Yield Protection as a Risk Management Strategy

by

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ABSTRACT

Risk management is critical in crop production as the challenges farmers face on a year to year basis are quite variable due to Mother Nature. There are many tools a farmer can utilize to help manage risk such as crop insurance and forward contracting or hedging. In recent years with lower prices, these tools have been more heavily used than they were a few years ago when corn and soybean prices were $8 and $15 per bushel, respectively.

Margins in crop production are tight when market prices are low and input prices are high relative to market prices, and due to land cost. In order for farmers to produce greater profit, they must find ways to lower expenses or produce more bushels to increase their revenue. As margins tighten, farmers typically try to lower expenses to be more profitable rather than trying to increase bushels that would ultimately increase their revenue. When farmers try to reduce expenses, agricultural retailers experience lower revenues holding all else equal; distributors have lower revenues because the retailer is not selling as much, and the manufacturers experience lower revenues because the retailer and distributor are not moving the inventory compared to when farmer margins are larger.

This thesis examines how yield protection for grain corn can be utilized as a risk management tool for crop production farmers. This thesis explores how increasing bushels and ultimately increasing revenue by protecting the bushels the crop is physically able to produce, can help manage producer risk. This thesis uses

yield protection as a tool alongside crop insurance and marketing, rather than as a tool to replace crop insurance or marketing.

Data used for yield protection is replicated fungicide, fungicide with an adjuvant, and fungicide with insecticide, that were evaluated against the untreated check over multiple locations and years across the Midwestern United States. Fungicide data were chosen because it is truly the definition of yield protection, protecting the crop against disease. Fungicides are usually the first products cut from a farmer's crop production program to help reduce expenses and maintain profitability as margins tighten. The results found in this study are consistent with work conducted at Iowa State University. Results exhibited an increase in corn yield, but were not consistently statistical significant across treatments and location. In conclusion, the average yield increase was not enough over multiple years to pay for itself, and it lacked sufficient evidence. Yield protection does not fit a risk management strategy annually. However, yield protection should be utilized when specific thresholds on disease or insects are present to warrant this strategy.

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CHAPTER I: INTRODUCTION

1.1 Introduction

The primary client this thesis has been developed for is a corn grain farmer. However, this thesis can also be utilized by agricultural retailers, distributors, and basic manufacturers. In a down farm economy, farmers can increase their net profit two ways. One way they can increase net profit is to produce more bushels per acre than their average production history; the second way is to find methods for reducing expenses. When farmers cut expenses from their operation, it may negatively affect yield, ultimately causing them to have a lower net profit.

Protecting yield allows farmers to grow more bushels per acre, lower their cost per bushel and ultimately increase their net profit. As a retailer sales representative working directly with the farmer, I think being able to talk to farmers about yield protection as a part of their risk management program encourages the farmer think differently about using yield protection products before saying “no” to product use.

Agricultural retailer sales representatives have observed growers looking for ways to cut expenses for the last two years. Farmers have been attempting to cut expenses because the price per bushel they are receiving in the market for their crop is much lower than their breakeven price. According to Iowa State Ag Decision Maker (2017), the total cost per acre for a 200 bushel corn on corn yield is about $700. At that cost, farmers need a grain price of $3.50 per bushel or they need to be able to produce a yield of 233 bushels per acre with today’s price per bushel of about $3.00. Don Hofstrand of Iowa State University shows that we are experiencing some of the lowest net farm income per bushel since 2003 (Hofstrand, Iowa State University Extension and Outreach, 2017). This may be an opportunity for a yield protection program to produce more bushels per acre and limit the yield risk. A yield protection program would encourage yields to be more consistent by managing factors we can control.

Each year a farmer has many expenses, and he/she can determine the expenses for the year prior to planting seed. A challenge that potentially limits farmers is that they think about cost per acre and not cost per bushel. A yield protection program can cost more than $30 per acre, and that can look very unattractive; but taking a different approach to a risk management program and utilizing a yield protection program to lower their cost per bushel would be a different way for the farmer to think. If a yield protection program could lower cost per bushel by $0.10 on 200 bushels per acre that would be a $20 per acre savings across the operation. This would allow farmers to think differently about their risk management program.

1.2 Objectives and Motivation

Today, risk management tools like crop insurance and forward marketing their crop are a couple approaches that most farmers utilize to manage weather and market price volatility. The objective of this thesis is to determine if a yield protection program in a farmer's crop plan should be part of their risk management strategy. This thesis explores several important questions. Should a yield protection program be utilized as a risk management tool, similar to how farmers utilize forward contracting and crop insurance? Does spending additional dollars per acre to protect crop yield make sense? Does a yield protection program allow a farmer to be more profitable by lowering the cost per bushel?

The category of products considered the yield protection in this thesis is fungicides since they truly protect yield. The use of fungicides may not pay off each year, but this is not dissimilar from other risk management tools. Does crop insurance pay off each year or forward contracting grain corn? Examining return on investment for the different risk management tools may be one way to help determine if yield protection should be a risk management tool. Crop protection products are products that are usually the first expenses cut from a farmer's crop plan in a down agriculture economy when net farm profits decline, but most of the products cut can consistently bring value to an operation.

1.3 Deliverables

The deliverables from this thesis project include a written thesis provided to Kansas State University, along with an oral defense presented to my Kansas State University thesis committee, classmates, and guests. Ultimately, I would like to create a thesis that encourages farmers to think differently about risk management and create a tool for agricultural retailers, distributors, and basic manufacturers that provides value to the farmer, thus enhancing profits.

1.4 Information Needed to Collect

Data needed for this thesis include, but are not limited to, information about crop insurance and grain marketing. Growers use these tools every year to help manage weather risk or to get more out of the local grain markets. This thesis will examine information about return on investment for tools used by farmers to manage risk. Personal interviews with industry professionals in crop insurance and grain marketing will be used to gain understanding of their risk management tools and how they work in a farmer's risk management program. These interviews will collect some of the return on investment data needed to make a correlation for the yield protection program. Replicated fungicide yield data are needed to examine the yield protection element. Replicated data are preferred because these data help manage variability in fields and treatments.

CHAPTER II: LITERATURE REVIEW

2.1 History of Fungicides

About 100 years ago, the science of plant pathology was born. This occurred a few decades after the concept that fungi were causal agents of plant diseases had been accepted, this concept was "spontaneous generation," which regarded fungi as symptoms on plants suffering from bad environmental conditions (Morton & Staub, 2008).

The development of the first fungicide resulted from a simple observation that seed wheat salvaged from the sea was free of bunt. In the 17th century, the first brining of grain with salt water followed by liming to control bunt transpired. This occurred long before Tillet established that seed-borne fungi caused wheat bunt of wheat and that it could be controlled by seed treatment of lime, or lime and salt (Morton & Staub, 2008).

Another important discovery was made in France in 1882 by Millardet, who noticed grape vines sprayed with a bluish-white mixture of copper sulfate and lime deterred pilferers and retained their leaves through the season, while the unsprayed vines lost their leaves. After countless spraying experiments, Millardet concluded that a mixture of copper sulfate and hydrated lime could effectively control downy mildew on grapes. Until the 1940s, chemical control relied upon inorganic chemical preparations which were frequently prepared by the user. Many of the early efforts to produce healthy crops involved diseases that had been newly introduced and left the growers helpless (Morton & Staub, 2008).

Tillet presented the results of well replicated and controlled experiments in 1755. He added black dust from bunted wheat to seed from healthy wheat and observed that bunt was much more prevalent in plants produced from such seed than from non-dusted seed. Since then, researchers and growers have been combating plant pathogens in various ways. The importance of epidemics was highlighted by late blight of potato in Europe in the

1840s which led to several severe famines. Key among the researchers at this time was DeBary, whose studies on the Peronosporaceae and the discovery of alternate hosts in the life cycle of rust fungi were two important contributions. At that time it took 100 years for man's knowledge to double, today this is accomplished in 16 years (Morton & Staub, 2008).

Up to 1940, proprietary products were available for those who did not want to make their own. Prior to the introduction of the dithiocarbamates, the testing of which was described by McCallan of Cornell University in 1930, most of the products used as fungicides were applied at high rates, e.g., about 9 to 18 pounds per acre for sulfur for powdery mildew on grapes. The products in 1940 did not always give good control, could be phytotoxic and had to be applied frequently (Morton & Staub, 2008).

From 1940 to 1970, a number of new classes of chemistries were introduced as "fungicides." Table 2.1 shows the classes of fungicides that were introduced between 1940 and 1970.

Table 2.1: Fungicide Class from 1940 to 1970

Year	Fungicide	Primary Use
1637	Brine	Cereal seed treatment
1755	Arsenic	Cereal seed treatment
1760	Copper sulfate	Cereal seed treatment
1824	Sulfur (dust)	Powdery mildew and other pathogens
1833	Lime sulfur	Broad spectrum foliar pathogens
1885	Bordeaux mixture	Broad spectrum foliar pathogens
1891	Mercury chloride	Turf fungicide
1900	CuOCl2	Especially Phytophthora infestans
1914	Phenylmercury chloride	Cereal seed treatment
1932	Cu2O	Seed and broad spectrum foliar diseases
1934	Dithiocarbamates patent(	Broad spectrum protectants
1940	Chloranil, Dichlone	Broad spectrum seed treatment

Source: Morton & Staub, 2008

Since the 1970s, important fungicides were introduced. Table 2.2 shows the modern fungicides that have been introduced since 1970.

Table 2.2: Fungicide Class since 1970

Year	Common Name of Compounds	Main Spectrum / Uses
1973	triadimefon	broad
	imazalil (imidazole)	post harvest & seed
1975	fenarimol (pyrimidine)	powdery mildew
1977	triadimenol	seed treatment
	prochloraz (imidazole)	cereal fungicide
1979	propiconazole, bitertanol	broad
	fenpropimorph (morpholine)	broad / cereals
1982	triflumizole	broad
1983	flutriafol, diniconazole, fluzilazole, penconazole	broad
1986	fenpropidin (morpholine)	broad / cereals
	hexaconazole, cyproconazole, myclobutanil,	broad
	pyrifenox (pyridine)	broad / leaf crops
	tebuconazole	broad, foliar & seed
1988	difenoconazole tetraconazole, fenbuconazole	broad, foliar & seed broad
1990	epoxiconazole	broad / cereals
1992	metconazole, fluquinconazole	broad
	triticonazole	broad, foliar & seed
2002	prothioconazole	broad
1992	azoxystrobin	broad
	kresoxim-methyl	cereal fungicide
1996	famoxadone (azolone)	oomycetes
1998	fenamidone (azolone)	oomycetes
	trifloxystrobin	broad
2000	picoxstrobin	cereal fungicide
	pyraclostrobin, fluoxastrobin	broad
2001	cyazofamid (Qi site of action, cyanoimidazole)	Oomycetes

Source: Morton & Staub, 2008

2.2 Fungicide Evaluations

The use of fungicides has become more popular with farmers. Each year before their corn crop tassels, farmers debate whether or not they should apply a fungicide on their corn crop. Some growers automatically apply a fungicide whether they have disease pressure or not; some growers scout their crops and determine if the fungicide treatment is warranted; other growers do not apply a fungicide because of its high cost per acre. Because of these debates, many universities have conducted research to determine whether a fungicide brings a yield increase per acre and an economic return on investment for the fungicide application.

An Iowa State University study from 2007 to 2009 using 574 fungicide observations found an average yield increase of 4.04 bushels per acre. Of the 574 observations, 173 were small plot trials with an average increase of 4.39 bushels per acre; 401 observations were farm strip trials with an average increase of 3.89 bushels per acre. The average increase for corn on corn acres was 4.54 bushels per acre compared to corn on soybean acres at 3.96 bushels per acre. The average yield increase was greatest when the disease severity on the ear leaf was greater than 5 percent and this produced an average yield increase of 9.46 bushels per acre. When the disease severity on the ear leaf was less than 5 percent, the average yield increase was only 4.83 bushels per acre (Mueller & Robertson, 2010).

In 2015, another study at Iowa State University evaluated commercial fungicides. This research noted that northern corn leaf blight was present at each of the four trial locations. Across all of the different fungicides tested, the data across four locations presented an average yield increase of 5.8 bushels per acre which contributed to a 91.7

percent yield increase across locations, along with a 62.5 percent economic return on investment (Morton & Staub, 2008; Robertson, 2016).

Using a study from the University of Illinois, Dr. Fred Below (2015) and his team developed the "Seven Wonders of the Corn Year World." These include weather, nitrogen, hybrid, previous crop, plant population, tillage, and growth regulators. Below places fungicides into the growth regulator category. Below (2015) states, "If the maximum positive yield responses of each of these individual factors are summed together, a yield of approximately 260 bushels/acre can result. Therefore, to surpass this yield level, new management approaches that either increase the potential contributions of individual factors or exploit positive synergistic interactions among multiple factors are needed. Typically, agronomic studies tend to investigate each factor in separate experiments as an attempt to simplify the experimental design and interpretation of data. This reductionist approach has resulted in an underestimation of the value of modern genetics, crop protection products, and fertilizers that contrasts with the complexity of modern agriculture. Therefore, it is critical to understand the interactions of these factors evaluated as a whole in order to efficiently maximize corn yield and exploit the yield potential of modern corn hybrids grown under advanced levels of management. We believe that this type of research and information will be needed to develop technology packages that can take corn yields to the next level (300 bushels/acre), which is needed to meet an ever increasing food, feed, and fuel demand while sustaining the efficiency and productivity of our agricultural systems."

Below's research in 2009 and 2010 found an average yield increase of 5 bushels per acre with a fungicide in a standard program and found an average yield decrease of 27 bushels per acre when they did not use a fungicide. In 2011, the same research resulted in an average yield increase of 3 bushels per acre with a fungicide in a standard program and an average yield decrease of 8 bushels per acre when a fungicide was not used. Below (2015) stated, “Although we did not experience measureable disease pressure in 2011, application of a strobilurin fungicide was still beneficial in the high tech package.”

2.3 Conclusion

The literature review in this chapter discussed the history of fungicide along with University research on yield increases and an economic return on investment for a fungicide application. The most common subject from the literature review is that there is a yield benefit from a fungicide application along with an economic return on investment. This research provides the foundation needed to evaluate yield protection as a risk management strategy for corn grain farmers, who are often more focused on the cost per acre of an application rather than the economic return from investment, to help manage their operations risk and to help lower their cost per bushel across their operation.

CHAPTER III: THEORY

3.1 Risk Management

Managing crop production risk in agriculture is very important. Farmers typically spend \$670-\$715 per acre without much of a guarantee that they will produce an average crop due to Mother Nature. Weather can make or break a farmer's production year by being too wet in the spring, dry and hot in the summer during pollination, and freezing early before the crop is physiologically mature. According to Below (2015), Mother Nature will account for about 27% of a farmer's corn yield. That means for a 200 bushel per acre average yield, Mother Nature could decrease the corn yield by 54 bushels per acre or increase the yield by 54 bushels per acre.

A farmer's crop production operation generally faces both operational and financial risks. Operational risk deals with yield, price, and cost changes. Financial risk deals with the financing issue of the operation and debt and interest (Gloy, 2011). According to Boehlje and Gloy (2011), the market price per bushel has been drastically volatile in the last few years in price movements of local cash bids and the futures markets. They also commented that the price volatility is double what it was 5 to 10 years ago.

Not only do farmers have to handle price volatility for marketing their crop, but they also have to handle input cost volatility as well. "The fluctuations in fertilizer, chemical and energy costs have been the most dramatic. To date, seed, equipment and land costs have not fluctuated as much, but have been in a general upward trend. The resulting volatility in operating margins (price minus cost) has been even more dramatic than that of prices, costs or yields. In general, volatility in operating margins has more than doubled, and some have argued that they have increased by as much as 3 to 4 times compared to the past. There is no doubt that the operating risk in grain farming has increased dramatically in recent times" (Gloy, 2011).

3.2 Yield Protection

Larson (2014) stated that the yield potential of corn is at the highest when coming out of the bag. With that said, there are many factors that can affect corn yield other than just weather. Factors like disease, insect, and weed control can rob bushels away from yield. Factors like these are things that can be controlled to ultimately achieve the highest yield possible given the weather conditions.

Yield protecting factors include irrigation, harvest, marketing, weed control, insect control, and disease control; these factors contribute to the end goal of grain yield (Lauer, 2008). Death of leaves on a corn plant dying early results in yield loss. The reason this happens is because the plant cannot produce its energy because it is not producing chlorophyll since photosynthesis is not working due to the leaves not being green to absorb the sunlight. Lauer (2008) indicated that a foliar fungicide can be recommended if the disease is present on the third leaf below the ear leaf on half of the plants when the plants are at the tassel stage.

3.3 Crop Insurance

Crop insurance is similar to home owners and auto insurance and is a tool farmers can use to manage their risk. During an interview with Chad Henderson of Prime Agricultural Consultants (2017), he stated that farmers have the choice of yield and revenue protection for their business. Henderson (2017) also stated that farmers should always pick revenue protection because farmers always need revenue, not yield. Henderson is not only a broker, but also, owner of Prime Agricultural Consultants. Prime Agricultural Consultants is not just a brokerage firm, but a risk management firm for farmers. They advise farmers on marketing strategies and provide them with crop insurance. Prime Agricultural Consultants goal is “to look at the big picture and make marketing decisions to keep your family in business years down the road” (Consultants, 2017).

With revenue insurance, a farmer has an average production history which is a ten year average from the farm. Then, there are different coverage levels, for example, 65, 70, 75 percent coverage of the revenue. The final aspect of revenue protection is the price per bushel. The fall price is set in October and is the average price of the December futures for that year. The spring price is set in February and is the average price of the December futures for that year. Farmers get the higher price between the spring and fall price. For example, if the spring price is $3 per bushel and the fall price is $3.10 per bushel, the price used is $3.10 per bushel.

For revenue insurance a producer must pick the percent coverage desired. Henderson (2017) recommends 75 percent coverage because it provides the most value per dollar spent. After selecting the coverage level, the average production history and price that was set are used. If the average production history is 200 bushels per acre and the price was $3.10 per bushel, then the guarantee is $465 per acre. This number is derived by multiplying 200 bushels per acre times $3.10 per bushel times 75 percent coverage. This is why Henderson (2017) recommends revenue protection since it covers having lower prices and/or having lower yields.

3.4 Grain Marketing

Grain marketing is another tool farmers can use to help manage their risk. There are many different ways a farmer can market their grain like hedging or forward contracting. According to Hart (2013) of Iowa State University, “hedging is the substitution of a futures contract for a later cash-market transaction." Forward contracting is simply contracting and locking in a price for future delivery of the grain. Forward contracting works well because farmers can look into the future and decide if the price is better than today to sell.

3.5 Summary

This chapter discussed theories for risk management. These theories can help farmers manage uncertainty from price and weather. The theory behind crop insurance and grain marketing is to help farmers from uncertainty in their outcome so the business does not go bankrupt, similar to how home owners and vehicle owners have insurance on those assets; home and vehicle owners want to have a more known outcome in case of loss or damage. Farmers are not guaranteed a perfect year for weather to grow a crop along with being guaranteed a profitable price per bushel for the crop. Farmers utilize these tools to guarantee the business with revenue to help manage the expenses incurred over the growing season. These theories allow farmers a more known outcome for the business that helps manage the uncertainty with weather and market price fluctuations.

CHAPTER IV: METHODS

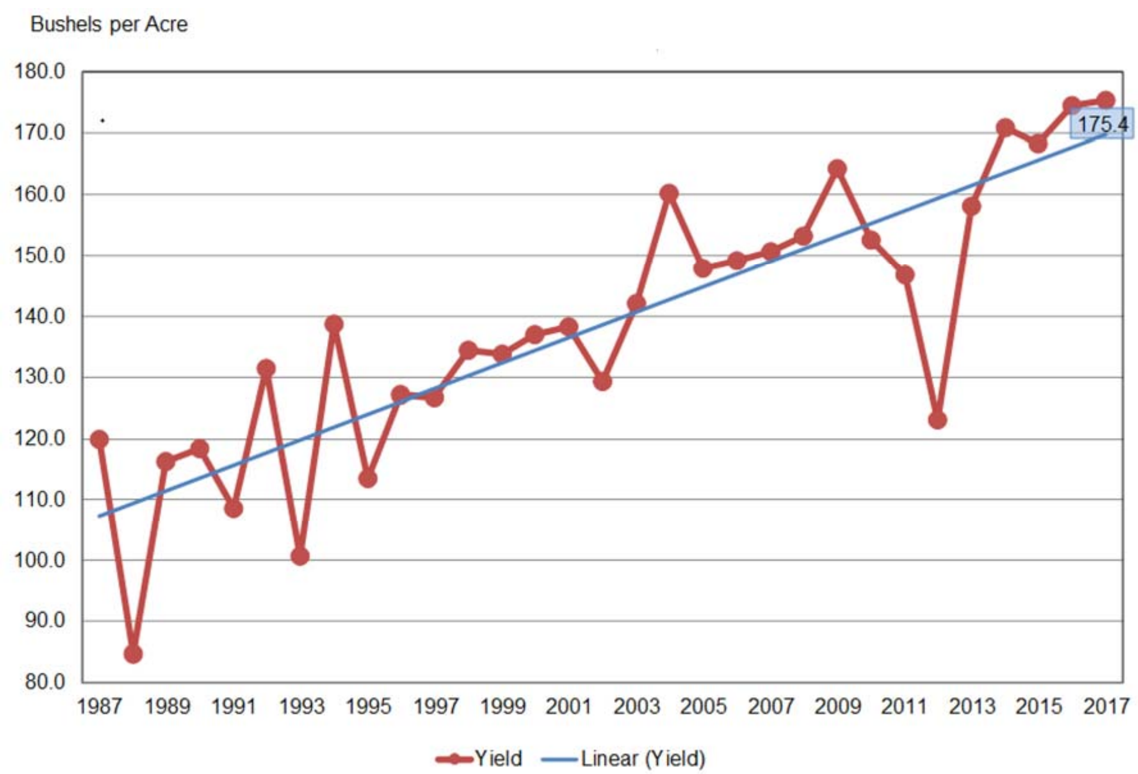
4.1 Overview

Since the 1970s, corn production has increased tremendously. According to the National Agricultural Statistic Service (NASS), U.S. average corn yield was 72.4 bushels per acre in 1970 compared to U.S. average corn yield in 2015 of 168.4 bushels per acre (Agriculture U. S., United States Department of Agriculture, 2016). In 45 years, the average U.S. corn yield production has increased by almost 100 bushels per acre because of advancements in today's modern corn hybrids. Corn yield is determined by the number of ears per acre and the number of kernels on each ear produced.

According to Abendroth (2011), "as with many plants, corn has been improved through years of genetic and management research to meet ever-growing demands for food, feed, and alternative uses. Advancements in corn management practices and genetics have substantially increased grain yield produced from an acre of land over the past 50 years. This increase in realized yields can be attributed in part to genetic advancements that have increased stress tolerance, improved resource capture, and increased yield stability. Genetic improvement has enabled corn plants to be grown in close proximity, resulting in greater yield potential from an acre of land. Contributing management factors made by producers include reduced tillage, earlier planting dates, increased plant density per acre, herbicide use for timely weed control, and synthetic fertilizers. As plant breeders selected for high grain yield, intentional and unintentional changes in plant architecture occurred, leading to improvements in grain production efficiency."

Although yield in the United States has increased, the variability in corn yield has not disappeared. Figure 4.1 shows the variability in corn yield since 1987. The chart shows less variability in recent years, but farmers still have factors outside their control that can affect their corn yield. Weather is the biggest variable farmers face each year. According to Below (2015), weather accounts for about 27% of corn yield. This is why farmers use risk management tools like crop insurance, and it is the same reason why home owners have home owners insurance, to protect themselves from a total or partial loss.

Figure 4.1: United States Average Corn Yield since 1987



Source: USDA-NASS

This thesis examines the use of fungicide for yield protection as a risk management strategy. A regression model is used to analyze the effect of corn treated with fungicide, fungicide with an adjuvant, fungicide with an insecticide, and an untreated check on corn yield. An Ordinary Least Squares (OLS) model is estimated to determine if there is a statistically significant difference between the treatments that protect yield against the untreated check. The variables used in the OLS models are listed below in Table 4.1 along with the expected sign for their coefficients.

Table 4.1: Expected Coefficient Signs

	Expected Coefficient Signs
Fungicide	+
FungicideAdjuvant	+
FungicideInsecticide	+
Untreated	Control
Location 1	-
Location 2	-
Location 3	-
Location 4	-
Location 5	+
Location 6	Control

The fungicide coefficient is expected to be positive. If a fungicide is applied on corn, it is expected to have a positive impact on corn yield.

The fungicide with an adjuvant expected coefficient is also expected to be positive. It is expected that using an adjuvant will have a greater positive impact compared to not using one since there should be less evaporation when an adjuvant is applied with the fungicide; adjuvants are oil based, not water based. When an airplane applies the fungicide, the spray can evaporate before it works into the crop canopy. When the adjuvant is incorporated, evaporation is more difficult because the water droplets have an oil base to them thus allowing them to work into the crop canopy with less loss to evaporation.

The fungicide with insecticide is expected to have a positive impact on yield. By incorporating the insecticide, the plant is protected from insects that can chew on the leaves and disrupt photosynthesis and is protected against the insects that clip the silks on the ear that transfers pollen from the tassel to ear. If silks are not accessible to the pollen, the ear will not be able to produce a kernel in that spot resulting fewer kernels per ear.

The untreated check expected coefficient is the control. By not treating the corn crop with a fungicide, fungicide and an adjuvant, as well as, fungicide and insecticide, we would expect to have less yield because we did not protect against disease or insects.

The Illinois location (location 1) coefficient is expected to have a negative impact on yield. By growing corn at location 1, we would expect to have lower yield because of soil type being less productive, weather conditions like temperature and precipitation not as favorable for growing corn along with the potential for disease being less compared to the Ohio (location 6) location.

The Kansas location (location 2) coefficient is expected to have a negative impact on yield. Growing corn at location 2, we would expect to have lower yield because of soil type being less productive, weather conditions like temperature and precipitation not as favorable for growing corn along with the potential for disease being less compared to the Ohio (location 6) location.

The Kentucky location (location 3) coefficient is expected to have a negative impact on yield. Growing corn at location 3, we would expect to have lower yield because of soil type being less productive, weather conditions like temperature and precipitation not as favorable for growing corn along with the potential for disease being less compared to the Ohio (location 6) location.

The Missouri location (location 4) coefficient is expected to have a negative impact on yield. Growing corn at location 4, we would expect to have lower yield because of soil type being less productive, weather conditions like temperature and precipitation not as favorable for growing corn along with the potential for disease being less compared to the Ohio (location 6) location.

The Nebraska location (location 5) coefficient is expected to have a positive impact on yield. Growing corn at location 5, we would expect greater yield because of the ability to control water for the crop with irrigation. Soils at this location are not as productive along with the climate being dry. Irrigation allows this location to be more productive than location 6 and with more productive corn, the disease potential is greater for growing corn.

The location 6 expected coefficient is the control.

The OLS model for yield is expressed as:

$$Yield = \beta_0 + \beta_1 (Fungicide) + \beta_2 (Fungicide\ Adjuvant) + \beta_3 (Fungicide\ Insecticide) + \beta_4 (Location\ 1) + \beta_5 (Location\ 2) + \beta_6 (Location\ 3) + \beta_7 (Location\ 4) + \beta_8 (Location\ 5)$$

4.2 Explanation of Variables

Variables used in this thesis were Fungicide, Fungicide Adjuvant, Fungicide Insecticide, Location 1, Location 2, Location 3, Location 4, and Location 5. These variables are all binary, also known as dummy variables, and are 0, 1 in value.

The fungicide variable is used where the corn crop was treated with a fungicide. When the crop is treated, it will have a 1 in value; when the crop is not treated with a fungicide it will have a 0 in value. For an example, the yield data associated to the fungicide treatments use 1 to code the data points to the fungicide variable. All other data points use 0 to code the data points not associated to the fungicide variable.

The fungicide adjuvant variable is used where the corn crop was treated with a fungicide and an adjuvant. When the crop is treated, it will have a 1 in value; when the crop is not treated with a fungicide and adjuvant it will have a 0 in value. For example, the yield data associated to the fungicide and adjuvant treatments use 1 to code the data points to the fungicide and adjuvant variable. All other data points use 0 to code the data points not associated to the fungicide and adjuvant variable.

The fungicide insecticide variable is used where the corn crop was treated with a fungicide and an insecticide. When the crop is treated, it will have a 1 in value; when the crop is not treated with a fungicide and insecticide it will have a 0 in value. For example, the yield data associated to the fungicide and insecticide treatments use 1 to code the data points to the fungicide and insecticide variable. All other data points use 0 to code the data points are associated to the fungicide and insecticide variable.

The location 1 variable is used when there was yield data at location 1. When there was yield data at location 1, it will have a 1 in value; when there was not any yield at location 1 it will have a 0 in value. For example, the yield data associated to location 1 use 1 to code the data points to location 1. All other data points use 0 to code the data points not associated to location 1 variable.

The location 2 variable is used when there was yield data at location 2. When there was yield data at location 2, it will have a 1 in value; when there was not any yield at location 2 it will have a 0 in value. For example, the yield data associated to location 2 use 1 to code the data points to location 2. All other data points use 0 to code the data points not associated to location 2 variable.

The location 3 variable is used when there was yield data at location 3. When there was yield data at location 3, it will have a 1 in value; when there was not any yield at location 3 it will have a 0 in value. For example, the yield data associated to location 3 use 1 to code the data points to location 3. All other data points use 0 to code the data points not associated to location 3 variable.

The location 4 variable is used when there was yield data at location 4. When there was yield data at location 4, it will have a 1 in value; when there was not any yield at location 4 it will have a 0 in value. For example, the yield data associated to location 4 use 1 to code the data points to location 4. All other data points use 0 to code the data points not associated to location 4 variable.

The location 5 variable is used when there was yield data at location 5. When there was yield data at location 5, it will have a 1 in value; when there was not any yield at location 5 it will have a 0 in value. For example, the yield data associated to location 5 use 1 to code the data points to location 5. All other data points use 0 to code the data points not associated to location 5 variable.

4.3 Summary

This thesis will examine corn treated with a fungicide, fungicide and an adjuvant, fungicide and an insecticide compared to corn treated with any treatment. These studies were conducted at multiple locations; the untreated check and location 6 are the controls for the study and are shown as the constant in the model.

CHAPTER V: DATA

5.1 Yield

Yield data for yield protection was collected from six separate locations across the Midwestern United States. Table 5.1 outlines location number to corresponding state. The data were replicated across all treatments with some locations having multiple years of data at the same site. The data consist of fungicide, fungicide with an adjuvant, fungicide with an insecticide, and untreated yield and moisture information. The moisture information is the grain moisture at time of harvest. The moisture information is to just be a visual to present the differences from the treatments. The same management practices and hybrids were used within each treatment, this way we can analyze the yield data to find out if using any of the treatments will allow farmers to increase yield consistently each year compared to the untreated check. Tables 5.2, 5.3, 5.4, 5.5, 5.6, and 5.7 provide the data for each location.

Table 5.1: Location Number to Corresponding State

Location	State	State Average Yield (Bu/ Ac)	Irrigation
1	IL	197.00	NO
2	KS	142.00	NO
3	KY	159.00	NO
4	MO	163.00	NO
5	NE	199.90	YES
6	OH	159.00	NO

Source: USDA-NASS

Table 5.2: Location 1 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
1	Fungicide/Adjuvant	166.80	16.16
1	Fungicide/Adjuvant	151.80	15.72
1	Fungicide/Adjuvant	149.20	17.12
1	Fungicide/Adjuvant	130.20	16.18
1	Fungicide/Adjuvant	125.70	16.17
1	Fungicide/Adjuvant	143.60	16.04
1	Fungicide/Insecticide	151.00	15.66
1	Fungicide/Insecticide	152.40	16.05
1	Fungicide/Insecticide	134.20	17.56
1	Fungicide/Insecticide	142.00	17.47
1	Fungicide/Insecticide	136.30	16.01
1	Fungicide/Insecticide	132.20	15.51
1	Fungicide/Insecticide	137.80	15.74
1	Untreated	148.60	19.71
1	Untreated	138.10	16.10
1	Untreated	118.00	15.21
1	Untreated	140.40	15.20

Table 5.3: Location 2 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
2	Fungicide	205.05	18.19
2	Fungicide	220.54	17.22
2	Fungicide	204.82	17.78
2	Fungicide	211.16	17.00
2	Fungicide	219.59	17.42
2	Fungicide	185.49	18.02
2	Fungicide	222.21	17.76
2	Fungicide	198.63	17.71
2	Fungicide/Adjuvant	198.10	17.58
2	Fungicide/Adjuvant	214.02	17.57
2	Fungicide/Adjuvant	217.64	17.78
2	Fungicide/Adjuvant	219.39	18.03
2	Fungicide/Adjuvant	212.40	17.87
2	Fungicide/Adjuvant	214.36	17.40
2	Fungicide/Adjuvant	208.65	17.36
2	Fungicide/Adjuvant	214.49	17.71
2	Fungicide/Insecticide	209.35	18.26
2	Fungicide/Insecticide	210.96	17.70
2	Fungicide/Insecticide	200.84	17.63
2	Fungicide/Insecticide	206.82	17.45
2	Fungicide/Insecticide	213.34	17.98
2	Fungicide/Insecticide	205.41	18.27
2	Fungicide/Insecticide	194.71	16.71
2	Fungicide/Insecticide	218.86	17.05
2	Untreated	203.27	17.81
2	Untreated	205.85	17.62
2	Untreated	203.57	17.19
2	Untreated	209.97	17.28

Table 5.4: Location 3 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
3	Fungicide	194.90	20.50
3	Fungicide	216.30	18.60
3	Fungicide	209.10	19.00
3	Fungicide	187.70	18.90
3	Fungicide	204.20	18.10
3	Fungicide	191.50	18.40
3	Fungicide	199.70	18.40
3	Fungicide	179.20	18.30
3	Fungicide	182.90	17.20
3	Fungicide	186.60	17.69
3	Fungicide	184.50	18.10
3	Fungicide	198.60	17.50
3	Fungicide	189.00	18.40
3	Fungicide	197.80	18.40
3	Fungicide	176.10	18.30
3	Fungicide	193.70	18.30
3	Fungicide	188.20	17.70
3	Fungicide	188.70	17.40
3	Fungicide	184.40	18.00
3	Fungicide	175.40	18.00
3	Fungicide/Adjuvant	193.40	18.40
3	Fungicide/Adjuvant	199.10	18.40
3	Fungicide/Adjuvant	205.40	18.60
3	Fungicide/Adjuvant	190.10	18.50
3	Fungicide/Adjuvant	205.40	18.60
3	Fungicide/Adjuvant	197.80	18.40
3	Fungicide/Adjuvant	209.40	18.50
3	Fungicide/Adjuvant	185.30	18.10
3	Fungicide/Adjuvant	177.30	17.10
3	Fungicide/Adjuvant	194.40	17.70
3	Fungicide/Adjuvant	197.50	17.50
3	Fungicide/Adjuvant	187.80	17.60
3	Fungicide/Adjuvant	199.90	19.30
3	Fungicide/Adjuvant	200.80	19.50
3	Fungicide/Adjuvant	196.50	19.30
3	Fungicide/Adjuvant	213.60	19.60

Table 5.4: Location 3 Data Continued

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
3	Fungicide/Insecticide	193.00	18.30
3	Fungicide/Insecticide	198.80	18.50
3	Fungicide/Insecticide	206.40	18.20
3	Fungicide/Insecticide	205.20	18.20
3	Fungicide/Insecticide	206.60	17.60
3	Fungicide/Insecticide	188.10	18.80
3	Fungicide/Insecticide	184.60	17.60
3	Fungicide/Insecticide	183.60	17.80
3	Fungicide/Insecticide	204.80	18.60
3	Fungicide/Insecticide	197.30	18.10
3	Fungicide/Insecticide	208.60	17.10
3	Fungicide/Insecticide	199.20	18.60
3	Fungicide/Insecticide	207.30	17.50
3	Fungicide/Insecticide	155.20	17.10
3	Fungicide/Insecticide	217.70	18.30
3	Fungicide/Insecticide	183.00	17.10
3	Untreated	177.80	18.40
3	Untreated	184.70	18.10
3	Untreated	171.10	18.60
3	Untreated	172.80	18.10
3	Untreated	173.10	17.90
3	Untreated	178.80	18.60
3	Untreated	184.80	17.20
3	Untreated	170.70	18.40
3	Untreated	194.20	18.70
3	Untreated	191.80	19.30
3	Untreated	203.30	18.60
3	Untreated	208.20	18.70

Table 5.5: Location 4 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
4	Fungicide	124.30	16.20
4	Fungicide	167.90	16.00
4	Fungicide	87.20	20.70
4	Fungicide	143.10	22.50
4	Fungicide	163.40	15.90
4	Fungicide	155.10	17.60
4	Fungicide	170.60	16.30
4	Fungicide	166.10	20.70
4	Fungicide/Adjuvant	94.00	24.40
4	Fungicide/Adjuvant	143.50	16.90
4	Fungicide/Adjuvant	171.10	20.70
4	Fungicide/Adjuvant	142.20	18.60
4	Untreated	162.20	16.00
4	Untreated	160.20	15.60
4	Untreated	157.40	16.40
4	Untreated	114.40	15.60

Table 5.6: Location 5 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
5	Fungicide	219.40	18.80
5	Fungicide	240.30	19.00
5	Fungicide	266.30	17.80
5	Fungicide	265.50	22.00
5	Fungicide	275.50	21.60
5	Fungicide	280.00	20.80
5	Fungicide	258.30	21.90
5	Fungicide	237.70	19.20
5	Fungicide	238.30	18.00
5	Fungicide	254.20	18.00
5	Fungicide/Adjuvant	252.70	18.80
5	Fungicide/Adjuvant	235.10	17.90
5	Fungicide/Adjuvant	218.00	17.80
5	Fungicide/Adjuvant	266.80	21.40
5	Fungicide/Adjuvant	284.70	21.20
5	Fungicide/Adjuvant	275.30	21.30
5	Fungicide/Adjuvant	260.20	21.90
5	Fungicide/Insecticide	228.30	18.90
5	Fungicide/Insecticide	262.30	18.50
5	Fungicide/Insecticide	266.80	18.80
5	Fungicide/Insecticide	193.00	19.00
5	Fungicide/Insecticide	281.40	18.00
5	Fungicide/Insecticide	257.50	18.30
5	Untreated	244.70	16.80
5	Untreated	256.60	18.50
5	Untreated	254.00	18.10
5	Untreated	237.40	20.70
5	Untreated	261.10	21.80
5	Untreated	267.60	20.40
5	Untreated	256.00	21.10

Table 5.7: Location 6 Data

Location	Treatment	Yield (Bu/Ac)	Moisture (%)
6	Fungicide	233.21	16.90
6	Fungicide	225.71	17.60
6	Fungicide	241.65	19.40
6	Fungicide	250.29	18.90
6	Fungicide	255.24	17.10
6	Fungicide	239.51	17.80
6	Fungicide	222.07	19.00
6	Fungicide	249.56	19.00
6	Fungicide/Adjuvant	240.56	16.50
6	Fungicide/Adjuvant	223.59	19.00
6	Fungicide/Adjuvant	226.95	19.10
6	Fungicide/Adjuvant	258.84	17.40
6	Fungicide/Insecticide	229.92	16.40
6	Fungicide/Insecticide	201.87	18.30
6	Fungicide/Insecticide	236.47	18.70
6	Fungicide/Insecticide	209.92	17.90
6	Fungicide/Insecticide	237.89	16.20
6	Fungicide/Insecticide	213.44	17.50
6	Fungicide/Insecticide	200.94	19.50
6	Fungicide/Insecticide	232.36	18.30
6	Untreated	214.31	17.60
6	Untreated	201.71	17.70
6	Untreated	234.56	17.20
6	Untreated	207.08	17.30

The fungicides were a combination of a Group 3&11 premix along with a Group 3&33 premix. According to the Fungicide Resistance Action Committee (2005), a Group 3 fungicide is a DeMethylation Inhibitor and consist of imidazoles, piperazines, pyridines, pyrimidines, and triazoles; a Group 11 fungicide is a Quinone outside Inhibitor and consist of methoxyacrylates, methoxy-carbamates, oximino acetates, oximino-acetamides, oxazolidine-diones, dihydro-dioxazines, and imidazolinones; a Group 33 is a Phosphonates and consist of ethyl phosphonates. By combining all fungicides together, it allows the data to be more uniform while still being able to use and analyze all data points.

The fungicide and adjuvant category utilizes the same combinations as the fungicides only category. These are a Group 3&11 premix along with a Group 3&33 premix. The adjuvant that is used with the fungicides is a Non-Ionic Surfactant. According to Pinnacle Agriculture Distribution, “Non-ionic surfactants are used for general wetting and spreading. They reduce the surface tension and contact angle of individual spray droplets. They may also provide physical penetration into the cracks, crevices and hairs of the leaf. Their primary use is with contact pesticides. Non-ionic surfactants work best with water-soluble herbicides, insecticides, fungicides and PGRs” (Distribution, 2017). Greater yield is expected when an adjuvant is added to the fungicide because together these provide better coverage and distribution of the material onto the plant.

The fungicide and insecticide category utilizes the same fungicides as the previous two categories, but adds a Group 3 insecticide. When thinking about yield protection of grain corn, there are two things that can rob yield from the crop, those are diseases and insects. With this combination, yield is truly protected; bugs are not able to affect the length of the silks to disrupt pollination by cutting and chewing on them and disease is not capable of spreading to disrupt photosynthesis.

The untreated category did not have any fungicides, fungicide and adjuvant, or fungicide and insecticides applied to them. The untreated segment represents the check or grower standard to analyze if the treatments bring yield protection or yield increases. The same management was used within the untreated and other treatments; for example, hybrid, pounds of fertilizer per acre, weed control, row spacing, etc.

5.3 Grain Marketing

Grain marketing is another tool farmers can use as a risk management strategy to get a better price for their crop compared to harvesting and selling all their grain at the cash price for that given day. Hart (2013) states, "hedging is the substitution of a futures contract for a later cash-market transaction." For a farmer to hedge, he/she would sell a futures contract and buy the futures contract back to offset the transaction when he/she sells the physical commodity in the cash market. Tables 5.9, 5.10, and 5.11 are examples of hedging as a risk management tool for farmers and marketing their crop.

Table 5.9: Hedging Example

Futures Price	Historical Basis	Commission	Expected Price
$5.90	($0.25)	($0.01)	$5.64

Table 5.9 is an example of a farmer hedging. This example shows the futures price for a contract that the farmer would sell their grain at today and buy the contract back at a later date when the grain is sold on the cash market.

Table 5.10: Hedging Example with Price Increase

Futures Price	Actual Basis	Local Cash Price	Net Value from Futures	Net Price
$6.00	($0.25)	$5.75	($0.11)	$5.64

Table 5.10 is an example of how hedging can be a disadvantage for farmers. As explained before, farmers receive the local cash price for their grain. In this example, the

farmer could have received $5.75 per bushel for the grain, but instead hedging was used to try and capture more than the local cash market. In this example, the farmer bought the contract back at $6.00 per bushel when the farmer originally sold the contract in Table 5.9 at $5.90 per bushel; the farmer lost $0.10 per bushel plus the $0.01 for commission which would get subtracted from the local cash price to determine the net price the farmer would receive for the grain. The farmer's net price was $5.64 per bushel. The goal of hedging for farmers is buy low, sell high.

Table 5.11: Hedging Example with Price Decrease

Futures Price	Actual Basis	Local Cash Price	Net Value from Futures	Net Price
$4	($0.25)	$3.75	$1.89	$5.64

Table 5.11 is an example of how hedging can be an advantage for farmers. As explained before, farmers receive the local cash price for their grain. In this example, the farmer could have received $3.75 per bushel for the grain, but instead hedging was used to try and capture more than the local cash market. In this example, the farmer bought the contract back at $4.00 per bushel when the farmer originally sold the contract in Table 5.9 at $5.90 per bushel; the farmer made $1.90 per bushel minus the $0.01 for commission which would get added to the local cash price to determine the net price the farmer would receive for the grain. The farmer's net price per bushel was $5.64. The goal of hedging for farmers is buy low, sell high.

Along with hedging, Hart (2013) also points out that there are also cash contracts. Most of these cash contracts are called forward contracts. These contracts lock in the price, as well as delivery terms for delivering the bushels on the contract. Henderson (2017) indicates that most farmers are utilizing forward cash contracts as their grain marketing risk management strategy.

5.2 Crop Insurance

Data for crop insurance came from a personal interview with Chad Henderson of Prime Agricultural Consultants. During a personal interview, Henderson provided a breakdown on insurance premium costs to the farmer and United States Government payment amounts. Table 5.8 provides a breakdown for non-irrigated corn in Racine County Wisconsin. The historical average production is 200 bushels per acre, and the number of acres covered is 1,000.

Table 5.8: Insurance Breakdown

Level (%)	Price ($)	Trigger (Bu/Ac)	Acre Guarantee ($)	Acre Coverage ($)	Acre Premium ($)	Total Guarantee ($)	Total Coverage ($)	Total Premium ($)
60	3.96	120	475.20	475.20	2.26	475,200.00	475,200.00	11,279.60
65	3.96	130	514.80	514.80	3.05	514,800.00	514,800.00	15,240.50
70	3.96	140	554.40	554.40	4.25	554,400.00	554,400.00	21,251.10
75	3.96	150	594.00	594.00	6.61	594,000.00	594,000.00	28,716.50
80	3.96	160	633.60	633.60	12.12	633,600.00	633,600.00	37,894.20
85	3.96	170	673.20	673.20	23.10	673,200.00	673,200.00	49,135.90

Source: Henderson, 2017

In Table 5.8, Level is the percent coverage for the average production history; for example, if 60 percent coverage is chosen with a 200 bushel per acre average production history, the covered amount will be for 120 bushels per acre which is what the trigger column shows. The trigger column shows the yield level below at which the insurance payment would be triggered. The price column is based on an average futures market corn price and is the higher price of the fall and spring price. Fall price is set in the month of October, based on the average December futures price for that year. The spring price is set in the month of February based on the average December futures price for that year. For example, if the average spring price was $3 per bushel and the average fall price was $3.10 per bushel, the insurance price used in the price column would be $3.10 per bushel. The acre guarantee column is simply the price times the trigger, and since everything is on an acre basis, the acre guarantee and coverage are the same. Acre premium is the cost per acre that the farmer would pay; the premium increases as the coverage percent increases. Total guarantee and coverage are based on the total acres that are covered in the insurance policy; since Table 5.8 is based on 1,000 acres, the total guarantee and coverage are 1,000 times the acre guarantee and coverage, respectively. Lastly, total premium is the total amount the policy would cost across the 1,000 acres. If the total premium is divided by 1,000 that equals total cost per acre for the policy. Looking at the 60 percent coverage, total cost would be about $11.28 per acre. The government is going to pay $9.02 per acre while the grower only pays $2.26 per acre for the policy.

5.4 Summary

This chapter provided the yield data used in model to examine yield protection as a risk management strategy. An example of crop insurance was provided to explain how the tool is advantageous to farmers in reducing the uncertainty faced and how crop insurance gives farmers a more known outcome for the business. An example of hedging was also provided to explain how the tool is advantageous to farmers in reducing the uncertainty faced with grain market pricing and how hedging gives farmers a more known outcome with revenue for the business. Crop insurance and hedging provide farmers a more known outcome with revenue to help offset expenses. The model that will use the yield data provided will determine if yield protection can protect bushels to give farmers a more known outcome with the volume of grain to be marketed.

CHAPTER VI: RESULTS

Table 6.1 provides summary statistics of the data.

Table 6.1: Data Summary of Dependent Variables

Treatment	Average Yield (bu/ac)	Average Mositure (%)	Minimum Yield (bu/ac)	Maximum Yield (bu/ac)	Minimum Moisuture (bu/ac)	Maximum Moisture (%)	Yield Standard Deviation	Moisture Standard Deviation
Fungicide	213.70	18.87	87.20	280.00	15.90	22.50	38.12	1.47
Fungicide/ Adjuvant	204.57	18.61	94.00	284.70	15.39	24.40	40.67	1.71
Fungicide/ Insecticide	201.81	17.74	132.20	281.40	15.51	19.50	34.83	0.97
Untreated	213.06	17.55	114.40	267.60	15.20	29.40	40.28	1.59

Table 6.2: Yield by Treatment and Location Regression

Dependent variable: Yield by Treatment and Location, using Observations 1-191					
	Coefficient	**Std. Error**	**t-ratio**	**p-value**	
Const	225.856	4.05615	55.6824	<0.0001	***
Fungicide	4.33755	3.27595	1.3241	0.1871	
FungicideAdjuvant	5.87868	3.42836	1.7147	0.0881	*
FungicideInsecticide	1.11017	3.50063	0.3171	0.7515	
Location1	−87.3119	5.23201	−16.6880	<0.0001	***
Location2	−20.1812	4.53183	−4.4532	<0.0001	***
Location3	−35.2251	3.87326	−9.0944	<0.0001	***
Location4	−88.1872	5.02543	−17.5482	<0.0001	***
Location5	26.741	4.3677	6.1224	<0.0001	***
Mean dependent var	200.9846		**S.D. dependent var**	40.2092	
Sum squared resid	48040.61		**S.E. of regression**	16.2468	
R-squared	0.843612		**Adjusted R-squared**	0.83674	
F(8, 182)	122.7214		**P-value(F)**	3.81E-69	
Log-likelihood	−798.8962		**Akaike criterion**	1615.79	
Schwarz criterion	1645.063		**Hannan-Quinn**	1627.65	

*, **, *** denote significance at the 10%, 5%, and 1% levels

Results from Table 6.2 provides the yield by treatment and location model. The fungicide treatment (Fungicide) was expected to have a positive effect on yield. The estimated coefficient was positive, but was insignificant at the 1, 5, and 10 percent levels. The fungicide and adjuvant treatment (FungicideAdjuvant) was expected to have a positive effect on yield. The estimated coefficient was positive, but was insignificant at the 1 and 5 percent levels. The fungicide and adjuvant treatment was statistically significant at the 10 percent level; one could expect to have about a 6 bushel per acre increase nine out of ten times when they use a fungicide with an adjuvant. The fungicide and insecticide treatment (FungicideInsecticide) was expected to have a positive effect on yield. The estimated coefficient was positive, but was insignificant at the 1, 5, and 10 percent levels. The location 1 treatment (Location1) was expected to have a negative effect on yield. The estimated coefficient was negative, and was statistically significant at the 1, 5, and 10 percent levels. The location 2 treatment (Location2) was expected to have a negative effect on yield. The estimated coefficient was negative, and was statistically significant at the 1, 5, and 10 percent levels. The location 3 treatment (Location3) was expected to have a negative effect on yield. The estimated coefficient was negative, and was statistically significant at the 1, 5, and 10 percent levels. The location 4 treatment (Location4) was expected to have a negative effect on yield. The estimated coefficient was negative, and was statistically significant at the 1, 5, and 10 percent levels. The location 5 treatment (Location5) was expected to have a positive effect on yield. The estimated coefficient was positive, and was statistically significant at the 1, 5, and 10 percent levels.

The equation for the estimated model is as follows:

Yield = 225.856 + 4.33755 (Fungicide) + 5.87868 (FungicideAdjuvant) + 1.11017 (FungicideInsecticide) - 87.3119 (Location1) - 20.1812 (Location2) - 35.2251 (Location3) - 88.1872 (Location4) + 26.741 (Location5)

An explanation of the slope coefficients is as follows:

- Fungicide: If a fungicide is used, yield would increase 4.33755 bushels per acre relative to no treatment holding all other variables equal.
- FungicideAdjuvant: If a fungicide with an adjuvant is used, yield would increase 5.87868 bushels per acre relative to no treatment holding all other variables equal.
- FungicideInsecticide: If a fungicide with an insecticide is used, yield would increase 1.11017 bushels per acre relative to no treatment holding all other variables equal.
- Location1: Yield levels at location 1 are 87.3119 bushels per acre less relative to location 6 holding all other variables equal.
- Location2: Yield levels at location 2 are 20.1812 bushels per acre less relative to location 6 holding all other variables equal.
- Location3: Yield levels at location 3 are 35.2251 bushels per acre less relative to location 6 holding all other variables equal.
- Location4: Yield levels at location 4 are 88.1872 bushels per acre less relative to location 6 holding all other variables equal.
- Location5: Yield levels at location 5 are 26.741 bushels per acre more relative to location 6 holding all other variables equal.

Coefficient signs and results were as expected. All treatments had a positive increase over the control along with yield levels compared to location 6 were correct. In the end, all locations were statistically significant at the one percent level while fungicide with an adjuvant was statistically significant at the ten percent level.

CHAPTER VII: CONCLUSION

The estimated OLS regression models provided some insights into the determination of whether yield protection could be used as a risk management tool like grain marketing and crop insurance. Understanding risk management and how yield protection works can result in a better and more profitable farming operation for farmers. If the farmers are not struggling, then the retailers, distributors, and manufacturers will also be more profitable.

The yield by treatment and location regression model showed yield protection brings a positive increase to yield compared to the untreated check. This model also showed that fungicide only and the fungicide with insecticide data was not statistically significant. This model showed there was a greater increase in yield when there was an adjuvant added with a fungicide compared to the untreated check, but the addition of an insecticide as well as fungicide alone was not as much of an increase.

The fungicide with an adjuvant treatment was statistically significant at the ten percent level. One could expect about a 6 bushel per acre yield increase when they use a fungicide with an adjuvant nine out of ten times. With a cost to the corn grain farmer of about $29 per acre, the treatment did not have a return on investment. However, what could that return on investment be if disease was the yield limiting factor? Instead of the fungicide with an adjuvant costing the corn grain farmer $29 per acre, the additional yield increase bought the cost of the treatment down to about $9 per acre which is what the net cost of the treatment is to the corn grain farmer.

The yield by treatment and location regression model showed a large amount of variability with the yield levels at each location. There are a number of factors from soil type and weather conditions, just to name a few, that can cause the inconsistency in the yield levels. Location 5 was able to control one variable which was water and that is why that location had the highest yield level across all locations. Each location provided a good representation of the data across a corn growing region, but location 5 goes to show how important water is to growing a corn crop and that yield levels can be significantly less without it. Each location was statistically significant at the 1, 5, and 10 percent levels which allows the focal point to be on the treatments and making sure they are statistically significant because each location would be able to support the treatments.

In the end, there was not enough statistically significant data within all the treatments to conclude yield protection can be utilized as a risk management tool. Fungicide with an adjuvant showed that it was statistically significant at the 10 percent level, but there was not enough of a yield increase across all treatments which resulted in none of the treatments breaking-even for the farmer. Though the results from the treatments did not break-even for the farmer, fungicide with an adjuvant treatment was able to buy the cost of the treatment down to about $9 per acre because of the yield increase it does have nine out of ten times. To compare, does crop insurance always pay off for the farmer? In some places it does, but in others it is a true expense to the bottom line. In the end, the goal of crop insurance should be to get out what has been paid in with premiums over a ten year period; the same thing could be true with the fungicide and an adjuvant treatment. The results of the data used in this thesis are consistent with results found by Daren Mueller and Alison Robertson at Iowa State University in 2007-2009 (2010). The breakeven for the data used in this thesis was 10 bushels per acre at a $3 per bushel market price; a $30 per acre cost that included the fungicide and application cost.

7.1 Study Improvements

Overall, while variables were statistically significant, they did not provide enough yield advantage compared to the control. With any study however, there is always room for improvement. In the data, more years of data points for each location would probably enhance the ability to see if yield protection could be a financially appealing risk management tool for corn grain farmers. Furthermore, more years of data at each location would allow a model to be run for each individual location to analyze significant yield between each treatment. This would allow the data to be examined on a regional basis compared to a yield level basis.

The disease scores were not included with the data. As it is today, there is not a standard for scoring disease on corn plants across two people. Being able to utilize the disease score ratings in the regression would require a standard process to score disease. This standard process would allow multiple people from multiple geographies to score plants the exact same thus being able to determine when treatments should be applied to maximize the return on investment for the farmer.

As corn grain market prices continue to remain low and input costs continue to rise, it is important for farmers to manage their risk. Crop insurance and grain marketing will be the fundamentals used to get through this time in production agriculture when margins are tight. Depending on the pricing of fertilizer and land rental cost, corn grain farmers are looking at a $3.00 per bushel to $3.50 per bushel breakeven market price to grow 200 bushel per acre corn yield (Hofstrand, Iowa State University Extension and Outreach, 2017). Yield protection is a tool farmers need to keep in their tool box. They should utilize this tool like any other pesticide; when the disease percentage and insect numbers are approaching application thresholds is when farmers should take action for yield protection. In order to achieve maximum return on investment for yield protection, farmers will continually need to scout their crops and determine if the presence of disease or insects is high enough to warrant a yield protection application.

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