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Title: A Farm-Level Analysis of Special Purpose Crop Production

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Abstract:

Special purpose crops are those with traits designed to meet the specific demands of an end user. A mean-variance (E-V) mathematical programming model and sensitivity analysis are used to quantify and discuss the potential net returns and risk associated with the adoption of special purpose crops at the farm level.

Background

The varieties of crops that are being produced in the US are changing rapidly. Within three years of the initial introduction of biotech crops (e.g. Bt Corn) in 1996, around 50 million acres were being grown (Riley, Hoffman and Ash). Approximately 60 percent of the harvested soybean acres in the U.S. were herbicide resistant and around 40 percent of the harvested corn acres were some type of biotech varieties by 1999 (Lin, Chambers, and Harwood). Biotech crops were followed by special purpose crops, which are those with output traits designed to meet the specific demands of end users. This category of crops includes special purpose soybeans, corn, and wheat. The focus of this study is high oil corn, which was developed through traditional breeding practices. Thus, as with many other special purpose crops, high oil corn can be distinguished from genetically modified crops, which have received such negative reactions in Europe. The high-oil corn varieties are currently the most popular special purpose crop with around one million acres planted in 1999 (Lin, Chambers, and Harwood). Around half of the high-oil corn grown in the U.S. in 1998 was under contract for the export market, while the rest was used in domestic livestock production (ISFP).

With low prices for traditional commodities, special purpose crops offer growers the opportunity to add value to their crop production and earn greater revenue. However, they must weigh these benefits against added costs and risks. Although special purpose crops may earn higher expected profits, the returns may show greater year-to-year variation than the returns for conventional corn. Research is needed to aid farmers in assessing the benefits of including these crops in their production plans. In addition, the marketing arrangements currently utilized for these crops may result in farmers losing profits to the contractors. With accurate knowledge about the potential net returns and risks of these crops, farmers will be in a position to better assess their net impact on farm profits.

The relatively small volume of the various special purpose crops limits the development of commodity markets for them. Thus, contractual arrangements have become increasingly popular among these varieties. The expeditious development of contracting has further hindered the development of commodity markets. The contractual arrangements meet the demands of end-users that desire a very specific product and wish to obtain more control over the type and quantity of crop produced and the production practices utilized.

Dupont Specialty Grains (DSG), originally formed in January 1998 as Optimum Quality Grains, a joint venture of Dupont and Pioneer, is the license holder of the Top Cross High Oil Blend®, the most popular method of producing high oil corn. This method consists of planting a blend of two types of corn. The first type is the "grain parent" and comprises about 90% of the planted seed. The remaining seed is a special pollinator that is responsible for shedding pollen that contains the gene that causes the kernel to produce a larger embryo. High-oil corn can have as much as twice the oil content of traditional varieties of corn due to its larger embryo (Riley, Hoffman and Ash). The embryo of the seed is the area where the oil and essential amino acids are contained; creating a larger embryo provides for greater value. This added oil produces a higher-energy feed that may be used to replace more expensive ingredients in feed rations. This system of pollination is the cause of additional production risk in high oil corn production.

There are additional risks associated with the production of high oil corn varieties over traditional hybrid corn varieties. Since such a small percentage of the crop is responsible for pollination, and therefore the resulting yields, the impacts from bad weather, insects, and other undesirable production conditions are enhanced. This results in greater variation in yields across years. Impacts from pests that feed on pollen or silk will reduce yields more in the high oil varieties than in traditional yellow corn varieties since there are less pollinators.

DSG recommends certain production practices that are important when using TC Blend seed. These recommendations include planting the seed following a soybean rotation, to improve yields and decrease insect and disease pressure, using conventional or minimum tilling practices to avoid cool soil temperatures, increasing planting rates by 2,000 seeds per acre, and although isolation is not required, it is recommended to avoid dilution of oil content at the field edges. Typical recommendations for isolation consist of a barrier of 150-200 feet or excluding the first 30 –40 rows of the high oil corn due to dilution of oil content. In addition, equipment must be cleaned prior to handling high oil corn, the crop must be stored separately, and low temperature drying is recommended to protect quality.

The primary objective of this paper is to quantify the net profit potential and risk associated with the adoption of special purpose crops at the farm level. Specifically, the adoption of high-oil corn into a typical Kentucky grain farm is analyzed to determine the percentage of special purpose crop acres needed to maximize net returns while minimizing risk. Sensitivity analysis explores how changes in premiums, prices, yields, costs, and other aspects of production affect the profit and risk profile of special purpose corn. Further, three levels of risk aversion levels (low, medium, and high) are used for each simulation.

Data and Methods

This study primarily uses Kentucky farm financial and production data from 255 Kentucky farms collected through the Kentucky Farm Business Management (KFBM) program in 2000 based on the 1999 crop year. Of the 255 participating farms, 177 were determined to be grain farms since the value of feed fed was less than 40 percent of the crop returns and the value of feed fed to dairy was less than one-sixth of the crop returns. The KFBM program reports farm level financial data as well as the revenue and expenses for various crop and livestock enterprises. The data from those classified as grain farms is used to develop a stylized farm for the analysis that represents an average Kentucky grain farm. Table 1 summarizes the data for a typical farm used in this analysis.

These KFBM data were also used in the development of enterprise budgets for conventional corn (Powers, Isaacs, and Trimble). The enterprise budget for conventional corn was modified to include the added costs of producing high oil corn. These data were used in the determination of estimated returns above variable costs for high oil corn.

High oil corn yield data comes from the 1998, 1999, and 2000 Kentucky Hybrid Corn Performance Tests of special purpose corn varieties in Kentucky (Pierce and Poneleit). Traditional corn hybrids were planted in the same locations from 1986 to 2000 (Poneleit and Evans; Pierce and Poneleit). High-oil corn data is available for 16 different TC High Oil Blend® hybrids planted in 2 locations in 1998 and for 13 different hybrids in 3 locations in 1999 and 2000. The data includes 6 different hybrids that were planted in the same two locations across years. Reported crop characteristics included are yield, moisture percentage, and percentage lodged, along with protein, oil, and starch content. Since the trial crop data includes spatially different locations, it provides some information to examine the impacts of weather on variability in crop chemical composition and yields. Data was also available from the Kentucky Agricultural Statistics Service, but these data consist of averages reported by various producers for each county in Kentucky. The Kentucky Corn Performance Test data are preferred because the varieties were produced under the same management practices and same locations across years, which more closely resemble the experiences an individual producer may face. Due to the novelty of the high-oil corn crops, limited yield data is available. Given the limited time-series of high oil corn yield data, a more comprehensive yield risk profile for the TC High Oil corn varieties was simulated using traditional corn hybrid data. This was accomplished by detrending the existing traditional corn data and creating mean and standard deviation statistics for the detrended series. The high oil corn data was expanded based on the relationships between the 10-year series of traditional corn and the 3-year series of the high oil corn.

Yield data for soybean yields were gathered from the Kentucky Soybean Performance Tests (Lacefield, Tutt, and Pfeiffer) and represent conventional varieties planted in the same locations as the corn. Summary statistics for the crop yield data are presented in Table 2. Kentucky production data is valuable in estimating the production risks associated with producing special purpose crops in this particular region because the closest data previously available geographically was for regions north of Kentucky with cooler climates.

The base corn price for the model was derived from the December futures contract price on the Chicago Board of Trade (CBOT), minus the basis, with a 22% level of variation used as a measure of price risk (Harwood et al). The soybean price data is the current Loan Deficiency Payment (LDP) for soybeans. The futures price is far short of the LDP, therefore the LDP of $5.40 is the only reasonable expected price to use for producers' planning decisions. A 20% level of variation was applied to this price to measure price risk (need source (Skees?)). The high oil corn premium was based on recent contract prices and the average oil content of the high oil varieties in the 1998, 1999, and 2000 Kentucky Corn Performance Tests (7.7%). A summary of the price data is reported Table 2. These data are for the average Kentucky grain farm with

1330 acres of tillable acres. T variance-covariance matrix of net returns for the three crops is shown in Table 3. This explicitly shows the added risk of growing high oil corn.

An E-V mathematical programming model was used to determine the optimal enterprise ratio for high oil corn for a typical Kentucky grain farm, as described above. This is essentially a portfolio selection problem. As first described by Markowitz, portfolio theory explains the problems associated a linear programming model resulting in a situation where an investor places all of his/her funds into the investment with the highest discounted value. Therefore, if two or more securities have the same value, then any combination of the securities is just as good as any other with no regard to risk. A variance term was introduced to the linear programming model for case of the expected returns variance of returns rule that assumes there is a portfolio that gives both the maximum expected return and minimum variance to the investor.

Freund developed an E-V programming model that consisted of a risk aversion parameter that was chosen for a producer, on the basis of the size of the operation and the producer's preference between net returns and risk that was constant without dependency upon changes in the parameters. This allows for a measure of the preference toward risk that is suitable for the producer and will be relevant for various parameter values (McCarl).

McCarl outlines the conditions in which maximizing the E-V problem is equivalent to maximizing expected utility when the distribution of net returns is normal (Freund), and these distributions satisfy Meyer's location and scale restrictions. Although the assumption of normality for returns is unlikely to be completely accurate, it is a reasonable assumption as long as the number of alternatives is not too small and risky prospects are diverse (Anderson et al.).

The model, which maximizes net returns less a proportion of the variance of those returns for 3 enterprises, is specified as follows:

$$\text{Max} \quad \sum_i \bar{R}_i T_i - \lambda \sum_i \sum_j \sigma_{ij} T_i T_j,$$

subject to :

$$1) \; \sum_i T_i \leq \text{ACREAVL}$$

$$2) \; T_i \geq 0$$

$$3) \; 0.4(\text{ACREAVL}) \leq T_{soyb} \leq 0.6(\text{ACREAVL})$$

where:

R_i = net returns above variable costs per acre for the i^{th} enterprise, i=1, 2, & 3

T_i = total acres of the i^{th} enterprise grown; $T_{soyb} = T_3$ and represents total acres allocated to soybeans

λ = the risk-return trade-off or risk aversion parameter

σ_{ij} = the variance/covariance of net returns of enterprises i and j (i=1,2, & 3; j=1, 2, & 3)

ACREAVL = total tillable acres available

The acreage constraint on soybeans was required due to the seed companies' recommendation that high oil corn should be used in a crop rotation with soybeans. This constraint requires the producer to raise approximately half of his/her acres in soybeans thus ensuring that high oil corn can be successfully grown in future periods, which proves to be a realistic assumption. The risk aversion parameter was chosen using the method described by McCarl and Bessler under the assumption of normality of net returns. Babcock, Choi, and Feinerman describe this method as testing to ensure that the risk aversion level is "reasonable" for the associated gamble size. The risk aversion parameter divided by two and multiplied by the standard deviation of net returns should always result in a value between .01 and .99, which is the same as the appropriate Z-value for the distribution. The assumption of normal distribution of net returns allows for the number of standard deviations in the confidence interval to be equivalent to a Z-value in the standardized normal distribution of net returns. McCarl and Bessler derive the following formula for calculating the risk aversion parameter:

$$\lambda = 2Z_{\alpha}/\sigma_{Y}$$

where:

λ = risk aversion parameter, Z_{α} = standardized normal Z-value for a given level of significance α, and σ_{Y} = the standard deviation of the risky prospect, which is net returns in this study.

The standard deviation that was used is that associated with the profit maximizing solution for the risk neutral case (Z=0). Risk aversion parameters represent those particular levels by looking up Z-values for the particular level of significance and applying them to the equation above. The risk aversion parameters (λ) that were calculated based on the Z=0 case are presented in Table 4. The significance level that is listed in Table 4 and used to determine the Z-value to use represents the percentage of the time that a producer would expect to receive the mean expected value of returns. For the Z=0 case, the producer would be indifferent to the risk. Half the time he/she would receive the mean expected value of returns or better and would receive the mean expected value of returns or less half the time. Three levels of risk aversion were chosen to represent low-risk aversion, medium-risk aversion, and high-risk aversion. The low risk averse producer is defined as one who requires the mean expected value of returns no less than 60% of the time, while the medium and high-risk averse producers are those who require a return to be 70% and 80% of the time, respectively. The low value was chosen at 60%

based on the assumption that producers are at least somewhat risk averse. The high level of 80% was used because there was no change worthy of noting for risk aversion levels greater than that level.

Results of Model Application

The model was calculated under the three different levels of risk aversion. Sensitivity analysis was then conducted by changing several variables that are likely to vary. The model was run for changes in the high oil corn premium, high oil corn yields, and changes in the soybean price. The simulations regarding the high oil corn yields and premium prices were important to examine because the data shows higher volatility in the high oil corn yields than in conventional corn, and there is substantial uncertainty regarding what the oil content of a crop may be in any given year. The simulation with changes in the soybean price notable because of the substantially lower variation in net returns for soybeans than for corn. Small increases in the soybean price should provide the ability for producers to enhance their risk adjusted net returns. The results from the first model calculation (the base case) are summarized in Table 6. This simulation consisted of an application of the data listed in Table 2 to the model. The results show a mix of all three crops at the low risk aversion level. At this level of risk aversion, a producer is willing to accept more variance in net returns in exchange for higher net returns. No high oil corn is produced for risk aversion levels above the medium preference level. The percent of acres in soybeans remains constant for all three levels of risk aversion for the base case due to the rotation constraint. The requirement to raise 40% of the crop acres in soybeans allowed high oil corn to be produced at the low risk aversion level. The lower variance in net returns due to the soybean production allows for this producer to take on more risk in return for higher returns via high oil corn production.

A mean value-variance diagram is presented in Figure 1 based on the same expected net returns. The increasing slope of the line connecting the points reveals the trade-off between risk and return. As the total variance of the crop mix increases, the producer requires a greater level of returns as compensation for the increased risk. Each point on the curve represents a different preference towards risk, and therefore, a different value of λ (listed in Table 4). There is a steep increase in the mean value in this diagram that is quite noticeable. This represents the point at which the producer chooses to add soybeans into production. Prior to this point the producer was constrained by the requirement to grow at least 40% of the total acres in soybeans in order to ensure acceptable yield results in corn. These requirement resulted in lower net returns, but lower variance as well.

Simulation One

Although the premium for most high oil corn production is set by a contractual-arrangement, the level of the premium is partially determined by oil content. The oil content varies from year to year due to weather impacts and the performance of different varieties. Thus, six other premium levels for high oil corn were used in the model besides the base case of $0.25/bu to examine the impact of higher and lower premium levels due to variance in oil content levels. Changing the premium levels illustrates the impacts of lower premium levels due to less than expected oil content levels. The lower (higher) premium levels directly lower (raise) the effective high oil corn price. At the given levels of risk aversion, it takes a minimum premium of $0.24 before any high oil corn is produced (Table 5). At a premium of $0.26, the low-risk averse producer maximizes the amount of high oil corn that can be produced with the given constraints. At $0.28, the medium-risk averse producer enters production, and finally the high-risk averse producer at a premium of $0.32. As the premium on the high oil corn increases, the associated price risk increases also since the mean value of the price used is multiplied by the coefficient of variation to get the standard deviation of the price.

Simulation Two

The price of soybeans was an important aspect in this simulation. The variance of net returns for soybeans (65.18) is much lower than that of either hybrid corn (246.34) or high oil corn (598.86). The low expected price of soybeans resulted in the minimum amount of acreage allocated to soybeans (0.4*ACREAVL) in the base case (Table 6). There is, however, no guarantee that the LDP payment for soybeans will be as high in future years as it presently is. Simulation two allows for soybean prices to increase and decrease. The results of allowing varying price levels for soybeans are presented in Table 6. An increase in the price of soybeans does not affect the percent of acreage allocated to soybeans until the price reaches $5.50. At soybean prices greater than $5.75, soybean acres are maximized at all risk aversion levels (0.6*ACREAVL).

Varying the soybean price has implications on the amount of acreage devoted to high oil corn production. For soybean prices less than $5.50 there is a substitution effect away from regular hybrid corn to high oil corn for the low-risk averse producer who is still producing high oil corn, even though the amount of soybeans produced remains constant. This may be due to the variance of net income decreasing with lower soybean prices and the producers able to take on more risk and substitute more acres into high oil production. When the price of soybeans rises enough for soybeans to be added into the crop mix, there is a substitution away from high oil corn to increased production of regular hybrid corn. None of the price changes in soybeans caused the medium and low-risk averse producers to include high oil production.

Simulation 3

The ability of high oil corn to achieve yields as high as regular hybrids has been questioned by several field tests, although claims have been made to the contrary by seed companies (DSG). In the University of Kentucky Corn Performance Tests the high oil varieties had lower yields on average than traditional corn. The data for this analysis, after being detrended, results in a difference in average yield of 153 bushels per acre for the regular hybrid corn compared to a yield of 146 bushels per acre for the high oil varieties. The simulation results for examining various yields for high oil corn are presented in Table 9. High oil corn was not planted at any of the risk aversion levels when yields were less than 145 bushels per acre. The low-risk aversion producer plants the maximum amount of high oil corn possible for all yields above 146 bushels per acre. At 147 bushels per acre, the medium-risk averse producer adds high oil varieties into production, with the high-risk averse producer joining at 150 bushels per acre. For a yield of 153 bushels per acre, the high-risk averse producer increases soybean acres. This could be a substitution away from hybrid corn to soybeans to compensate for some of the added variance that comes with increasing high oil acres. Eventually, at 158 bushels per acre yields, the high-risk averse producer maximizes high oil corn acres, when the added net returns more than compensates for the increased variance that must be taken on to reach these higher returns.

Simulation 4

The size of the farm used in this analysis is one of 1330 tillable acres, based on the KFBM statistics. When dealing with topics related to risk aversion and risk quantification, the size of the farm has important implications with the amount of risk that a producer is willing to accept. To evaluate how farm size impacts risky crop adoption, four other farm sizes (on the basis of tillable acres) were analyzed. These included farms with 500, 1,000, 1,500, and 3,000 tillable acres. When farm size increases, the risk aversion parameter must be adjusted to account for the producer's ability to take on more risk. As the farm size increases, the producer can increase net returns by adopting enterprises with riskier net returns, this explicitly shows how the risk aversion parameter decreases with farm size. Table 10 shows the various risk aversion parameters corresponding to alternative farm sizes. As the farm size increases, the producer can take more risk, therefore the risk aversion parameter approaches zero as the farm size increases.

Conclusion

With low prices for traditional commodities, special purpose crops offer growers the opportunity to add value to their crop production and earn greater returns. However, the risks associated with these crops can be substantial, and without accurate information regarding these risks, producers can find these crops financially devastating in some years.

The results of this study provide a reasonable estimate of the value of special purpose crop production at the farm level. It appears that the optimal adoption of high oil corn is very marginal and dependent upon the producers' willingness to accept risk. The analysis of varying premium levels shows that contracts that offer more protection for producers against price risk may increase the amount of high oil corn acres produced in Kentucky. However, it is also important to note the yield lag in the high oil corn varieties, and the increased susceptibility to depressed yields and oil content due to weather, insects, and other conditions that prohibit the ability of the varieties to yield the same as traditional hybrids. The requirement to raise soybeans as a rotation crop to reduce these risks had substantial implications on the acreage of high oil corn and hybrid corn produced.

Although the numerical results are specific to Kentucky, the general trends and implications should apply to other regions. The results should also be useful for producers growing or interested in growing other special purpose crops. The model will be easily modified to examine other special purpose crops such as soybeans and wheat.

Table 1. Summary of Kentucky Grain Farm for 1999

Percent of Grain Fed		0.9%
Total Acres		
	Acres tillable	1332
	Acres owned	291
	Acres crop shared	431
	Acres cash rented	265
Labor		
	Unpaid months	12.0
	Paid months	16.0
Revenue		
	Crop revenue	$249,354
	Livestock revenue	6,563
	Government payments	70,869
	Other farm payments	23,844
	GROSS REVENUE	$350,630
(-)	Feed & livestock purchases	3,437
	VALUE OF FARM PRODUCTION	$353,364
Expenses		
	Cash operating expenses	$265,351
	Depreciation	34,823
	Change in Acct. pay/Prepaid exp.	(510)
	TOTAL OPERATING EXPENSES	$300,726
	TOTAL INTEREST EXPENSE	$26,970
Net Farm Income from Operations		$36,421
Net Farm Income		$38,226
Interest on equity capital		$40,806
Unpaid family labor		0
Operator(s) labor and mgmt. Income		(454)
Unpaid operator labor		24,000
Management returns		($29,536)
Production ($) per $1 non-feed cost		0.91
Farm production ($) per person year		152,407

Table 2. Base Case Data

	Mean Yield	Yield Var	Mean Price	Price Var
Hybrid Corn	153	902	2.40	0.28
High Oil Corn	146	956	2.65	0.63
Soybeans	48	58	5.40	1.08

Table 3. Variance-Covariance Matrix of Net Returns

	Hybrid Corn	High Oil Corn	Soybeans
Hybrid Corn	246.34		
High Oil Corn	345.68	598.86	
Soybeans	95.04	156.09	65.18

Table 4. Risk Aversion Parameters at Various Risk Preferences

Significance Level	Z-value	Risk Aversion Parameter
50	0	0
55	0.126	0.00001092
60	0.253	0.00002193
65	0.385	0.00003337
70	0.524	0.00004542
75	0.675	0.00005851
80	0.842	0.00007299
85	1.037	0.00008989
90	1.282	0.00011113
95	1.645	0.00014260

Table 9. Farm Size Impact on Risk Aversion Parameters

Till/Ac	Risk Pref	Risk Aversion Parameter
500		
	Low	0.000058
	Medium	0.000121
	High	0.000194
1,000		
	Low	0.000029
	Medium	0.000060
	High	0.000097
1,500		
	Low	0.000019
	Medium	0.000040
	High	0.000065
3,000		
	Low	0.000009
	Medium	0.000020
	High	0.000032

Table 5. Results from the Base Case

Risk Pref	RAP	Crop	Acres Planted
Low	(0.000022)		
		Hybrid Corn	29 %
		High Oil Corn	31 %
		Soybeans	40 %
Medium	(0.000045)		
		Hybrid Corn	60 %
		High Oil Corn	0
		Soybeans	40 %
High	(0.000073)		
		Hybrid Corn	60 %
		High Oil Corn	0
		Soybeans	40 %

Table 6. Changes in the Premium Levels

Premium	Risk Pref	Hybrid Corn	High Oil Corn	Soybeans
$0.22				
	Low	60 %	0	40 %
	Medium	60 %	0	40 %
	High	60 %	0	40 %
$0.24				
	Low	44 %	16 %	40 %
	Medium	60 %	0	40 %
	High	60 %	0	40 %
$0.26				
	Low	14 %	46 %	40 %
	Medium	60 %	0	40 %
	High	60 %	0	40 %
$0.28				
	Low	0	60 %	40 %
	Medium	52 %	8 %	40 %
	High	60 %	0	40 %
$0.30				
	Low	0	60 %	40 %
	Medium	39 %	21 %	40 %
	High	60 %	0	40 %
$0.32				
	Low	0	60 %	40 %
	Medium	26 %	34 %	40 %
	High	59 %	1 %	40 %

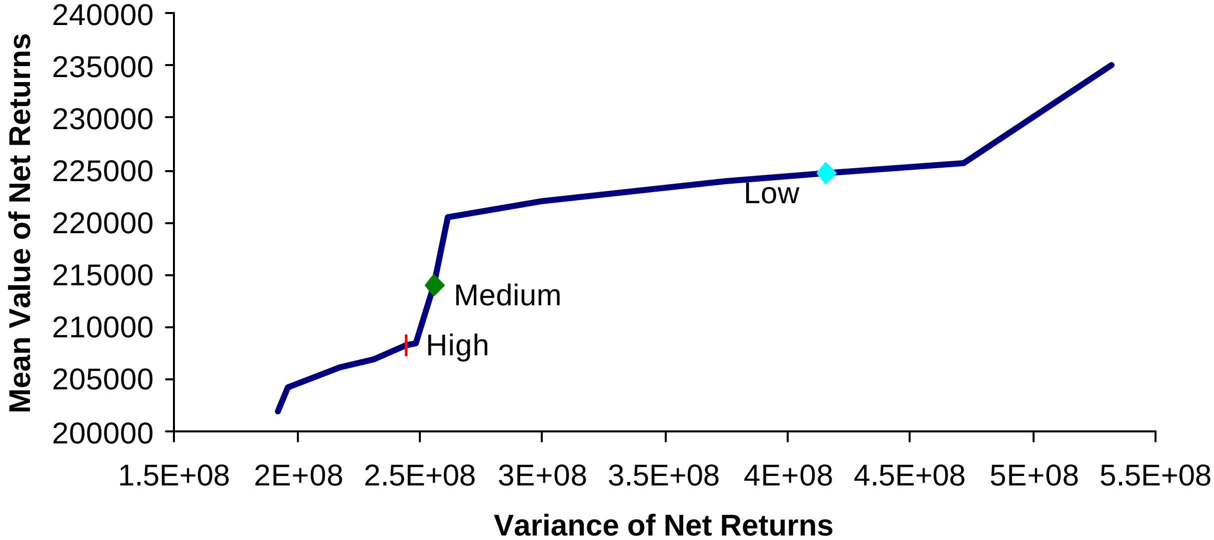
Table 7. Soybeans Price Changes

Soybean Price	Risk Pref	Hybrid Corn	High Oil Corn	Soybeans
$4.75				
	Low	357	441	532
	Medium	798	0	532
	High	798	0	532
$5.00				
	Low	367	431	532
	Medium	798	0	532
	High	798	0	532
$5.25				
	Low	377	421	532
	Medium	798	0	532
	High	798	0	532
$5.50				
	Low	387	411	532
	Medium	798	0	532
	High	617	0	713
$5.75				
	Low	73	459	798
	Medium	532	0	798
	High	532	0	798
$6.00				
	Low	88	444	798
	Medium	532	0	798
	High	532	0	798

Table 8. Changes in Yield Levels of High Oil Corn

High Oil Yield	Risk Pref	Hybrid Corn	High Oil Corn	Soybeans
145				
	Low	776	22	532
	Medium	798	0	532
	High	798	0	532
147				
	Low	0	798	532
	Medium	784	14	532
	High	798	0	532
150				
	Low	0	798	532
	Medium	215	583	532
	High	709	89	532
153				
	Low	0	798	532
	Medium	0	798	532
	High	270	460	600
156				
	Low	0	798	798
	Medium	0	798	798
	High	0	737	593
158				
	Low	0	798	798
	Medium	0	798	798
	High	0	798	532

Figure 1. Mean Value-Variance of Net Returns



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