Cultivar Diversity:
A Neglected Risk
Management Strategy

Dawit Tadesse and Steven C. Blank

Risk reduction through diversification across cultivars is evaluated. A case study of peach growers in California shows that cultivar diversity reduces both yield and revenue variability. As a result, the probability of falling below minimum income requirements set using a safety-first model is reduced using this strategy.

Key words: cultivar, diversification, peaches, risk management, safety first

Introduction

Cultivar diversification is a traditional production risk minimization strategy still practiced around the world (Richards; Van Noordwijk and Van Andel). However, in modern agriculture, its use differs across commodities. Producers of high-value annual crops, such as vegetables, commonly use all three types of diversification: across crops, locations, and cultivars. For perennial crop producers, diversification across crops is common, while specialization in cultivars is often promoted for both production and marketing reasons. In general, farmers reluctant to use cultivar diversification usually practice specialized production as a means of achieving economies of scale in one particular enterprise, such as practiced in the grain-producing regions of the United States, or cultivar specialization in response to markets' desires for product standardization (Boehlje and Lins).

In industries producing tree crops, such as fruits and nuts, risk reduction through diversification across cultivars is seldom practiced, as more farmers pursue specialization. One notable exception is the peach industry; cultivar diversity is practiced, but peach growers vary widely in the degree to which they use the strategy. Thus, the peach industry provides a good case study for evaluating the benefits of cultivar diversity as a risk management tool.

To motivate such an assessment, it is important to first place cultivar diversity into context relative to the two other types of diversification used by farmers, and then to place diversification into context relative to other risk management tools. Although cultivar diversification has received little attention in the risk management literature, it deserves research attention because it is a management tool that offers growers the potential of both higher average revenues per acre and lower variance in returns.

Dawit Tadesse is a former graduate student, the University of California, Davis; Steven C. Blank is an extension economist in the Agricultural and Resource Economics Department, the University of California, Davis, and a member of the Giannini Research Foundation.

To begin, it is noted that farmers use three types of production diversification. The most common type is diversification across products—a strategy derived from portfolio theory developed in the stock market. This strategy can be applied by any farmer with knowledge of how to grow more than one commodity, including growers with small and/ or contiguous parcels of land. The goal of this type of diversification is to reduce variance in sales revenues by participating in more than one product market. To be successful, the product markets must have low or negative levels of correlation in their prices.

The second type of diversification, across locations, has also been well known for some time (Goland), but practiced less often because it requires operating two or more parcels that are geographically separated—a requirement which could be infeasible for some growers (Nartea and Barry). Peach growers do use this risk management strategy (Davis et al.). Under this spatial diversification, a grower must scatter crop production across locations sufficiently far apart to have low levels of correlation in their weather extremes. Thus, because the focus is on reducing yield variance, this strategy can be applied by growers specializing in one commodity.

Finally, cultivar diversity is a form of temporal diversification, but it incorporates aspects of each of the other two diversification strategies. The common goal of cultivar diversity is to have portions of total acreage (either contiguous or scattered) reach the harvest stage at different times of the year (Park and Florkowski). By selecting cultivars of a single commodity that are not highly correlated in their growth schedules, farmers can both (a) reduce average yield variability by reducing weather risk exposure (a feature of geographical diversification), and (b) raise average price received and/or lower price variance by being able to sell output in more than one market season (similar to product diversification). While the practice of cultivar diversity complicates both production and marketing, it can increase profits (Larson and Mapp).

Diversification is a favorite risk-management tool of many farmers (Boehije and Lins). For example, a recent survey in California found most farmers use some type of diversification as a risk management strategy, while few producers use the available financial risk management tools (Blank, Carter, and McDonald). That study reported only 23.4%, 6.2%, and 24.4% of growers in the state used forward contracting, hedging, and crop insurance, respectively, as risk reduction strategies, suggesting these tools may be ineffective. Farmers described diversification across crops as an easily implemented and effective strategy for managing revenue risk. This view was supported in an earlier study by Blank, who showed there was an optimal amount of crop diversification among crop portfolios, and that this risk management strategy was always preferable to specialization.

For peach growers, diversification of some type is one of the few risk management strategies available or acceptable to a majority of producers. In California, only 4.2% of peach growers have crop insurance, and there is no price risk management tool available for peaches (Blank, Carter, and McDonald). Peach growers in the southeastern United States have shown interest in revenue insurance, signaling that protection against only yield or price risk is insufficient (Miller, Kahl, and Rathwell). Because diversification reduces revenue risk, it suits the needs of most producers. As a result, all peach growers use some type of diversification. To date, however, no published research has focused on the performance of cultivar diversity as a tool for managing revenue risk.

Our intent is to extend the literature by examining this diversification tool. Therefore, the objective of this study is to analyze cultivar diversity as a risk management strategy

in orchard farming systems. Hypotheses regarding income and production risk reduction through diversity are tested using survey data from peach growers in California. This industry provides a rare case study allowing comparisons between fairly specialized tree crop operations versus others which are diversified in their cultivars for a single commodity.

Measuring Risk Management Performance

In this analysis, the effect of using cultivar diversification to manage risks faced by California peach growers is measured using a safety-first criterion. A safety-first or "probability of disaster" approach has been useful in varied risk assessments, ranging from analyzing the behavior of farmers in Medieval England and explaining the choice of scattered fields versus consolidated farm holdings (McCloskey) to analyzing risk minimization strategies of peach growers in Georgia (Davis et al.), low-income rice farmers (Roumasset), peasant farmers in Peru (Goland), and grazing in Mexican ejidos (Thompson and Wilson).

Safety-first criteria are alternative performance measures (Hagigi and Kluger). They are also widely used tools for decision making under risk (Berck and Hihn; van Kooten, Young, and Krautkraemer), compatible with the standard utility theory (Bigman; Pyle and Turnovsky). In agriculture, risk-averse investors have been shown to adopt safety-first decision rules when the scale of possible losses from an investment is significant (Atwood, Watts, and Helmers).

Safety-first models create a rank ordering of decision alternatives by placing constraints upon the probability of failing to achieve certain goals of the firm. Several forms of safety-first models have been proposed as alternatives to expected utility maximization (Bigman; Hatch, Atwood, and Segar). In his seminal 1952 work, Roy argued that in some situations, such as when the survival of the firm is at stake, decision makers select activities which minimize the probability of failing to achieve a certain goal for income, i.e.:

(1)   minimize $\text{Prob}\{\pi < \pi^*\}$,

where $\text{Prob}\{\cdot\}$ is the probability of some event $(\cdot)$ specified within the braces, π is an income random variable, and π^* is an income goal often referred to as the "disaster level" or the "safety threshold."

In another approach, Telser's criterion maximizes expected income subject to probabilistic constraints on failing to achieve income goals:

(2)   maximize $E(\pi)$

subject to:

(3) $\text{Prob}\{\pi < \pi^*\} < \Gamma$,

where Γ is an upper (acceptable) limit on $\text{Prob}\{\pi < \pi^*\}$. Telser's approach is a two-step procedure whereby the individual first eliminates alternatives that fail to meet the safety requirements for a given level of Γ, and then selects among the remaining alternatives the one(s) most likely to maximize expected utility.

Building on the framework of the two basic models identified above, many researchers have proposed improvements (see Bigman for a brief review of the literature). Nevertheless, what all safety-first models have in common is some safety threshold or income goal. Therefore, this study assumes a farmer's objective is to generate sales revenue which is expected to produce at least some designated minimum level of return, π^* (Mahul). The designated safety threshold (π^*) is a personal preference based on financial obligations, lifestyle goals, and opportunity costs. Consequently, this threshold will vary across individuals.

Empirical applications of safety-first models often employ a measure called the "probability of disaster" (PD), or "risk of ruin." This measure incorporates π^*, and can be calculated for any market. The PD measure indicates the chance (in percentage terms) that a producer will generate a return below some critical level. The PD is found by calculating a "z" score and then identifying the relevant probability for that z-value in a statistical table. The z-value is calculated here as follows:

$$(4) \qquad\qquad z = \frac{E(R_i) - \pi^*}{\sigma_i},$$

where $E(R_i)$ is the expected revenue (or yield or other factor) for cultivar i, and σ_i is the standard deviation of revenues for cultivar i. The z-score measures the distance of the expected outcome from disaster in units of standard deviation. In other words, a risk management alternative reduces the probability of disaster if it causes z to rise, compared to the current situation. The z-score model, developed by Stephen and adapted by Winterhalder and by Goland, assumes a threshold requirement. In the current study, π^* is calculated based on responses from California farmers during interviews.

Empirical Methods

The main variables considered in this study are yield per acre of freestone peach cultivars and income (revenue) in dollars per acre. Yield is reported as the number of 25-pound boxes per acre. Growers' gross income per acre is computed as a product of yield and the average price for each season for each cultivar.

The data were collected from peach growers in California's Fresno County, known for its importance in freestone peach production. A listing of 498 growers was provided by the Fresno County Agricultural Commissioner's office. From that list, a stratified random sample was selected, consisting of 70 growers. Personal interviews with each grower were conducted by the senior author in 1999. Interviewees were asked questions about peach cultivars and their production of each cultivar over the previous five years (1994–1998). Of the 70 growers interviewed, 50 provided complete yield data on each cultivar for the five-year period, and thus were included in the final sample for the study. A summary of data from the 50 farms is presented in appendix table A1. The 50 farms represent 73% of the 15,885 total acres of peaches in Fresno County reported in the *1997 Census of Agriculture* [U.S. Department of Agriculture (USDA), p. 425]. Also, the sample size gives a 95% confidence level for being within $475 of the actual mean income per acre, according to the standard formula for determining sample size without replacement from small populations.

As a preliminary step, analysis of variance (ANOVA) was performed using subsamples of growers who produced identical combinations of cultivars during the study period, to determine whether yield variance was influenced by management and/or seasonal factors. The variability in yield and income of each farm was determined by computing the standard deviation and coefficient of variation of each cultivar for each year. Then, the average standard deviation and coefficient of variation were computed to determine overall variation for each farm over the five-year period.

In this study, the benefits of peach cultivar diversification are defined in two forms. The first form is the resulting absolute reduction in variance compared to the level observed for a single cultivar. Blank employed a similar approach to evaluate the benefits of crop diversification. This form of benefits was analyzed first by applying diversity equations relating the coefficient of variation of a single crop to that for a portfolio of crops (Eisgruber and Schuman; McCloskey). If the average output of each cultivar is defined to be 1.0, then v will be the coefficient of variation of the ith cultivar on a farm, and V is the coefficient of variation for all cultivars in a farmer's portfolio.

Following earlier studies, the variance of a portfolio of cultivars is approximated with the formula:

$$(5) \qquad V = v\left(\frac{1 + [N - 1]r}{N}\right)^{\frac{1}{2}},$$

where N is the number of cultivars and r is the average correlation between cultivars. Correlation coefficients between a farmer's cultivars were calculated; then the mean of those r values was computed to obtain a single correlation value per grower. The estimates of V provide a quantitative assessment of the value of diversity (multiple cultivars), relative to a single cultivar, in reducing variability of yield and income per farm. If $r = 1$ or $N = 1$, then $V = v$, indicating no reduction in variability from diversity. When $r = 0$, variability will decrease continuously as the number of cultivars increases. The maximum effect of diversity in lowering variance is $vr^{\frac{1}{2}}$, assuming $r \geq 0$ for cultivars of the same commodity.

Next, the effects of farm size on the effectiveness of cultivar diversity must be assessed. The cultivar diversity of agricultural systems can be represented by the Shannon-Weaver diversity index (Meng et al.). This index combines the number of cultivars, their distribution in a geographic area, and the size of the area. The Shannon-Weaver diversity index (H) is defined as:

$$(6) \qquad H = -\sum_{i=1}^{N} A_i \log(A_I),$$

where A_i is the proportion of a farm's total area (A_I) occupied by cultivar i. For a farm diversified across crops, the sum of A_i for a single crop (peaches in this case) will not total one, but will instead total the proportion of total acreage planted to the single crop being studied. The index grows as the degree of specialization drops for a farm. In other words, as the importance of each single crop or cultivar decreases (i.e., the percentage of total farm acreage planted to that crop declines), the value of H increases, indicating a more diverse operation (note, however, that H is defined to be negative).

The scattering of cultivars within a farm is considered a potentially important decision factor because it affects risk levels, but has offsetting costs (Nartea and Barry;

Davis et al.). The effects of cultivar scattering within a farm are expected to be influenced by a farm's total size, primarily due to the effects of geographic diversification likely to occur as a farm grows larger. Also, larger farms may be able to support more cultivars operating in efficient plot sizes.

Consequently, to analyze the relationship between cultivar diversity and variance reduction from diversity, a farm size variable is needed to account for any effects of geographic diversification. Therefore, a regression equation of the form

$$(7) \qquad\qquad Y_j = \beta_1 + \beta_2 H_j + \beta_3 SZ_j + \varepsilon_j$$

is estimated for both yield and revenue. Y_j (R_j) is the percentage that yield (revenue) variance decreased on farm j compared to the variance from farm j's single-best cultivar, SZ refers to farm size in acres [A_I in equation (6)], and ε is an error term. A farm's "single-best" cultivar is defined to be the one with the highest average yield (revenue) over the study period. To calculate Y_j (or R_j), the v for the farm's best cultivar is used with V_j [from equation (5)] to obtain $Y_j \equiv (v_j^* - V_j)/v_j^*$, which is expressed as a percentage. As noted above, there are 50 observations in this study.

Finally, the second form of benefit from diversity can be measured directly by how much it lowers the probability of income falling below the disaster level set for each household. This benefit is identified through the difference in z-scores for each farm's diversified versus single-crop operation. In this study, the disaster level for each grower was set at the point denoted by the lowest 10% of the (income or yield) distribution for the industry in any given year. In other words, the probability of a disastrous result is estimated to be 10%. This level was identified during the grower interviews by eliciting responses to questions asking each respondent to specify a minimum income or yield threshold necessary to meet his or her financial obligations. Details of the calculation are presented in a later section.

Results

The 50 California farmers interviewed provided data representing 73% of Fresno County's peach acreage. As observed from appendix table A1, most of the peach farms are relatively small. This is because no peach grower produces only peaches; all survey respondents are diversified across crops. The acreages evaluated in this study are those with peaches only. Growers' other crop acreages are not included. The representativeness of the farms surveyed was assured by utilizing a stratified random sample. Eight strata were used with six or seven farms selected from each. The strata were defined to cover one-eighth of the entire distribution of farm sizes from the Fresno County Agricultural Commissioner's office comprehensive list of 498 peach growers in the county.

The normality of the yield and income distributions was tested to assure the validity of the z-score results, which are derived from a standard normal distribution. The Kolmogorov-Smirnov test for normality was significant at the 95% confidence level, confirming the yield and income distributions of the surveyed growers are normal, as expected. According to the central limit theorem, the means, as a multitude of equal sized random samples, are gathered from the same population, and if the mean of each sample is computed and the means of the means of different samples are combined to form a new distribution, this new distribution is normal (Weinberg and Schumaker, p. 114). In

this study, the mean yield and income over five years for each grower and cultivar were computed and averaged; thus the yield and income distributions are expected to be normal.

Yield Variability

The mean, standard deviation, and coefficient of variation of peach yield for the 50 farms are 707 25-pound boxes, 73 25-pound boxes, and 10%, respectively. The mean yield for all cultivars on a farm ranged from 262 to 1,264 25-pound boxes over the data period. The coefficient of variation ranged from 2% to 67% over the 50 surveyed farms, and appeared to be relatively higher for farms with a larger number of cultivars.

The ANOVA to compare yield variance differences between growers within subsets producing the same cultivars was limited by the small subset sizes. For example, the largest subset included just five growers who produced only the same three cultivars— O'Henry, Elegant Lady, and Queen Crest—over the entire 1994–98 five-year period. As reported in table 1, the ANOVA results for this subset revealed significant F-values for cultivars and growers. However, no significant differences were observed across years or for any of the interaction factors. Thus, the null hypothesis of no significant grower-related differences in productivity can be rejected. When the variance components were divided into "among growers" and "among cultivars" (which represents within-grower components), 11% of the variance is from within growers, and 17% is from among growers. These findings indicate that, although differences in unobserved resources and farm management among growers are important in explaining variation, random factors within each farm also cause variation in yield.

Yield variability originating within farms was evaluated in more detail by assessing yield variation between cultivars maturing in different seasons. Interview responses revealed this temporal diversification (i.e., across seasons) is an important consideration in growers' risk management decision-making processes. As observed from the survey data reported in table 2, early-season cultivars (defined as those marketed before July 1) provide lower yield and show relatively higher variation compared to mid-season (July 1–31) and late-season cultivars (those marketed August 1 or later). Early-season cultivars, however, receive premium prices, thereby offsetting the low yield (Davis et al.). Therefore, planting combinations of early-, mid-, and late-season cultivars may be less risky than relying on cultivars that mature during a single season. The cross-season strategy can both reduce yield variance and extend the marketing season (Wilson and Thompson).

Price Variability

Peach prices during the five-year period are summarized in table 3. These prices are reported by the USDA's Federal-State Market News Service for Fresno-Central and Southern San Joaquin Valley sales. Prices are available for 10 grades and fruit sizes of peaches for all seasons. For this study, prices of all sizes and grades of freestone peaches for each harvest season (early, mid, and late) were averaged and used as the mean price received by growers in each season. For early-, mid-, and late-season harvests, respectively, the mean price was computed using data from June 30 and before, all of July, and August 1 and later.

Table 1. Analysis of Variance of Yield for Subset of Five Fresno County Peach Growers Producing Three Identical Cultivars, 1994–1998

Source of Variation	Degrees of Freedom	F-Statistic	Variance Components (%)
Among cultivars	2	5.78*	11
Among growers	4	6.04*	17
Among years	3	1.14	3
Interactions of cultivars by growers	8	0.97	18
Interactions of cultivars by years	6	0.12	—
Interactions of growers by years	12	0.71	15
Interactions of cultivars by growers by years	24	—	39

Error   = 0
Total observations = 60

Notes: An asterisk (*) denotes a significant value at the 95% confidence level. The variance component percentages do not total 100 due to rounding. There are four observations for "years" because that variable is measured as the change in variance between years.

Table 2. Peach Yield Mean, Standard Deviation, and Coefficient of Variation for Each Season (25-pound boxes per acre)

Peach Cultivar Harvest Period	Mean	Standard Deviation	Coefficient of Variation (%)
Early season (marketed before July 1)	592	280	47
Mid-season (marketed between July 1 and July 31)	929	402	43
Late season (marketed August 1 or later)	998	389	39

Table 3. Annual Peach Prices in Fresno, California, 1994–1998 (dollars per 25-pound box)

Year	Early Season Mean	Early Season Std. Dev.	Early Season CV (%)	Mid-Season Mean	Mid-Season Std. Dev.	Mid-Season CV (%)	Late Season Mean	Late Season Std. Dev.	Late Season CV (%)	All Seasons Mean CV (%)
1994	7.30	3.6	49	6.37	2.1	32	6.70	1.6	24	35
1995	10.49	2.7	19	7.59	1.5	19	8.90	1.2	13	17
1996	11.08	2.6	24	11.21	1.3	12	9.57	1.6	16	17
1997	9.24	3.8	42	5.79	1.5	25	5.87	0.7	11	26
1998	14.26	7.4	52	7.18	1.7	24	6.75	1.7	26	34
Average	10.47	4.0	37	7.63	1.6	22	7.56	1.4	18	26

Notes: The early season is defined to include all peach sales before July 1, the mid-season includes all sales between July 1 and July 31, and the late season includes all sales from August 1 or later.

The coefficients of variation of these prices were calculated to determine the relative variability of prices during each seasonal harvest period. The average coefficient of variation of prices was 37% for early-season harvests, 22% for mid-season, and 18% for the late season. The high price variability of early-season cultivars occurs because peach prices are highest in the "early periods" of the early-season harvest when supply is short, but prices decline quickly as supplies increase. During mid- and late-season harvest periods, however, price gradually stabilizes with the supply of peaches.

Because there is no government or industry price-stabilizing mechanism for peaches, prices are determined by supply and demand. Freestones are sold predominantly for fresh-market consumption; other varieties are used for canning and other processing, and thus may be sold on contracts. As a result, freestone peach prices vary on the spot market from year to year on the basis of variation in production and demand. Over our study period (1994–98), the coefficient of variation of peach prices across all seasons ranged from 17% to 35%, as shown in the last column of table 3.

Income Variability

Peaches are perennial crops, so year-to-year variation in bearing acreage is low. Therefore, the major year-to-year changes in production come primarily from yield variation. Cultivars that have high price and yield variabilities may generate relatively stable gross income because of negatively correlated prices and yields. For the 50 farmers surveyed, revenue per acre had a mean of $6,512 (with a range of $2,741 to $9,558); a standard deviation of $1,803 (with a range of $274 to $1,927); and a coefficient of variation of 28% (with a range of 7% to 46%).

Determination of the Disaster Level

The minimum threshold for yield and gross income was determined by using the average responses of farmers to interview questions asking them to specify a level below which they could not meet their financial obligations. For each factor, the cut-off value identified was approximately 10% on the normal distribution.

For yield, growers agreed that about 400 boxes per acre is a reasonable approximation of disastrous production. For example, a large-scale peach grower in Fresno responded during his interview by saying, "I believe 400 boxes per acre is a reasonable estimate on the low end, and I believe 10% of the cultivars produce at this level. With today's cultural costs and FOB prices for peaches, bankruptcy certainly appears likely."

The 10% cut-off level was then converted into a z-score. Using a standard normal distribution table, 1.28 was found to be the appropriate value in this one-tailed application. The five-year mean yield and standard deviation were 708 and 231 boxes per acre, respectively. Thus, the cut-off level for yield was calculated as $1.28 \times 231.42 = 296$, and $708 - 296 = 412$ boxes per acre. Therefore, in this analysis, any cultivar yielding 412 or fewer boxes per acre is considered to have a disastrous result for growers.

Similar calculations were made to determine the disaster level for revenue. The mean and standard deviation of gross income were $6,512 and $1,803 per acre, respectively. The z-value for 10% is 1.28. Thus, $1.28 \times \$1,803.46 = \$2,308.43$, and $\$6,512 - \$2,308 = \$4,204$. Therefore, the cut-off level for gross income disaster was calculated to be $4,204 per acre.

Different degrees of disaster in income or yield can be experienced by growers from their cultivars. If a grower obtained less than $4,204 per acre from all of the farm's cultivars, that grower would suffer what is termed here a "100% disaster." The grower can also experience an intermediate level of disaster by receiving less than $4,204 per acre from some of the orchard's cultivars.

Based on the calculations above, 38% of the growers showed some level of yield disaster, and 8% experienced a 100% disaster level. Similarly, 44% of growers had some income disaster because revenue from at least one cultivar was less than the minimum threshold. However, only 2% experienced a 100% income disaster. The percentage of growers who had 100% disasters was lower for revenue than yield, suggesting income variance may be reduced by offsetting price and yield variation. Nevertheless, this study's findings verify that peach growers experience considerable income and yield risk in California.

Correlation Between Cultivar Yield and Income

To reduce risk through diversification, farmers should choose cultivars with negative or low correlations for yield or income, because a potentially disastrous result from one cultivar can be offset by an adequate result from another. For this study, the average yield correlation across all cultivars on a particular farm ranged from -0.05 to 0.98, and for income ranged from -0.85 to 0.99, showing good potential for risk reduction for some farms. Farms with high positive correlation between the yield and/or revenue of its cultivars tended to be those with only a few cultivars and all maturing during the same season—in other words, those farms not using cultivar diversity as a temporal diversification strategy.

The offsetting effect of high price on low yield can be seen by comparing tables 2 and 3. The average price of early cultivars was consistently higher than the prices of mid- and late-season cultivars, whereas average yield was lower for early cultivars than for mid- and late-season cultivars. Gross income per acre calculated over the 1994–98 period averaged $6,200 for the early season, $7,090 for the mid-season, and $7,480 for the late season. The difference in gross income between early- and late-season cultivars is 20%. In contrast, the difference in yield between early- and late-season cultivars is 69%. As observed from the relatively small difference in gross income between seasons, variations in prices and yields are offsetting. This finding clearly reflects California's prominent position in the U.S. peach market—supply changes in California affect the national market's price.

Variance Reduction Through Diversity

The motivation for maintaining orchard diversity is the notion that revenues from some cultivars do not show strong positive correlations, thereby reducing risk. The 50 farms comprising our survey sample were characterized by a wide range of diversity. The number of cultivars on a farm ranged from two to 15, with an average of five (see appendix table A1).

The within-farm variability of yield and income observed with multiple cultivars was compared to the variability observed from a single cultivar for each farm. The "diversity" equation (5) facilitated comparing the coefficient of variation for a grower's single-best

cultivar (v) to that of the entire farm (V). The results from individual farms show cultivar diversification reduced yield variance from 93% to 4% and income variance from 87% to 0% (appendix table A2). Seven producers who grew two or three cultivars showed no income variance reduction compared to what they would have experienced by producing only their single-best cultivar. Examination of the data, however, reveals those seven growers benefitted from diversity by reducing yield variability by amounts ranging from 16% to 63%.

For 86% of growers, income variability decreased as a result of cultivar diversity. Although the average reduction in yield variance was higher at 46%, income variability was reduced by 21% on average. The smaller effect of diversity on income variability is due to offsetting variation in prices and yields.

The relationship of variance reduction to diversity and farm size was evaluated by estimating equation (7) using ordinary least squares. For yield variance reduction, the results are represented by:

$$(8) \qquad Y_j = 32.17 + 27.21 H_j + 0.005 SZ_j ,$$
$$(2.81)^* \qquad (0.16)$$

with an R^2 of 0.14 and an F-statistic of 3.9, which is significant at the 95% confidence level. Values in parentheses are t-statistics, and an asterisk (*) denotes significance at the 99% confidence level. Similarly, the results for revenue variance reduction are designated by:

$$(9) \qquad R_j = 6.20 + 24.8 H_j + 0.001 SZ_j ,$$
$$(2.44)^* \qquad (0.37)$$

with an R^2 of 0.11 and a significant F-statistic of 3.01. These results show that both yield and income variance decrease as diversity increases, but are not affected by farm size. (Remember that Y and R are variance *reduction* percentages, and H is defined to be negative.[1]) The positive relationship between variance reduction and diversity suggests risk is reduced by increasing the number of cultivars and reducing the percentage of total acreage planted in any single cultivar, as expected.

Finally, positive results are also found for the second form of benefits. The z-scores show that diversity reduces the probability of income falling below the disaster level. To express the distance from the disaster level of $4,204 per acre, z-scores were calculated for each farm (appendix table A1). Eighty-eight percent of the growers reported income above the disaster level. Descriptive statistics showing the difference between farmers' diversified and single cultivar operations are presented in table 4. On average, diversified farms had income 2.47 standard deviations above the disaster level, with the highest z-score being 6.5 and the lowest being -4.41 (table 4). In contrast, z-scores for each farmer's single-best cultivar averaged 1.85. Also, the group of most-diversified farms was further removed from disaster compared to the group of least-diversified farms.

---

[1] These definitions of the variables facilitated handling the heterogeneous sample without introducing heteroskedasticity into the regression results. As shown in the results of both equations (8) and (9), farm size was not significant. This outcome was expected because the summary data in appendix table A1 show little correlation between farm acreage and number of cultivars on the 50 farms. For example, a farm with only 160 acres had the most cultivars (15), while a farm with 1,900 acres had only three cultivars—one fewer cultivar than a farm of 1% its size (19 acres). For each regression, a Goldfeld-Quandt test for heteroskedasticity generated an F-statistic not significantly different than one, meaning the null hypothesis of homoskedasticity could not be rejected at the 99% confidence level. Thus, maximum-likelihood estimation methods were not required (Pindyck and Rubinfeld, pp. 104–105).

**Table 4. Descriptive Statistics Showing *z*-Score Distance
Above the 10% Income Disaster Level ($4,204/acre) for
Entire Farms and for Their Single-Best Cultivar**

Description	Entire Operations	Single-Best Cultivar
Mean	2.47	1.85
Median	2.70	1.60
Standard Deviation	2.20	1.60
Minimum	-4.41	-0.34
Maximum	6.50	8.70

**Table 5. Sensitivity of Farm *z*-Score Distances from Various Income Disaster
Probability Levels**

	Disaster Probability Level, % / (Threshold, $/acre)			
Description	5% ($3,537)	10% ($4,204)	15% ($4,637)	20% ($4,997)
Mean *z*	3.36	2.47	1.89	1.40
Median *z*	3.60	2.70	2.10	1.80
Standard Deviation	2.00	2.20	2.30	2.50
Minimum *z*	-2.40	-4.41	-5.73	-6.82
Maximum *z*	7.30	6.50	5.90	5.40
% of Farms with $z < 0$	4%	12%	16%	24%

Table 5 shows the sensitivity of *z*-score distances to the disaster threshold level used. The 10% probability of disaster level ($4,204) was used in this study because most farmers said that level of income was the minimum necessary for them to meet their financial obligations. The incomes for the three other probability levels in the table are 5% = $3,537, 15% = $4,637, and 20% = $4,997. Thus, the percentage of peach farms at risk of financial disaster increases rapidly with relatively small increases in costs per acre.

In summary, two forms of benefits from cultivar diversity were evaluated: the reduction in variance measured in absolute terms and in terms of the change in the probability of avoiding a disaster. The empirical methods applied (i.e., the calculated *V*s, the regressions, and the calculated *z*-scores) are not directly related, although each contributes to the general assessment of whether cultivar diversity reduces the risk exposure of growers.

Concluding Comments

Growers face tradeoffs when considering cultivar diversification versus specialization as a production strategy. Specialization may lead to economies of scale that can lower per unit production costs, increasing the profitability of operations. However, diversification of all types has been found to reduce variance in returns. Therefore, the tradeoff involves risk and returns. Interviews with California peach farmers revealed they are concerned about income variability and the probability of avoiding a financial disaster.

Like most farmers, peach growers are a heterogeneous group. The operations of the 50 growers interviewed for this study ranged widely in size, necessitating the use of a stratified sample to assure representation from each scale of operations, and the growers varied in their approaches to risk management. One common component of the risk management strategies being used by the farmers interviewed was diversification of at least two types. All of the growers were practicing cultivar diversification (which is usually a temporal diversification method) and crop diversification.

It is possible that some growers' crop diversification activities influenced their cultivar diversification decisions. Peach variety adoption decisions are influenced by attributes of both the farm and the grower (Park and Florkowski). Specifically, growers who are focusing on a crop diversification strategy may be susceptible to hysteresis in their peach (and other perennial crop) cultivar decisions—a finding supported by Richards and Green in their recent investigation of variety adoption decisions of grape growers. In other words, some peach growers may be less concerned about variation in peach returns because they are diversified across other enterprises.

The results of this study provide strong support for cultivar diversification as a risk management strategy. Compared to the results surveyed farms would have generated as single-cultivar operations, cultivar diversity reduced yield variation in all cases, and 86% of farms had lower income variation with diverse cultivars. Most importantly, z-score results show the probability of disaster was significantly lowered by diversification. This strategy can be critical to the survival of farms in an industry like peaches where the probability of disaster increases rapidly with relatively small increases in cost per acre. Therefore, when a grower is unwilling to consider production systems that may include a financial result with some "risk of ruin," cultivar diversification is an alternative shown to provide a safer balance between risk and returns.

[*Received January 2003; final revision received June 2003.*]

References

Atwood, J. A., M. J. Watts, and G. A. Helmers. "Chance-Constrained Financing as a Response to Financial Risk." *Amer. J. Agr. Econ.* 70,1(February 1988):79–89.

Berck, P., and J. Hihn. "Using the Semivariance to Estimate Safety-First Rules." *Amer. J. Agr. Econ.* 64,2(May 1982):298–300.

Bigman, D. "Safety-First Criteria and Their Measures of Risk." *Amer. J. Agr. Econ.* 78(1996):225–35.

Blank, S. C. "Returns to Limited Crop Diversification." *West. J. Agr. Econ.* 15(1990):204–12.

Blank, S. C., C. A. Carter, and J. McDonald. "Is the Market Failing Agricultural Producers Who Wish to Manage Risks?" *Contemporary Econ. Policy* 15(1997):103–12.

Boehlje, M. D., and D. A. Lins. "Risks and Risk Management in an Industrialized Agriculture." *Agr. Fin. Rev.* 58(1998):1–16.

Davis, S., J. Price, M. E. Wetzstein, and M. Rieger. "Reducing Yield Variation in Peach Orchards by Geographic Scattering." *Amer. J. Agr. Econ.* 79(1997):1119–26.

Eisgruber, L., and L. Schuman. "The Usefulness of Aggregated Data in the Analysis of Farm Income Variability and Resource Allocation." *J. Farm Econ.* 45,3(1963):587–91.

Goland, C. "Agricultural Risk Management Through Diversity: Field Scattering in Cuyo, Peru." *Culture and Agr.* 45/46(1993):8–13.

Hagigi, M., and B. Kluger. "Safety First: An Alternative Performance Measure." *J. Portfolio Mgmt.* 13,4(Summer 1987):34–40.

Hatch, U., J. A. Atwood, and J. Segar. "An Application of Safety-First Probability Limits in a Discrete Stochastic Farm Management Programming Model." *S. J. Agr. Econ.* 21(1989):65–72.

Larson, J. A., and H. P. Mapp. "Cotton Cultivar, Planting, Irrigating, and Harvesting Decisions Under Risk." *J. Agr. and Resour. Econ.* 22,1(1997):157–73.

Mahul, O. "The Output Decision of a Risk-Neutral Producer Under Risk of Liquidation." *Amer. J. Agr. Econ.* 82(2000):49–58.

McCloskey, N. D. "English Open Fields as Behavior Towards Risk." *Res. in Econometrics History* 1(1976):144–70.

Meng, E., M. Smale, H. Ruffa, J. P. Brennan, and D. Godden. "Measurement of Crop Genetic Diversity in Economic Analysis." Paper presented at 43rd annual conference of the Australian Agricultural and Resource Economics Society, Christchurch, New Zealand, 1999.

Miller, S., K. H. Kahl, and J. Rathwell. "Revenue Insurance for Georgia and South Carolina Peaches." *J. Agr. and Appl. Econ.* 32,1(2000):123–32.

Nartea, G., and P. J. Barry. "Risk Efficiency and Cost Effects of Geographic Diversification." *Rev. Agr. Econ.* 16,3(1994):341–51.

Park, T. A., and W. J. Florkowski. "Selection of Peach Varieties and the Role of Quality Attributes." *J. Agr. and Resour. Econ.* 28,1(April 2003):138–51.

Pindyck, R., and D. Rubinfeld. *Econometric Models and Economic Forecasts.* New York: McGraw-Hill Book Co., 1976.

Pyle, D., and S. Turnovsky. "Safety First and Expected Utility Maximization in Mean-Standard Deviation Portfolio Analysis." *Rev. Econ. and Statis.* 52(1970):75–81.

Richards, P. "Spreading Risks Across Slopes: Diversified Rice Production in Central Sierra Leone." *Informationcentre for Low External Input Agriculture* 3(1987):8–9.

Richards, T., and G. Green. "Economic Hysteresis in Variety Selection." *J. Agr. and Appl. Econ.* 35,1(2003):1–14.

Roumasset, A. J. "Rice and Risk: Decision Making Among Low-Income Farmers." In *Contributions to Economic Analysis.* Amsterdam: North-Holland Publishing Co., 1976.

Roy, A. "Safety-First and the Holding of Assets." *Econometrica* 20(1952):431–49.

Stephen, D. W. "Risk and Incomplete Information in Behavioral Ecology." In *Risk and Uncertainty in Tribal and Peasant Economies, A Westview Special Study,* ed., E. Cashdan, pp. 19–46. Boulder CO: Westview Press, 1990.

Telser, L. "Safety-First and Hedging." *Rev. Econ. Stud.* 23(1955):1–16.

Thompson, G. D., and P. N. Wilson. "Ejido Reforms in Mexico: Conceptual Issues and Potential Outcomes." *Land Econ.* 70,4(1994):448–65.

U.S. Department of Agriculture, National Agricultural Statistics Service. *1997 Census of Agriculture: California State and County Data,* Vol. 1, Geographic Area Series, Part 5. Pub. No. AC97-A-5, USDA/NASS, Washington DC, March 1999.

van Kooten, G. C., D. Young, and J. Krautkraemer. "A Safety-First Approach to Dynamic Cropping Decisions." *Eur. Rev. Agr. Econ.* 24,1(1997):47–63.

Van Noordwijk, M., and J. Van Andel. "Reduction of Risk by Diversity: A Theoretical Basis for Age-Old Farming Systems." *ILEA Newsletter* 4(1988):8–9.

Weinberg, G., and J. Schumaker. *Statistics: An Intuitive Approach,* 2nd ed. Monterey CA: Brooks/Cole Publishing Co., 1969.

Wilson, P. N., and G. D. Thompson. "Time Integration: Agribusiness Structure for Competitive Advantage." *Rev. Agr. Econ.* 25(2003):30–43.

Winterhalder, B. "Open Field, Common Pot: Harvest Variability and Risk Avoidance in Agriculture and Foraging Societies." In *Risk and Uncertainity in Tribal and Peasant Economies, A Westview Special Study,* ed., E. Cashdan, pp. 67–87. Boulder CO: Westview Press, 1990.

Table A1. Summary Data from Fresno County Peach Growers, 1994–1998 (N = 50)

Farm Number	Total Peach Acreage	Number of Cultivars	Mean Yield (boxes/acre)	Mean Gross Revenue ($/acre)	Distance from 10% Disaster (z-score)
10	160	15	1,107	9,457	5.56
9	4,900	13	728	6,041	1.58
7	180	12	767	6,704	3.72
11	118	11	974	7,847	3.98
3	200	9	479	4,729	0.56
14	150	9	890	7,204	4.03
8	122	9	839	7,353	3.58
32	70	9	435	3,843	-0.58
4	600	8	376	8,028	3.49
5	500	8	586	5,415	1.28
15	96	8	877	7,120	3.43
21	135	7	930	8,416	2.29
12	100	7	911	7,703	4.09
41	80	7	799	6,742	3.12
16	90	6	734	6,130	2.18
19	85	6	1,015	8,741	4.09
20	90	5	1,050	8,999	4.13
38	75	5	640	5,903	2.49
50	60	5	1,020	9,486	5.44
2	250	4	918	7,388	3.40
6	100	4	435	4,834	1.02
17	85	4	730	6,374	2.56
31	80	4	894	7,757	5.28
35	66	4	817	7,003	3.23
36	65	4	844	7,146	3.90
30	43	4	538	5,153	1.80
47	30	4	780	6,634	4.98
28	19	4	262	2,741	-4.41
1	1,900	3	608	5,781	1.41
24	70	3	553	4,503	0.27
33	60	3	628	6,640	3.18
40	40	3	373	3,840	-1.32
42	40	3	468	4,877	0.92
26	30	3	646	5,496	0.88
46	30	3	883	9,110	6.45
18	102	2	444	4,679	0.91
13	100	2	733	8,302	2.13
29	80	2	660	6,193	2.58
37	80	2	523	5,459	2.21
43	80	2	609	5,403	0.98
23	75	2	400	4,291	0.14
22	50	2	983	7,388	3.71

(continued . . .)

Table A1. Continued

Farm Number	Total Peach Acreage	Number of Cultivars	Mean Yield (boxes/acre)	Mean Gross Revenue ($/acre)	Distance from 10% Disaster (z-score)
27	50	2	419	3,628	−0.86
44	50	2	378	3,431	−1.79
25	40	2	1,264	9,558	4.51
45	40	2	713	7,624	3.18
48	40	2	861	9,053	5.67
34	30	2	893	9,366	5.48
39	30	2	394	4,121	−0.20
49	25	2	565	5,984	2.75
Survey Mean	232	5	707	6,512	2.47

Note: The farm number (column 1) is used for identification purposes only; z-score values in the last column refer to income disaster.

Table A2. Summary of Regression Data (50 observations)

Description	Shannon-Weaver Diversity Index (H)	Yield Variance Reduction (%)	Revenue Variance Reduction (%)
Mean	−2.37	46.2	21.1
Median	−1.90	50.0	17.0
Highest	−1.28	93.0	87.0
Lowest	−3.69	4.0	0.0