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MICROECONOMIC EFFECTS OF REDUCED YIELD VARIABILITY CULTIVARS OF SOYBEANS AND WHEAT

Carl R. Dillon

Abstract

Economic analysis was conducted on hypothetical agronomic research on new crop cultivars for Arkansas dryland soybean and wheat producers. In relation to farmers' attitudes toward risk, the microeconomic effects and level of adoption of yield variability reducing cultivars were analyzed utilizing a production management decision-making model formulated with mathematical programming techniques. The study indicated that negative covariance between crops continues to be an effective means of reducing production risk associated with yield variability. However, under varying circumstances, agronomic research on the breeding of new soybean and wheat cultivars with reduced yield variability is worthwhile if there is only slight concurrent reduction in expected yields.

Key words: farm management, risk analysis, yield variability, mathematical programming

The importance of risk in the production management decision-making process is well evidenced and studied (Boisvert and McCarl; Anderson et al.; McCarl; Kennedy; Dillon). While the consideration of risk can apply to any component of the decision process, the element of production risk is extremely well represented in the literature (e.g., Brink and McCarl; Teague and Lee; Weimar and Hallam; Johnson; Lin et al.; Dillon et al.; Pope and Shumway). The variability of yields can lead to a major source of fluctuation in profits for farmers and is therefore a primary production risk. However, little study has been focused upon agronomic research directed at the reduction of the variability of yields of major commercial crops. The objective of this study is to provide insight into the adoption process, production practices, and microeconomic effects of alternative cultivars for hypothetical dryland soybean and wheat producers of differing attitudes towards risk in the Delta region of Arkansas in order to provide economic analysis of alternative agronomic research functions.

Economic analysis directly addressing agricultural research has been conducted and philosophically discussed (White and Araji; Rasmussen; Norton and Davis). Consideration of the desired level of research and potential adoption by recepients is useful in evaluating benefits of research projects. While much research has focused upon evaluating agricultural research (Martinez and Norton; Hess; Holloway; Pardey and Craig), little attention has been directed at the mathematical programming approach in an *ex ante* framework (see Norton and Davis for a thorough literature review of agricultural research evaluations). Furthermore, considerations of risk and of potential reduction of production risk from the findings of agronomic research appear to be lacking in the literature. This research focuses upon a specific empirical case in providing microeconomic analysis on the value of reduced yield variability cultivars.

In terms of agronomic research, several areas of economic importance can be addressed other than the investigation of new cultivars strictly aimed at increasing yield potential (Brill). While economic benefits have been evaluated in relation to agronomic research such as breeding resistance into soybean host plants (Zavaleta and Kogan), consideration of risk could be included in the microeconomic analysis of agronomic research. A risk-averse farmer may in fact be willing to sacrifice some expected yield in order to decrease the variability of yields, thereby reducing the fluctuation of overall profits. The question arises as to the degree of expected yield sacrifices that the farmer would be willing to accept. If a higher or unaltered expected yield would accompany a reduced yield variability, risk averse farmers would obviously prefer such a cultivar. Consequently, the less certain results of tradeoffs between lower yield mean and reduced yield variability are the focus here. If an agricultural producer could select how much agronomic research was undertaken to reduce yield variability, what would be the desired variability of these new cultivars? The question of adoption and farmers' desired level of yield variability reduction is coupled with

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questions of associated production practices and profit distributions. This research project is aimed at addressing these issues. This study does not focus upon the macroeconomic value of agronomic reseearch but rather on the individual, hypothetical producer's response to new cultivars. Rather than the cost of agronomic research as the amount paid by government or industry, this study concentrates on the farmer's perspective of potential costs of reduced yield levels. As opposed to the overall value of agronomic research on cultivars to society, this study discusses the preliminary issue of what farmers would be willing to select in terms of new cultivars.

ANALYTICAL PROCEDURE

The study involved the use of an E-V (expected value-variance) production risk analysis utilizing mathematical programming procedures. The expected value-variance resource allocation nonlinear programming model representing the decision-making environment of the hypothetical producer is structured (in summation notation) as follows:

$$\text{MAX } \bar{Y} - \Phi \sum_{c} \sum_{p} \sum_{c'} \sum_{p'} f(A_{c,p})\, P_c^2 \sigma_{c,p,c',p'} X_{c,p} X_{c'p'},$$

subject to:

$$(1) \sum_{c} \sum_{p} X_{c,p} \leq 320$$

$$(2a) -\sum_{c} \sum_{p} (1 - \lambda A_{c,p})\, EXPYLD_{c,p}\, X_{c,p} + SALES_s = 0 \qquad \text{for } c = 1,2$$

$$(2b) -\sum_{p} (1 - \lambda A_{3,p})\, EXPYLD_{3,p}\, X_{3,p} + SALES_w = 0 \qquad \text{for } c = 3$$

$$(3) -\sum_{c} \sum_{p} VARCST_c\, X_{c,p} + P_s\, SALES_s + P_w SALES_w - \bar{Y} = 0, \text{ and}$$

$$(4)\ A_{c,p} \leq 100 \qquad \text{for all c,p,}$$

where:

activities include:

$\bar{Y}$ = expected net return above variable costs

$A_{c,p}$ = adoption of cultivars undergoing agronomic research reducing yield variability of crop c under planting date p by f ($A_{c,p}$) percent at a cost of $\lambda A_{c,p}$ percent lower average yields

$X_{c,p}$ = production of crop c under planting date p in acres

$SALES_s$ = bushels of soybeans sold , and

$SALES_w$ = bushels of wheat sold ;

constraints include:

(1) Land resource limitations
(2a) Soybean sales balance
(2b) Wheat sales balance
(3) Expected profit balance, and
(4) Agronomic research limits;

coefficients include:

Φ = Pratt risk - aversion coefficient

P_c = Price of crop c less yield dependent costs (hauling)

$\sigma_{c,p,c'p'}$ = Covariance of yields for crop c under planting p with yields of crop c prime under planting p prime or variance when c , p = c prime, p prime)

λ = Yield reduction factor

$EXPYLD_{c,p}$ = Expected yield of crop c by planting date p, and

$VARCST_c$ = Variable costs of production for crop c; and

indices include:

c = Crops (1 = Soybean cultivar Forrest, 2 = Soybean cultivar Lee-74, 3 = wheat cultivar Coker 68-15). Also c'.

p = Planting date (For soybeans: 1 = June 1, 2 = June 10, 3 = June 20; For wheat: 1 = October 5, 2 = November 10, 3 = December 15). Also p'.

s = Soybeans (c = 1, 2), and

w = Wheat (c = 3).

The activities of the production management decision-making model may be categorized into four types:

1. Production activities—The decision to engage in single cropped soybean or wheat production is embodied in these activities. Production practices distinguish the different crops, the different cultivars currently in use, and alternative planting dates. Double cropping soybeans and wheat in the same season is not considered.
2. Product sales—The product sales permit the accumulation of gross revenue. Product sales are identified by the different crops and provide the total number of bushels sold.
3. Expected profit—The mean level of profits is provided as a measurement of returns above variable cost.
4. Agronomic research adoption—The ability of the farmer to adopt newly developed hypothetical cultivars is embodied in these activities. These activities are identified by crop, current cultivars, and planting dates. The possibility of reducing variability at a cost of lower yields is

represented herein. The activities are in percentage units such that a value of 50 represents argonomic research leading to a new cultivar with a λ50 percent lower average yield but a lower variability of f(50). Note that the agricultural producer can select the degree of agronomic research adopted.

The constraints of the production management decision-making model are as follows:

1. Land balance—The model restricts total planted acreage to the tillable acreage available.
2. Sales balance—Sales of the commodities produced are conducted within these rows.
3. Expected profit balance—Calculation of the net returns above variable costs is provided within this constraint.
4. Agronomic research limitations—The maximum limit for variability of yield reduction is enforced within these constraints. The agronomic research activities are limited to 100 percent.

The objective function maximizes expected profit (net returns above variable costs) less the Pratt risk-aversion coefficient times the variance of profit. As a long-run equilibrium programming model, government programs under alternative base acreages are excluded to reflect the desired production practices and acreage levels to move toward over time. As demonstrated in the model description above, the ability of agronomic research to reduce variability of yields, thereby reducing variability of profits, is represented, but at a cost of lower average yields.

The acreage allotment for the farm is 320 acres representing the average Arkansas farm size (Arkansas Agricultural Statistics Service). Prices for soybeans are given at the level of $7.55 per bushel with wheat prices being at the level of $3.39 per bushel. These figures are the 1988 season average prices per bushel as provided by the Arkansas Agricultural Statistics Service and are utilized rather than 1989 data because of the preliminary nature of the 1989 information provided. Variable costs of production for soybeans are $86.89 per acre while wheat variable costs are $61.42 exclusive of hauling costs of 15 cents per bushel (Cooperative Extension Service). Two major soybean cultivars commonly utilized within the area are included: Forrest (early season) and Lee-74 (midseason). Soybean planting dates included are June 1, June 10, and June 20. A single cultivar of wheat is used (Coker 68-15) with planting dates of October 5, November 10, and December 15. Yield data were obtained from Trice for the weather patterns of 1964 through 1983. Production practices and cultivars selected therefore parallel those in the experimental design utilized by Trice and their selection does not imply that these cultivars were developed for reduced yield variability. Lower yield variability cultivars are reflected as resulting from new agronomic research as discussed later. These data were developed from biophysical simulation using the CERES model (Ritchie and Otter) for wheat, and SOYGRO (Wilkerson et al.) for soybeans. Model validation as performed by Trice and discussions with agronomists provided evidence that the models performed acceptably overall as well as with respect to planting date and cultivar response. A variance-covariance matrix and summary descriptive statistics for the alternative crops and production practices are provided in Table 1.

Note that wheat yields tended to be less variable than soybean yields and generally were negatively correlated with soybean production (Table 1). Also, the Forrest (early season) cultivar soybean possessed greater expected yields for equivalent planting dates in comparison to the Lee-74 (midseason) cultivar soybeans. However, the standard deviation of the Lee-74 cultivar soybeans was more favorable with the exception of the June 20th planting date. Lee-74 displayed greater levels of negative covariance than did Forrest for cross combinations of all planting dates. Later planting dates of both soybean cultivars experienced greater negative covariances with wheat than did early soybean planting. Mean wheat yields declined with later planting dates while mean soybean yields were highest at the middle planting of June 10 for both cultivars (Table 1). Note that the June 10th planting is meant to represent the midpoint of planting from June 5th through June 15th; similar interpretations apply to other planting dates. As a result of these mean, variance, and covariance results, no individual practice and cultivar combination can be excluded prior to analysis as inferior in all respects to another combination.

The use of E-V analysis is quite common in the literature. Boisvert and McCarl list 39 articles using this approach with many recent applications cited. The use of E-V analysis is consistent with expected utility theory when the net returns associated with the decision variable are normally distributed or for a quadratic utility function (Meyer). For the case at hand where yield is the only random component of net returns, normality of yields is a sufficient condition for normality of net returns. Nonetheless, normality of yields must be statistically tested as an empirical condition since the biophysical simulation models utilized do not explicitly assume any particular distribution form. Normality of yields depends on the specific data in question. Utilization of the Kolmogorov-Smirnov test failed to reject normality at the 5 percent level of significance for all 9 decision variables (3 planting dates for 3 cultivars—1 wheat

Table 1. Descriptive Summary Statistics on Crop Yields (bu / ac)

Minimum, Maximum, Mean, and Standard Deviation[a]									
	Soybeans						Wheat		
	Forrest Cultivar			Lee-74 Cultivar			Coker 68-15 Cultivar		
	June 1	June 10	June 20	June 1	June 10	June 20	Oct 5	Nov 10	Dec 15
Minimum	5.76	6.91	8.58	5.38	7.61	1.44	43.10	30.70	19.90
Maximum	50.66	50.75	47.33	43.57	45.99	44.99	71.80	62.60	50.80
Mean	29.44	30.99	30.27	27.15	28.71	24.58	57.73	45.75	34.95
Std Dev	14.12	13.65	11.78	12.35	11.55	11.92	6.88	8.40	8.65
Variance-Covariance Matrix[b]									
	SoyFJ1	SoyFJ10	SoyFJ20	SoyLJ1	SoyLJ10	SoyLJ20	WhtO5	Wht10	WhtD15
SoyFJ1	199.49	184.49	133.91	168.85	146.65	59.49	-18.47	3.55	1.30
SoyFJ10	184.49	186.40	145.65	167.55	153.90	84.67	-30.26	-9.16	-11.48
SoyFJ20	133.91	145.65	138.69	127.99	128.47	109.24	-30.77	-24.85	-18.75
SoyLJ1	168.85	167.55	127.99	152.64	137.21	70.42	-26.52	-6.88	-7.45
SoyLJ10	146.65	153.90	128.47	137.21	133.35	81.41	-32.56	-20.16	-15.61
SoyLJ20	59.49	84.67	109.24	70.42	81.41	142.14	-33.43	-39.00	-36.40
WhtO5	-18.47	-30.26	-30.77	-26.52	-32.56	-33.43	47.27	47.41	48.33
Wht10	3.55	-9.16	-24.85	-6.88	-20.16	-39.00	47.41	70.48	50.15
WhtD15	1.30	-11.48	-18.75	-7.45	-15.61	-36.40	48.33	50.15	74.90

Source: Calculations are based upon data from Trice.
[a]STD DEV refers to standard deviation.
[b]Decision variable indicates the following.
SoyFJ1 = Soybean of Forrest cultivar planted June 1
SoyFJ10 = Soybean of Forrest cultivar planted June 10
SoyFJ20 = Soybean of Forrest cultivar planted June 20
SoyLJ1 = Soybean of Lee-74 cultivar planted June 1
Soy LJ10 = Soybean of Lee-74 cultivar planted June 10
Soy LJ20 = Soybean of Lee-74 cultivar planted June 20
WhtO5 = Wheat of Coker 68-15 cultivar planted October 5
WhtN10 = Wheat of Coker 68-15 cultivar planted November 10
WhtD15 = Wheat of Coker 68-15 cultivar planted December 15

and 2 soybean). While this does not prove normality exists, it does fail to prove it doesn't.

An E-V model can be further justified on the basis of Meyer's findings. He resolves that E-V analysis is completely consistent with expected utility theory if the cumulative density functions (CDF) of the random variables differ only by location and scale parameters. It is sufficient for all yields when they are ranked to be linear functions of one another to meet Meyer's location and scale conditions for this study's model. This may be proven as follows:

$$G_{ij}(X_{ij}) = G_{kj}(X_{kj}) = \frac{j}{N} \quad \forall_j$$

If $X_k = \alpha + \beta X_i$ then

$$G_i(X_i) = G_k(\alpha + \beta X_i)$$

Thus, because (1) the cumulative probability in a CDF represented by a discrete number of observations (G_i and G_k) is the ratio of the rank of that observation (j) to the number of states of nature (N), and (2) there is a similar number of states of nature for all random variables (X_i and X_k). If ranked yields are a linear function of one another, then E-V analysis is completely consistent with expected utility theory. The correlation matrix for the ranked yield variables demonstrates exceptionally high degrees of linear relationships as evidenced in Table 2. The lowest correlation was 96.5 percent. E-V analysis was therefore deemed an appropriate analytical tool for this problem.

The Pratt risk-aversion coefficient is calculated using the method described in McCarl and Bessler, wherein a decisionmaker is assumed to maximize the lower limit from a confidence interval from a normal distribution of net returns above variable costs. The risk-aversion parameter is calculated by equating the marginal value of net returns above variable cost under an E-V (mean-variance) formulation with the marginal value of net returns when maximizing the mean minus a normal Z value times the standard

Table 2. Correlation Matrix on Ranked Crop Yields (bu / ac)[a]

	SoyFJ1	SoyFJ10	SoyFJ20	Soy LJ1	Soy LJ10	SoyLJ20	WhtO5	WhtN10	WhtD15
SoyFJ1	1.00000	0.99072	0.98714	0.99243	0.98185	0.98467	0.96565	0.96601	0.97290
	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SoyFJ10	0.99072	1.00000	0.98884	0.99670	0.99382	0.98818	0.97375	0.97381	0.97813
	0.0001	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SoyFJ20	0.98714	0.98884	1.00000	0.98973	0.98541	0.98395	0.97000	0.96923	0.97375
	0.0001	0.0001	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Soy LJ1	0.99243	0.99670	0.98973	1.00000	0.99101	0.98883	0.96556	0.96578	0.97686
	0.0001	0.0001	0.0001	0.0	0.0001	0.0001	0.0001	0.0001	0.0001
Soy LJ10	0.98185	0.99382	0.98541	0.99101	1.00000	0.98559	0.97823	0.97895	0.98136
	0.0001	0.0001	0.0001	0.0001	0.0	0.0001	0.0001	0.0001	0.0001
SoyLJ20	0.98467	0.98818	0.98395	0.98883	0.98559	1.00000	0.98629	0.97460	0.97977
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0	0.0001	0.0001	0.0001
WhtO5	0.96565	0.97375	0.97000	0.96556	0.97823	0.98629	1.00000	0.98312	0.97012
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
WhtN10	0.96601	0.97381	0.96923	0.96578	0.97895	0.97460	0.98312	1.00000	0.98049
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0	0.0001
WhtD15	0.97290	0.97813	0.97375	0.97686	0.98136	0.97977	0.97012	0.98049	1.00000
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0

Source: Calculations are based on data from Trice.
[a]See footnote b, Table 1.
Probabilities associated with the Pearson correlation coefficient testing for equality to zero is given below estimates.

error. Simply stated, solve for the Pratt risk-aversion coefficient as a function of a representative standard deviation and appropriate normal Z value to reflect a decisionmaker who maximizes a target level of net returns that is α percent likely (where $100 \geq \alpha > 50$ for a risk-averse individual). McCarl and Bessler demonstrate that this leads to the following general formula for calculating the appropriate risk parameter:

$$\Phi = 2Z_\alpha / S_y$$

where Φ = risk-aversion coefficient, Z_α = the standardized normal Z value of α level of significance, and S_y = the relevant standard deviation.

The relevant standard deviation utilized for this procedure is developed from the profit maximizing solution provided later ($32,329.92). The probability levels used vary from 50 percent at risk neutrality (Z = 0) to 90 percent (Z = 1.645). Resultant risk coefficients are presented later in Table 3 accompanying their respective results.

RESULTS AND ANALYSIS

The results are provided for a systematic alteration in the risk-aversion parameter at the levels of 50 percent to 90 percent in 5 percent increments. Base case risk analysis is performed for current cultivars under the condition of no additional cultivars arising from agronomic research. Additionally, three different yield variability reduction functions are represented in the analysis. In these functions, three separate costs in terms of average yield reductions required (λ) to achieve a certain amount of yield variability decrease are utilized. The expected yield reduction factors (λ) are 1 percent, 0.5 percent, and 0.1 percent lower yields for each 1 percent of agronomic research adopted. Experimentation utilizing the yield variability reduction function is conducted for two levels of maximum yield variability reduction: 100 percent and 75 percent. The yield variability reduction function for agronomic research is given by:

$$f(A_{c,p}) = 1 - \{1 - [\,1 - (\,LOG(\,A_{c,p}+1\,))\,*\,\psi\,]^2\,\}$$

where $A_{c,p}$= agronomic research as described before (0-100), LOG= logarithm base 10, and ψ = a multiplier of value $((100/\delta)/LOG(101))*0.01$ where $100/\delta$ is the maximum allowable percent reduction in yield variability. For this study, two levels of δ are used ($\delta = 1$ giving 100 percent and $\delta = 2$ giving 75 percent potential yield variability decreases).

Base case risk analysis results are given in Table 3. For the risk-neutral dryland soybean-wheat farmer (50 percent risk significance level), the optimal decision for the conditions modeled was to plant all 320 acres in the Forrest cultivar of soybeans on June 10th. These results are consistent with the growing predominance of the Forrest cultivar over Lee in Arkansas and with averages for planting practices in the area (Arkansas Agricultural Statistics Services). However, as a microeconomic model for a single farmer, this model does not attempt to parallel aggre-

Table 3. Base Case Risk Analysis Results for the Current Cultivars

Decision Variable[a]	Risk Significance Level[b] 50%	55%	60%	65%	70%	75%	80%	85%	90%
SoyFJ1	0	0	0	0	0	0	0	0	0
SoyFJ10	320.00	122.55	73.12	43.83	28.93	19.70	13.35	8.52	4.53
SoyFJ20	0	0	8.11	26.00	35.10	40.74	44.62	47.58	50.01
SoyLJ1	0	0	0	0	0	0	0	0	0
SoyLJ10	0	0	0	0	0	0	0	0	0
SoyLJ20	0	0	0	0	0	0	0	0	0
WhtO5	0	197.45	238.77	250.17	255.97	259.56	262.03	263.90	265.46
WhtN10	0	0	0	0	0	0	0	0	0
WhtD15	0	0	0	0	0	0	0	0	0
Land	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
Sales-S	9,916.80	3,797.90	2,511.32	2,145.38	1,959.14	1,843.79	1,764.40	1,704.03	1,645.26
Sales-W	0	11,398.65	13,784.49	14,442.20	14,776.91	14,984.23	15,126.92	15,235.42	15,324.87
Mean Prof	45,579.52	42,260.27	41,522.33	41,235.48	41,089.50	40,999.08	40,936.85	40,889.53	40,850.52
Std Dev Prof	32,329.92	11,174.35	7,379.28	6,266.24	5,826.50	5,609.85	5,488.87	5,413.36	5,362.32
Risk Coef	0.00	.00000779	.00001565	.00002381	.00003241	.00004175	.00005208	.00006415	.00007930
Rel Risk	0.00	0.33	0.65	0.98	1.33	1.71	2.13	2.62	3.24

[a]Decision variable indicates the following:
SoyFJ1 = Soybean of Forrest cultivar planted June 1
SoyFJ10 = Soybean of Forrest cultivar planted June 10
SoyFJ20 = Soybean of Forrest cultivar planted June 20
SoyLJ1 = Soybean of Lee-74 cultivar planted June 1
SoyLJ10 = Soybean of Lee-74 cultivar planted June10
SoyLJ20 = Soybean of Lee-74 cultivar planted June 20
WhtO5 = Wheat of Coker 68-15 cultivar planted October 5
WhtN10 = Wheat of Coker 68-15 cultivar planted November 10
WhtD15 = Wheat of Coker 68-15 cultivar planted December 15
Sales-S = Soybean sales in bushels
Sales-W = Wheat sales in bushels
Mean Prof = Mean level of net returns above variable costs
Std Dev Prof = Standard deviations of net returns above variable costs
Risk Coef = Pratt risk aversion coefficient
Rel Risk = Mean Prof * Risk Coef

[b]The risk level represents the certainty of receiving or exceeding a maximized lower level confidence limit on net returns. Assuming a normal distribution of net returns, a 50 percent certainty exists at risk neutrality that the actual net returns will be at or higher than the expected net returns. With risk aversion, a higher percentage of certainty in net returns is required; therefore, a certainty parameter larger than 50 percent is necessary. McCarl and Bessler provide details.

gate production practices and represent all of the potential circumstances of an agricultural producer's decision-making environment. Additionally, sales totaled the expected yield for 320 acres of 9917 bushels of soybeans and achieved an expected profit level of $45,579.52. The standard deviation of profits for the risk neutral case was $32,329.92. As risk aversion increases, wheat production under planting on October 5th increases in acreage. Even at the level of least risk-aversion (55 percent), wheat production enters the optimal solution at a substantial level of 197 acres. Increasing wheat acreage is experienced to the level of 265 acres at extremely high levels (90 percent risk significance level) of risk-aversion. Fur-

thermore, as attitudes toward risk become more averse, the substitution away from the June 10th planting of the Forrest cultivar of soybeans is altered to June 20th planting of the Forrest cultivar of soybeans. This strategy relies upon the lower variance and greater negative covariance of June 20th planted soybeans to wheat. Notice also that a substantial reduction of the standard deviation of profits is possible with only a slight reduction in the level of expected profits. This demonstrates the relatively close profitability levels between wheat and soybean production as well as the ability of using concurrent wheat and soybean production in order to take advantage of the negative covariance between yields as a method of reducing fluctuations in the level of profits. Acreage is completely utilized under all scenarios.

Risk aversion coefficients greater than those presented in Table 3 were run with little relative effect on mean and standard deviation of net returns up to the point of acreage reduction to decrease risk. With decreases of less than 3 percent in the mean net returns and about 2 percent in the standard deviation of net returns compared to risk neutrality, the presented risk coefficient range exposes almost all of the economic effects of risk aversion. Relative risk aversion is also presented to facilitate interpretation as a multiplicative result of expected net returns and the absolute risk aversion coefficient (Table 3).

The risk analysis results for the various agronomic research yield variability reduction factors are found in Tables 4, 5, and 6. Initially, for the 1 percent yield reduction factor scenario with a maximum of 100 percent yield variability reduction possible, soybean agronomic research was adopted in order to reduce variability of soybean yields by about 15 percent with a reduction in expected yields of about 0.4 percent. Such a cultivar was selected for the 133 acres of soybeans planted with the remainder of the acreage being planted in wheat of the current cultivar type. With increasing risk aversion, less soybean research was adopted until the 70 percent level of risk, where no research is adopted for soybeans or wheat. However, the optimal level of wheat research increased with growing aversion to risk beyond the 70 percent risk level. As in the base risk analysis results, the utilization of the latest (June 20) planting date for soybeans began replacing the earlier planting for soybeans with more risk averse attitudes. Also, overall wheat acreage increased under increasing aversion to risk. Notably, the 1 percent yield reduction factor coupled with the 75 percent maximum yield variability reduction function (representing the lowest yield variability reduction per unit of average yield reduction accepted) provided results parallel to those of the base case scenario with the exception of the utilization of some wheat agronomic research at the extreme 90 percent risk aversion level. These results indicate the need for a substantive decrease in yield variability to accompany a reduction in expected yields if the new cultivars are to be adopted by farmers as a risk management practice given the current availability of negative covariance to reduce risk.

As the cost of agronomic research in terms of lower expected yields became more favorable, cultivars undergoing greater degrees of yield variability reducing research were adopted, as would be expected. However, the increased adoption of soybean yield variability-reduced cultivars precluded the need for continued research adoption of wheat under the 100 percent maximum yield variability reduction and 0.1 percent yield reduction factor. Relatively more soybean production occurred as the yield reduction factor decreased from 1 percent to 0.1 percent for the 100 percent maximum yield variability reduction function. Thus, the ability to engage in the slightly more profitable but more variable soybean enterprise was encouraged when agronomic research lowered fluctuations. The intermediate yield reduction factor of 0.5 percent displayed similar increases in soybean production at lower levels of risk but displayed increases in wheat production at the 75 percent risk level and beyond. This is also the point where mean profits stop exceeding the base case scenario but standard deviations begin to exhibit more favorable lower levels relative to their base case counterparts.

With the exception of an initial 5 acre decrease for the 55 percent risk level, total wheat acreage remained relatively consistent for the 75 percent maximum yield variability reduction as the yield reduction factor decreased from 1 percent to 0.5 percent. Further yield reduction factor decrease to 0.1 percent resulted in increased soybean production at the lower risk levels through 75 percent, but it increased wheat production thereafter in comparison to the base case with no agronomic research selection conditions. These results demonstrate the utilization of yield reducing variability cultivars as a means of increasing profitability within acceptable bounds of riskiness for lower risk aversion but as a technique of lowering profit fluctuations with higher aversion to risk. As the yield reduction factor lessened, the agricultural producer was interested in greater amounts of agronomic research for both crops in the case of the 75 percent yield variability reduction factor.

A graphical presentation of the risk analysis results under agronomic research for the 100 percent maxi-

Table 4. Risk Analysis Results for the 1 Percent Yield Reduction Factor

100 percent Maximum Yield Variability Reduction

Decison Variable[a]	Risk Significance Level[b] 55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	132.82	79.90	45.01	28.93	19.75	13.63	9.02	5.26
Yield Avg % Dec	0.42	0.31	0.11	0	0	0	0	0
Yield Var % Dec	14.68	11.30	4.32	0	0	0	0	0
Soybeans (6-20)	0	5.39	25.71	35.10	40.47	43.13	44.89	46.08
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Wheat (10-5)	187.18	234.71	249.28	255.97	259.78	263.24	266.09	268.66
Yield Avg % Dec	0	0	0	0	0.05	0.28	0.54	0.86
Yield Var % Dec	0	0	0	0	2.06	10.51	17.94	25.02
Mean Profit	42,304.41	41,548.65	41,240.96	41,089.50	40,973.09	40,785.23	40,596.31	40,386.82
Std Dev Profit	11,313.29	7,468.25	6,283.16	5,826.50	5,552.61	5,176.73	4,850.61	4,537.71

75 percent Maximum Yield Variability Reduction

Decision Variable[a]	Risk Significance Level[b] 55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	122.55	73.12	43.83	28.93	19.70	13.35	8.52	4.56
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Soybeans (6-20)	0	8.11	26.00	35.10	40.74	44.62	47.58	49.88
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Wheat (10-5)	197.45	238.77	250.17	255.97	259.97	262.03	263.90	265.56
Yield Avg % Dec	0	0	0	0	0	0	0	0.04
Yield Var % Dec	0	0	0	0	0	0	0	0.93
Mean Profit	42,260.27	41,522.33	41,235.48	41,089.50	40,999.08	40,936.85	40,889.53	40,827.45
Std Dev Profit	11,174.35	7,379.28	6,266.24	5,826.24	5,609.85	5,488.87	5,413.36	5,334.51

[a]Soybeans are the Forrest cultivar planted June 10 or June 20. Wheat is the Coker 68-15 cultivar planted October 5. Yield Avg % Dec refers to the percent decrease in expected yields and Yield Var % Dec refers to the percent decrease in variance of yields from the level of currently available cultivars. Mean Profit is the mean of net returns above variable costs. Std Dev Profit is the standard deviation of net returns above variable costs.
[b]See footnote b, Table 2.

mum potential yield variability reduction is provided in Figure 1. Note that the E-V frontiers are truncated at an upper variance bound rather than displaying the common risk neutral intersection to allow focus on risk-averse results and to provide a more clearly distinguished graphic addressing the differences between E-V frontiers. Interestingly, the mean-variance function for the 1 percent yield reduction factor function is almost identical to the base case risk results mean variance function with the exception of covering more surface area at the lower range of net returns above variable cost and variance of net returns. These results demonstrate that the only advantage of agronomic research under these conditions is

Table 5. Risk Analysis Results for the 0.5 Percent Yield Reduction Factor

100 Percent Maximum Yield Variability Reduction

Decision Variable[a]	Risk Significance Level[b]							
	55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	172.63	111.29	90.96	53.95	21.05	14.31	9.71	5.95
Yield Avg % D ec	1.16	1.21	1.29	1.02	0.07	0	0	0
Yield Var % Dec	45.14	46.25	47.60	42.48	5.23	0	0	0
Soybeans (6-20)	0	0	0	22.66	36.75	39.41	41.11	42.30
Yield Avg % Dec	0	0	0	0.52	0	0	0	0
Yield Var % Dec	0	0	0	28.51	0	0	0	0
Wheat (10-5)	147.37	208.71	229.04	243.39	262.19	266.28	269.18	271.75
Yield Avg % Dec	0	0	0	0.18	0.43	0.64	0.86	1.13
Yield Var % Dec	0	0	0	12.64	25.21	32.50	38.75	44.66
Mean Profit	42,644.91	41,761.35	41,460.49	41,134.05	40,760.48	40,574.97	40,400.56	40,211.22
Std Dev Profit	12,101.30	7,842.52	6,751.15	5,812.06	4,851.26	4,419.57	4,063.56	3,722.43

75 Percent Maximum Yield Variability Reduction

Decision Variable[a]	Risk Significance Level[b]							
	55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	127.15	75.75	44.33	28.93	19.73	13.50	8.79	4.94
Yield Avg % Dec	0.19	0.13	0.05	0	0	0	0	0
Yield Var % Dec	6.99	4.88	1.90	0	0	0	0	0
Soybeans (6-20)	0	7.17	25.89	35.10	40.59	43.81	46.09	47.81
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Wheat (10-5)	192.85	237.08	249.79	255.97	259.68	262.69	265.12	267.25
Yield Avg % Dec	0	0	0	0	0.03	0.16	0.30	0.48
Yield Var % Dec	0	0	0	0	1.12	5.78	10.00	14.13
Mean Profit	42,280.89	41,533.18	41,237.82	41,089.50	40,984.97	40,853.67	40,726.91	40,590.17
Std Dev Profit	11,241.13	7,415.96	6,273.48	5,826.50	5,578.85	5,319.99	5,109.49	4,918.19

[a]See footnote a, Table 3.
[b]See footnote b, Table 2.

to reduce variability and profits concurrently, which is of benefit only to extremely risk-averse farmers. Consequently, this particular yield variability reduction function of agronomic research only provided a possible extension of the E-V function for existing crop cultivars for dryland soybeans and wheat, expanding the choice set for lower profits and profit variability. However, more favorable yield reduction factors providing less decrease in average yields shifted the E-V frontier to the right, slightly for the 0.5 percent yield reduction factor, but substantially for the 0.1 percent yield reduction factor. Therefore, under these lower mean yield reduction functions, greater net returns above variable costs can be achieved at similar levels of variance of net returns. Similarly, a given level of expected net returns above variable cost can be realized with ever decreasing variance of net returns as the yield reduction factor becomes more favorable.

Table 6. Risk Analysis Results for the 0.1 Percent Yield Reduction Factor

100 Percent Maximum Yield Variability Reduction

Decision Variable[a]	Risk Significance Level[b]							
	55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	320.00	320.00	274.54	251.07	239.37	233.54	230.98	230.60
Yield Avg % Dec	1.70	2.63	3.02	3.37	3.73	4.10	4.48	4.91
Yield Var % Dec	86.02	91.99	93.53	94.64	95.58	96.38	97.07	97.70
Soybeans (6-20)	0	0	0	0	0	0	0	0
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Wheat (10-5)	0	0	45.46	68.93	80.63	86.46	89.02	89.40
Yield Avg % Dec	0	0	0	0	0	0	0	0
Yield Var % Dec	0	0	0	0	0	0	0	0
Mean Profit	44,333.41	43,646.09	42,912.91	42,479.97	42,176.87	41,932.14	41,707.38	41,477.68
Std Dev Profit	12,089.79	9,152.52	6,746.98	5,458.14	4,637.90	4,030.69	3,514.31	3,020.70

75 Percent Maximum Yield Variability Reduction

Decision Variable[a]	Risk Significance Level[b]							
	55%	60%	65%	70%	75%	80%	85%	90%
Soybeans (6-10)	170.69	108.03	84.64	51.42	32.73	14.43	9.74	5.89
Yield Avg % Dec	0.75	0.75	0.72	0.62	0.42	0	0	0
Yield Var % Dec	40.91	41.06	40.45	38.13	32.65	0	0	0
Soybeans (6-20)	0	0	0	22.62	31.52	38.71	40.89	42.56
Yield Avg % Dec	0	0	0	0.34	0.15	0	0	0
Yield Var % Dec	0	0	0	29.55	19.06	0	0	0
Wheat (10-5)	149.31	211.97	235.36	245.96	255.75	266.86	269.37	271.55
Yield Avg % Dec	0	0.03	0.13	0.22	0.33	0.47	0.59	0.74
Yield Var % Dec	0	4.83	16.90	23.77	29.22	34.01	37.47	40.83
Mean Profit	42,777.54	41,819.56	41,427.19	41,131.70	40,910.55	40,654.87	40,536.18	40,411.09
Std Dev Profit	12,398.78	7,883.46	6,440.09	5,530.72	4,958.39	4,351.88	4,108.82	3,889.34

[a]See footnote a, Table 3.
[b]See footnote b, Table 2.

With the exception of the most favorable yield variability reduction function model for the lowest two risk aversion significance levels, the reliance upon the negative covariances between agricultural enterprises served as a desirable and effective means of dealing with much of the risk associated with fluctuating yields. This is indicated by the utilization of a crop mix of both wheat and soybean in every other case. However, the importance of the ability of agronomic research to produce new cultivars which can reduce yield variability is still relevant. This is indicated by the adoption of cultivars produced by agronomic research in several scenarios. Yield variability reducing research was used to complement negative covariances of agricultural enterprises. In no case were yields reduced by more than 5 percent, but yield variability was reduced up to 98 percent. Hence, dryland soybean-wheat farmers would be willing to adopt risk reducing cultivars with lower yields and variability of yields providing there is an

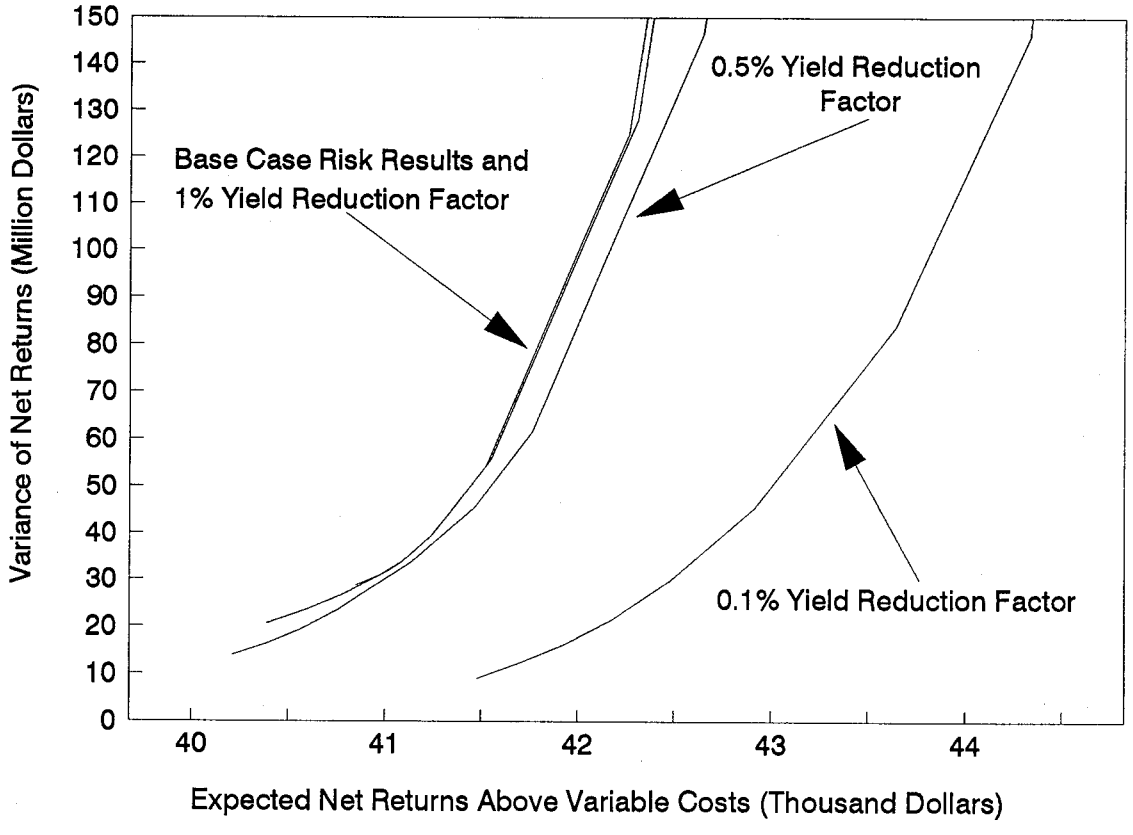

Figure 1. Mean-Variance Results Under Agronomic Research: 100 percent Maximum Potential Yield Variability Reduction Function.

adequate tradeoff between mean and variation. Given these results, it seems unlikely that agronomic research on the reduction of yield variability would not be adopted by farmers unless sizeable reductions in the variability of yields can be achieved with only slight (or no) expected yield decreases. However, research that can accomplish this objective appears to be desirable from the farmers' perspective based on model results in which newly developed cultivars were selected under several of the experimental conditions.

SUMMARY AND CONCLUSIONS

Economic analysis can provide insight into the adoption and production practices associated with decreased yield variability cultivars. Given the considerations of production risk associated with fluctuating yields, the potential exists for farmers to adopt new cultivars that reduce the variability of yields even at a cost of the reduction of expected yield levels. A production management decision-making model was formulated utilizing mathematical programming techniques to conduct an E-V (mean-variance) risk analysis in order to determine the level of potential adoption of new cultivars and the microeconomic effects of agronomic research. Consequently, the costs of agronomic research to government and industry are excluded. E-V analysis is appropriate under tests developed satisfying Meyer's location and scale conditions. Given the objective of the study, research was focused upon production risk involving yield fluctuations, with marketing risks being excluded. The case of a hypothetical dryland soybean and wheat producer in the Delta region of Arkansas was considered.

For the conditions modeled and the agronomic research functions considered, results indicate that negative covariance of yields between different crops and production practices continues to provide an extremely effective method for the reduction of the risk borne by agricultural producers. The currently available risk management tool of utilizing negative covariance between agricultural enterprises sets the stage for the results on new cultivar adoption. Adoption of new cultivars does occur, but only when a reduction in expected yields is accompanied by substantial reduction in the fluctuation of yields because negative covariance is already used to offset some risk. Dependent upon the agronomic research function and the risk attitudes of farmers, conducting yield variability reducing agronomic research is potentially worthwhile from the producers' perspective

for both soybean and wheat cultivars under minimal decreases in expected yield. Obviously, the ability of agronomic research to shift the E-V frontier to the right will enable agricultural producers to achieve similar expected net returns above variable costs while lowering the variability of net returns above variable costs. Results indicate that good risk management strategies entail continuing production of negatively correlated agricultural enterprises while simultaneously searching for new cultivars with lower variability of yield but similar expected yields.

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