, high income farms were most willing to pay a seed price premium for cereal varieties that are more frost tolerant or mature more quickly. According to these results, large farms with frequent frost exposure were willing to absorb an increase in seed cost of about 45.8 percent for a variety combining the two improvements. Using an approximate current wheat seed cost of $9 per bushel and a seeding rate of 1.75 bushels per acre, this translates to a per acre seed cost increase from $15.75 to $22.96, an increase of $7.21 per acre. Younger farm operators and those in the more commonly affected Peace area were also slightly more willing to pay for frost tolerance than the average person. A summary of the willingness to pay can be found in table 1.

Conclusions

Results of the survey and analysis as well as discussions with producers during the administration of our survey indicate that there is strong interest among farm operators in trying new frost tolerant varieties. However, it will be important to focus advertising and distribution on areas in which producers must frequently deal with frost problems. Marketing efforts should also focus on large, high income operations whenever possible, as most product introductions should. Interest in increased frost tolerance is slightly higher than that for decreased days to maturity, but the highest willingness to pay is achieved when synergies between the two traits are created. Geographical location and risk exposure are key elements in the variety adoption decision. The findings of this project should provide confidence to researchers investing time in the development of cold tolerant varieties, as they indicate a healthy interest in technologies to expand production possibilities for cereals in Western Canada.

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Appendix

Sample of Variety Dichotomous Choice Question

Suppose you have the opportunity to adopt a new Wheat variety that has increased cold tolerance. You will be asked to make a decision to switch to this variety or keep growing the current variety on your farm based in changes in costs and frost risk factors. Assume all other factors such as yield will remain constant between the new variety and your current one.

		New variety	Existing variety
A	**Increase in current production costs (e.g. seed cost cost/acre)**	10%	-
	Increase in frost tolerance (degrees Celsius)	No change	-
	Decrease in days to maturity	2	-

I would choose

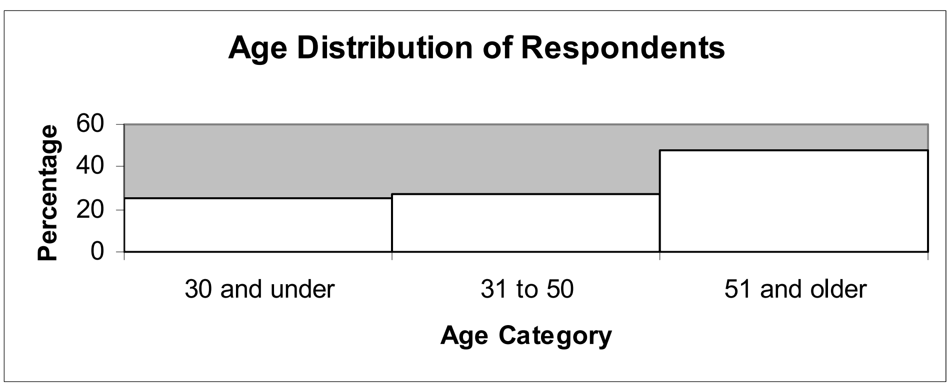


Figure 1. Age Distribution of Survey Respondents

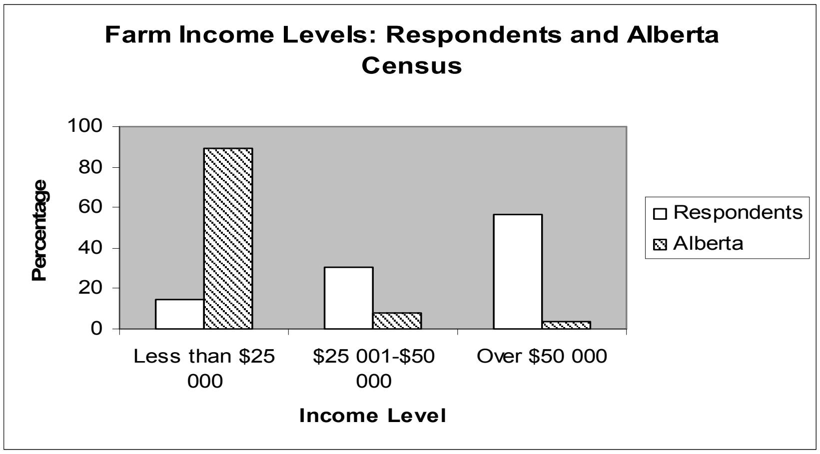


Figure 2. Comparison of Farm Income Levels Reported on Census and by Survey Respondents

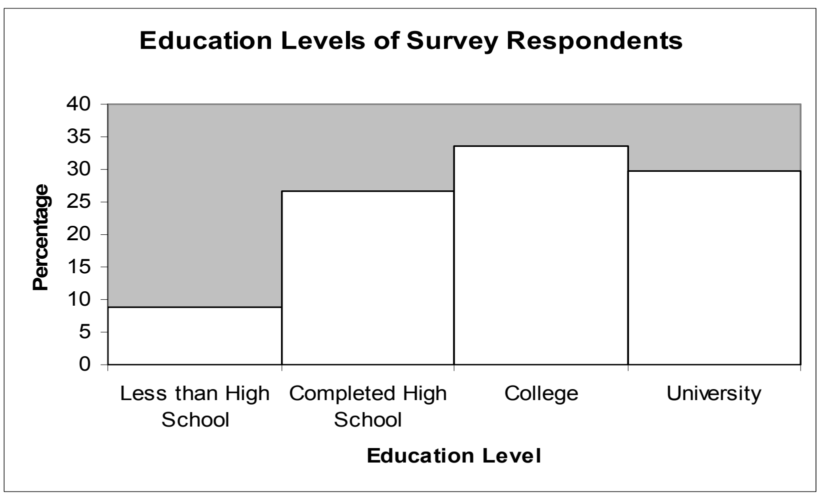


Figure 3. Education Levels Reported by Survey Respondents

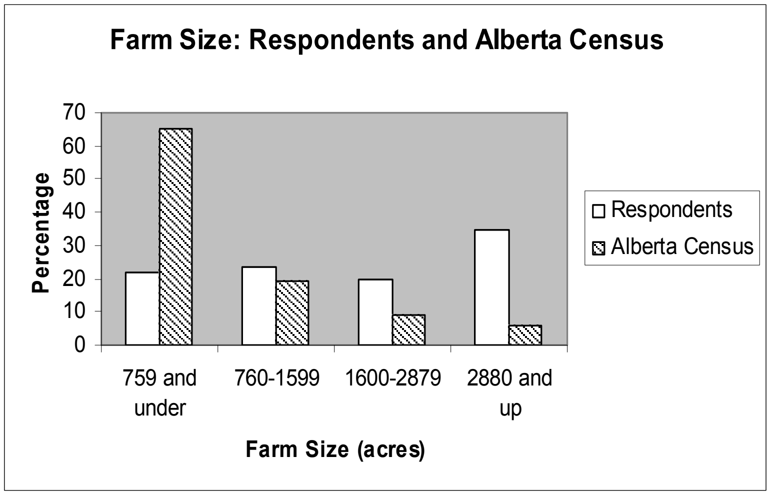


Figure 4. Comparison of Farm Sizes Reported on Census and in Survey

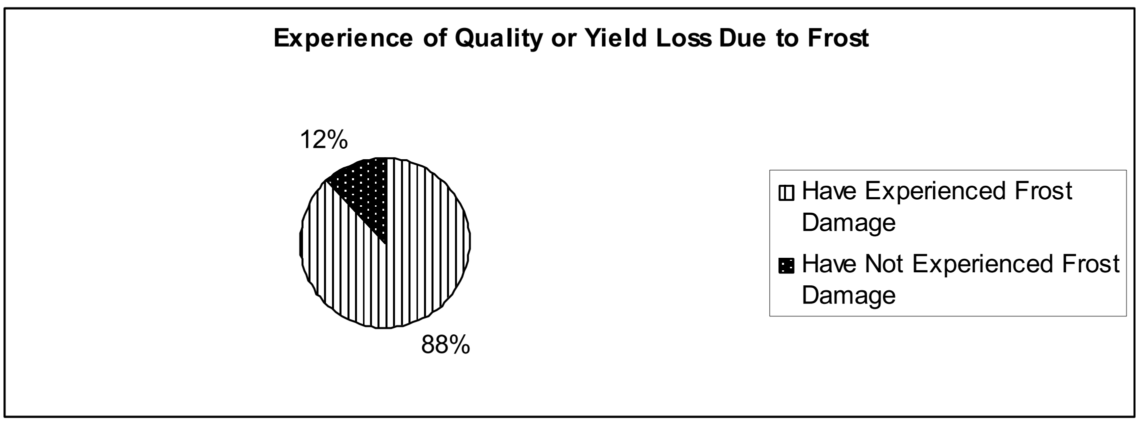
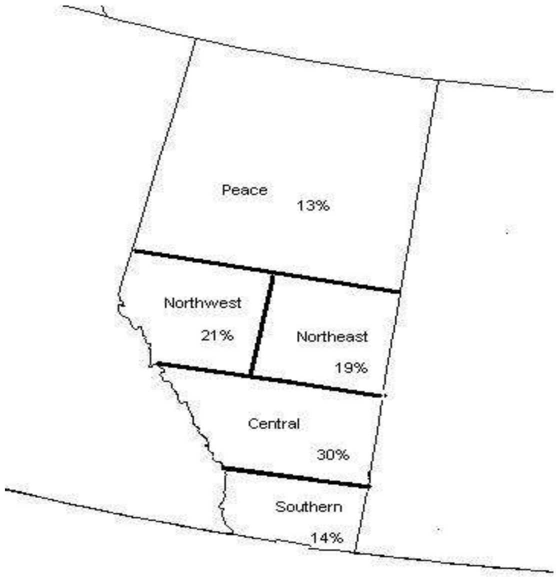


Figure 5. Frost Experience by Survey Respondents



Source: http://geography.about.com/library/blank/blxalberta.htm
Free map from About.com
Figure 6. Regions of Alberta and Percentage of Respondents
Note: 3 percent were from out of province or did not indicate region

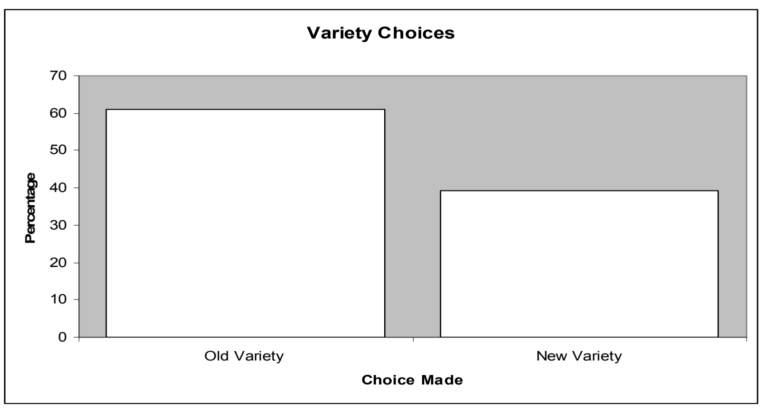


Figure 7. Distribution of Variety Choices

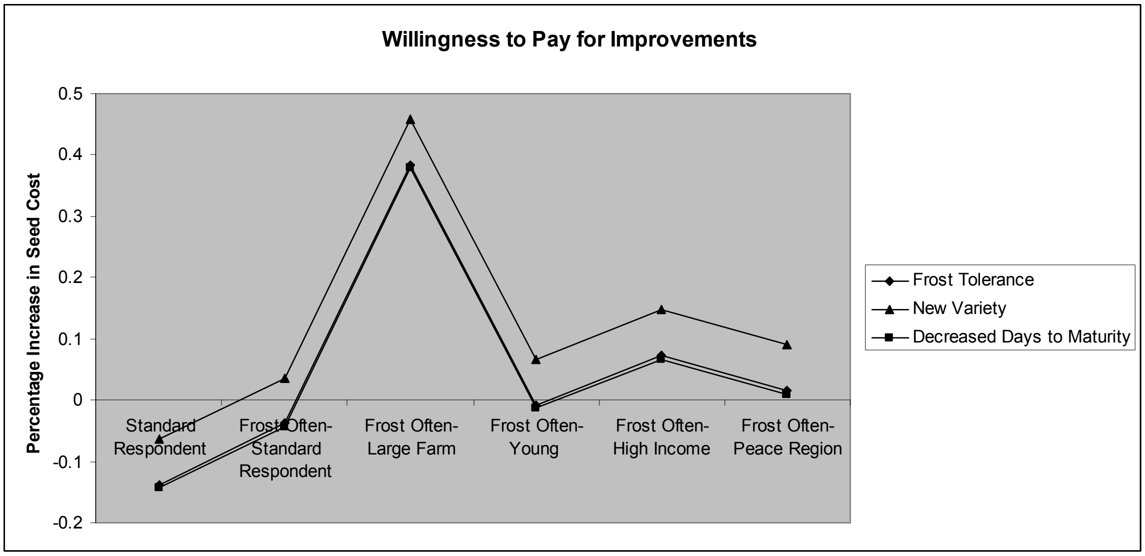


Figure 8. Percentage Increase in Seed Cost Willing to Pay for Increased Frost Tolerance, Decreased Days to Maturity, or Both

Table 1. Mixed Logit Stated Choice Model Results

Parameter	Estimate	Standard Error	T Statistic	P Value
SC Seed Cost	-4.33	0.661252	-6.55526	[.000] **
FT Frost Tol.	0.34	0.052784	6.52715	[.000]**
DD Days Earl.	0.321617	0.055436	5.80161	[.000]**
SQ Status Quo	0.413898	0.628695	0.658345	[.510]
SIZEA2 Acres	7.90E-05	2.21E-05	3.57763	[.000]**
AGE2 Years	-0.06332	0.054175	-1.16888	[.242]
EDUCATION2	-0.2124	0.081861	-2.59467	[.009]**
INCOME2	0.238765	0.066987	3.56433	[.000]**
REGION2	-0.11509	0.064033	-1.79727	[.072]*
HOWOFTEN2	-0.21622	0.09387	-2.30342	[.021]**

800 observations (8 per respondent) Scaled r square 0.18
**= significant at 5 percent level
*=significant at 10 percent level

Table 2. Willingness to Pay for Improved Cold Tolerance by Demographic Groups

Willingness to Pay	Frost Tolerance	Decreased Days to Maturity	New Variety
Standard Respondent	-0.137	-0.142701079	-0.063218857
Frost Often- Standard Respondent	-0.0377	-0.042936852	0.03654537
Frost Often- Large Farm	0.383688023	0.37840205	0.457884273
Frost Often-Young	-0.008433498	-0.013719471	0.065762752
Frost Often- High Income	0.072514115	0.067228143	0.146710365
Frost Often- Peace Region	0.015448773	0.0101628	0.089645022

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