Fruit Varieties Journal 52(1):41-46 1998

Impact of Production Risk on the Selection of Peach Rootstocks

JAYSON K. HARPER[1] AND GEORGE M. GREENE II[2]

Abstract

Nine peach rootstocks used in a nine-year experiment conducted at Biglerville, PA were evaluated based on their acceptability to generalized classes of fruit growers with different attitudes towards production risk. Tree mortality and its effect on orchard yield had a major impact on the economic performance of the rootstocks evaluated. In terms of average net returns, Halford, own-rooted 'Redhaven,' Bailey, and Lovell appeared to be good rootstock choices. However, in most cases, net return variability increased as average net returns increased. Using stochastic dominance with respect to a function techniques, Halford, own-rooted 'Redhaven,' and Bailey were ranked consistently in the top three across all risk preference intervals. Replacement of trees did not have a major impact on the preference ranking of a rootstock. The rootstocks Amandier, St. Julien, Damas, Siberian C, and 'Citation' performed very poorly compared to the other rootstocks in the trial.

Introduction

Selection of a suitable rootstock is a critical aspect in the production of any tree fruit crop. This is especially true in peaches which are very susceptible to diseases, nematodes, and cold injury and have short life expectancies (8, 11). The ability to survive has been the main determinant of a good peach rootstock. For example, extension recommendations in Pennsylvania suggest that Lovell and Halford are the best widely available rootstock choices (22). Regional trials (8, 10) and individual experiments (4, 12, 17) have focused on collecting data on the survivability and productivity of alternative peach rootstocks. As a result of these studies, the impact of rootstock selection on peach nutrition, cold hardiness, flowering, yield, and disease susceptibility has been well-documented for the scion cultivar 'Redhaven' in different production regions (1, 2, 3, 4, 8, 9, 12, 15, 16, 17, 18, 19, 26).

Although such comparative production data are invaluable, the large initial cost of establishing a peach orchard makes it imperative that a fruit grower also have data on economic factors when selecting a rootstock. The choice of rootstock will affect the future profitability of the orchard through its impact on productivity and tree mortality. Not all growers will respond in the same way when confronted with these types of production risk. Evaluating the economic performance and relative riskiness of alternative rootstocks is vital to preserving and improving the competitive position of peach growers in the northeastern United States.

Materials and Methods

As part of the NC-140 regional rootstock trial, nine rootstocks with the 'Redhaven' scion variety were planted in 1984 at the Pennsylvania State University Fruit Research and Extension Center in Biglerville (Table 1). This planting was one site of the 16 locations in North America that participated in the experiment (10). The rootstock treatments included seedling, clonally propagated, and own-rooted trees. The soil at the site was an Arendtsville Gravely loam, which was not fumigated, and trees were spaced 4.5 by 6.0 m. The experiment utilized a randomized complete block design (blocking was

[1]Associate professor, Dept. of Agricultural Economics and Rural Sociology, 214-A Armsby Building, The Pennsylvania State University, University Park, PA 16802.
[2]Associate professor, Dept. of Horticulture, The Pennsylvania State University, P.O. Box 309, Biglerville, PA 17307.
Original submission, 11 June 1997. Revised, 4 October 1997. Research conducted at the Pennsylvania State University's Fruit Research and Extension Center in Biglerville, PA and its Dept. of Agricultural Economics and Rural Sociology in University Park, PA.

accomplished on initial trunk size) with each block consisting of one row. The upper and lower rows were guarded with trees on Halford roots and the ends of the rows were guarded with a tree on either Stark Red Leaf or on a locally produced tree on Halford. The rows were oriented NW-SE across the slope to retard erosion and a permanent grass cover crop with a 2 m herbicide-treated strip under the trees was used as the orchard floor management system. Trees were trained to the low, open center system commonly used in the Mid-Atlantic area to facilitate fruit thinning and harvest. Local disease, insect and fertility management practices were followed (22). Data were collected annually on total yield (from 3 to 4 harvests), mean fruit weight (in the second harvest), tree death, trunk circumference, trunk cross-sectional area, tree height, tree canopy cross-sectional area, and canopy width.

One problem encountered in the experiment was poor initial tree quality for some of the rootstocks provided. Of the 90 non-guard row trees planted in Spring 1984, 10 died (11%) by Autumn (<5 months later). Some of the trees were very small and had few roots when planted. For these trees to die by fall of the same year is more an indication of poor initial tree quality than susceptibility to the two major causes of peach tree death in Pennsylvania (winter injury-cytospora canker-lesser peach tree borer syndrome and *Prunus* stem pitting virus). For this reason, yield and mortality data used in the analysis did not reflect the trees that died in 1984. This included 2 own-rooted, 1 Halford, 2 Amandier, 1 St. Julien, and 4 'Citation.' 'Citation was weak for all participants in the NC-140 trial, suggesting a possible incompatibility with 'Redhaven' or perhaps a virus infection (10). For the purposes of this analysis, it was assumed that there were 100% live trees in each rootstock treatment at the end of 1984. Mortality in 1985 and beyond was treated as affecting the average number of mature trees. To maintain tree-to-tree competition, a commercially available peach tree was used to replace any dead trees.

In order to evaluate the effect of rootstock and tree mortality on profitability, net return streams must be projected for each of the alternative rootstocks. Cost of production estimates for the various rootstocks were estimated by adjusting existing tree planting and fresh-market peach production budgets (22) by accounting for differences in tree spacing and the impact on planting, fertilizing, and pruning costs. Tree density was estimated from tree width measurements made in 1990 and by allowing for an additional 0.3 m between trees and 1.8 m between rows (25). Another consideration was harvest cost, which depends on yield and was charged at 6.9¢/kg ($1.50/bu). Annual per acre yields were calculated by multiplying the estimated tree density by the average yield for the trees in each rootstock treatment. Average yields used reflect the death of trees (in 1985 and beyond) in each treatment. Using this yield and a six-year (1986-1992) average price for peaches of 47.8¢/kg (21), gross returns were calculated for each rootstock for each year. Net returns were then calculated by subtracting the appropriate production, planting, pruning, and harvest expenses from gross returns. A six-year average price was used rather than actual prices because the purpose of the analysis is to determine the effect that yield variability and relative mortality had on rootstock selection. Price variability is important, especially in the comparison of crop alternatives, but unlike rootstock selection, it is beyond the control of the grower. In addition, an average price was used because no detailed information on fruit size and quality was collected as part of the NC-140 protocol. Data from mean fruit weights, although not conclusive, indicated fruit from own-rooted, Halford, Siberian C, Bailey, Amandier, and Lovell were not statistically different in weight, while fruit from St. Julien, Damas and 'Citation' weighed less.

One way to select a profitable rootstock would be to compare the average net returns, net present values, or internal rates of return generated by each alternative and select the highest one (27). Although the simplicity of such measures is attractive, they overlook the variability of returns and ignore the role that the attitude of the individual fruit grower towards risk plays in the selection of a rootstock. A better way to evaluate this type of decision-making process is to employ procedures which take into account the distribution and variability of net returns and rank alternatives based on different assumptions about grower attitudes towards risk.

Stochastic dominance is a risk analysis technique that chooses between a set of risky alternatives by comparing the distribution of possible incomes for each alternative, selecting preferred alternatives based on risk preferences. Three stochastic dominance tools are available to the researcher: first-degree stochastic dominance (FSD), second-degree stochastic dominance (SSD), and stochastic dominance with respect to a function (SDRF). The first two analyze the problem for generalized categories of risk behavior, while SDRF analyzes specific intervals which approximate specific risk categories. For SDRF, preferred alternatives are identified by comparing the cumulative density function of net returns from each alternative for the risk categories of interest. A summary of stochastic dominance efficiency criteria can be found in Cochran, Robison, and Lodwick (6).

Stochastic dominance uses risk preference intervals determined with the Pratt absolute risk aversion function, R(x). This function, defined by Pratt (23) as $R(x) = -U''x)/U'(x)$, represents the ratio of first and second derivatives from the decision-maker's utility function, U(x). A utility function is a mathematical conceptualization of the way in which an individual ranks alternative levels of x. In this case, x is net returns. Utility is an ordinal rather than cardinal measure, so interpersonal comparisons are meaningless, but decision-makers can be grouped by how their utility changes with changes in the level of x. FSD rules identify strategies preferred by the individual whose utility is a positive function of income. The criteria are consistent for individuals who prefer more income to less. SSD criteria identify strategies preferred by individuals who receive greater satisfaction from increases in low levels of income than in increases at high levels of income.

This study utilized SDRF to analyze the peach rootstock selection decision. SDRF is a generalized version of FSD and SSD and is more flexible and discriminating, though it does require more specific information about the decision maker's preferences (14). In order for the researcher to use SDRF, risk preference intervals must be specified which are bounded by lower and upper risk aversion coefficients, R1(x) and R2(x). This interval allows for the comparison of alternatives using integration. Six risk preference intervals approximating risk attitudes ranging from moderate risk preference (risk-takers) to strong risk aversion (risk avoiders) were used for the peach rootstock analysis. The range of the Pratt absolute risk aversion coefficients used in this study were originally elicited from growers for a 10-acre orchard block (5) and adjusted to a per hectare basis using a scale transformation (24). The analysis was conducted using a generalized stochastic dominance computer program developed by Cochran and Raskin (7).

Results and Discussion

Descriptive statistics for the nine alternative rootstocks are given in Table 1. Estimated tree densities varied from a low of 259 trees/ha for four of the rootstock treatments to 526 trees/ha for 'Citation.' Mortality, yield, and net returns were calculated based on two assumptions concerning orchard management. The first assumed that dead trees are never replaced and the second assumed dead trees were replaced with young trees of the same rootstock and scion cultivar. The first assumption was how the yield data were collected in the rootstock trial and the second approximates how a commercial fruit grower would manage a peach orchard. In such a situation, replacement of dead trees may either increase or decrease average net returns depending on whether the trees

Table 1. Estimated tree densities, percent of bearing trees, yield, and net returns (US$) for 'Redhaven' on 9 rootstock treatments (1986-1992).

		Without tree replacement				With tree replacement			
Rootstock	Estimated tree density (trees/ha)	Average % bearing trees (1986-92)	Average yield (kg/ha)	Average net return ($/ha)	S.D. for net return ($/ha)	Average % bearing trees (1986-92)	Average yield (kg/ha)	Average net return ($/ha)	S.D. for net return ($/ha)
Own-rooted	287	100	9063	1206	2103	100	9063	1206	2103
Halford	259	97	8255	969	1804	97	8255	951	1775
Siberian C	319	83	5967	–5	1581	91	7311	420	1319
Bailey	259	100	8602	1091	1944	100	8602	1091	1944
Amandier	259	89	6679	378	1316	93	6869	396	1348
St. Julien	358	59	3305	–988	802	73	4473	–795	808
Damas	358	97	5354	–435	1293	97	5354	–457	1254
Lovell	259	88	8000	911	1897	95	8395	1006	2075
'Citation'	526	71	3534	–1317	1010	86	4121	–1443	857

were replaced early (and have a chance of generating income) or late (and so far only represent additional costs to the grower). Average percent of mature trees gives an indication of tree mortality over the productive life of the orchard (1986-1992). In the case of not replacing dead trees, four of the nine rootstock treatments had an average of over 90% mature trees per hectare. Two rootstocks, own-rooted and Bailey, had no trees die from 1985 to 1992. St. Julien and 'Citation,' however, had substantial tree mortality. Even when trees are replaced, a significant portion of the orchard would contain unproductive trees. Average yield per hectare varied greatly between the various rootstocks and the impact of tree mortality is only part of the story. Certainly, the high mortality of St. Julien and 'Citation' contribute to their poor average yields, but some rootstocks with low mortality also had low average yields. Siberian C did not have a high enough average yield to generate positive average net returns unless dead trees were replaced. In terms of average net returns, own-rooted appears to be the best choice, although Bailey, Halford, and Lovell also appear to be good rootstock choices. In most cases, variability as indicated by the standard deviation increased as net returns increased.

The results of the SDRF analysis are summarized in Table 2. The top 3 rootstocks for each risk attitude interval are ranked under both the with and without

Table 2. Ranking of top 3 peach rootstocks with and without tree replacement based on general classes of grower risk preferences.

Approximate risk attitude	Range of Pratt-Arrow risk aversion coefficient	Ranking of alternative peach rootstocks: First	Second	Third
Without tree replacement:				
moderately risk preferring	–.001 to –.0004	own-rooted	Bailey	Lovell
slightly risk preferring	–.0004 to 0.0	own-rooted	Bailey	Lovell, Halford
risk neutral	–.0004 to +.0004	own-rooted	Bailey	Halford
slightly risk averse	0.0 to +.0004	own-rooted	Bailey	Halford
moderately risk averse	+.0004 to +.001	Bailey	Halford	own-rooted
highly risk averse	+.001 to +.002	Bailey	Halford, Lovell	own-rooted, Amandier
With tree replacement:				
moderately risk preferring	–.001 to –.0004	own-rooted	Lovell	Bailey
slightly risk preferring	–.0004 to 0.0	own-rooted	Bailey, Lovell	Halford
risk neutral	–.0004 to +.0004	own-rooted	Bailey	Lovell
slightly risk averse	0.0 to +.0004	own-rooted	Bailey	Halford, Lovell
moderately risk averse	+.0004 to +.001	Bailey	own-rooted	Halford

tree replacement assumption. In either case, growers who are willing to accept some risk would select own-rooted trees as their best rootstock choice. Own-rooted trees had the highest average net return, but also the highest standard deviation of all rootstocks. For risk neutral or slightly risk averse growers, own-rooted 'Redhaven' also appears to be their best choice. For more risk averse growers, Bailey would be the preferred rootstock choice. This shows that these growers would be willing to give up some net returns for lower variability. Bailey has both a lower average net return and lower standard deviation than own-rooted 'Redhaven.' First choice of rootstock was the same with or without tree replacement. The rankings of second and third choices varied somewhat, usually with Bailey, Lovell, and Halford switching places. In general, only four rootstocks are regularly ranked in the top three: own-rooted, Bailey, Lovell, and Halford. Amandier makes an appearance only in a tie for third choice (with own-rooted) for strongly risk averse growers. The ranking of alternatives under SDRF provides the decision-maker with additional information on alternatives, which may be valuable if the preferred rootstock is unavailable.

Conclusions

Stochastic dominance with respect to a function (SDRF) is a useful tool for evaluating production alternatives under risk. When applied to the problem of peach rootstock selection, the ability of SDRF to rank alternatives provides the producer with information as to the preferred rootstock and possible alternatives. In the case of the present study, the finding that Lovell and Halford are consistently highly ranked is supported by the wide adoption of these rootstocks in Pennsylvania and the northeastern United States. The strong performance by Bailey is suggestive that it probably should be more widely tested by growers. The finding that own-rooted 'Redhaven' trees performed very well was somewhat unexpected, primarily because very little is known commercially about the characteristics of peach varieties grown on their own roots. Under Pennsylvania conditions, the French rootstocks (Amandier, St. Julien, and Damas), the Canadian rootstock (Siberian C), and the dwarfing rootstock ('Citation') performed very poorly when compared to the other rootstocks in the NC-140 trial.

Alternative sites with differing soil and environmental conditions and differing levels of tree loss could also be evaluated with stochastic dominance. The basic procedure used in this analysis has been used to evaluate many types of production alternatives which are subject to risk. Examples include its use in the selection of crop rotations (13, 20) and levels of crop insurance protection (28, 29). At present, the authors are evaluating Pennsylvania's NC-140 apple rootstock data using this technique. When a sufficient number of years of data become available in the NE-183 project, it is expected that the selection of apple cultivars will be analyzed in a similar manner. The only drawback of this technique is that the validity of its results depend on long-term data series. However, because of the long-term nature of most tree fruit research, such data are well-suited to evaluation using stochastic dominance techniques.

Literature Cited

1. Beckman, T. O., W. R. Okie, and S. C. Meyers. 1992. Rootstocks affect bloom date and fruit maturation of 'Redhaven' peach. J. Amer. Soc. Hort. Sci. 117:377-379.
2. Brown, S. K. and J. N. Cummins. 1988. Rootstock influenced peach flower bud survival after a natural freeze. HortScience 23:846-847.
3. Brown, S. K. and J. N. Cummins. 1989. Rootstock effect on foliar nutrient concentrations of 'Redhaven' peach trees. HortScience 24:769-771.
4. Byers, R. E., K. S. Yoder, and C. G. Lyons. 1994. Incidence of stem pitting of Lovell and own-rooted 'Redhaven' and 'Cresthaven' peach trees. HortScience 29:1269-1270.
5. Cochran, M. J. 1982. Selection of optimal pest management strategies under uncertainty: A case study in Michigan apple production. Unpublished Ph.D. dissertation. East Lansing, MI: Michigan State University.
6. Cochran, M. J., L. Robison, and W. Lodwick. 1985. Improving the efficiency of stochastic dominance techniques using convex set stochastic dominance. Amer. J. Agr. Econ. 67:289-95.

7. Cochran, M. J. and R. Raskin. 1988. User's guide to generalized stochastic dominance program for IBM PC version GSD 2.1. SP0688. Fayetteville, AR: Department of Agricultural Economics, University of Arkansas.
8. Dozier, W. A., J. W. Knowles, C. C. Carlton, R. C. Rom, E. H. Arrington, E. J. Wehunt, U. L. Yadava, S. L. Doud, D. F. Ritchie, C. N. Clayton, E. I. Zehr, C. E. Gambrell, J. A. Britton, and D. W. Lockwood. 1984. Survival, growth and yield of peach trees affected by rootstocks. HortScience 19:26-30.
9. Durner, E. F. 1990. Rootstock influence on flower bud hardiness and yield of 'Redhaven' peach. HortScience 25:172-173.
10. Ferree, D. C. and R. L. Perry. 1988. Rootstock evaluation through the NC-140 project. HortScience 23:102-104.
11. Greene, G. M., G. Burns, R. M. Crassweller, M. F. Dickert, L. B. Forer, K. D. Hickey, B. A. Jaffee, C. A. Powell, C. B. Smith, and J. W. Travis. 1986. Save the peaches. Amer. Fruit Grower. 106:34-35.
12. Harber, R. M., A. P. Nyczepir, U. L. Yadava, and R. R. Sharpe. 1992. Rootstock, pruning, and soil fumigation in relation to dormancy and cold hardiness of 'Redhaven' peach. HortScience 27:99-100.
13. Harper, J.K., J. R. Williams, R. O. Burton, Jr., and K. W. Kelly. 1991. Effect of risk preferences on incorporation of double-crop soybeans into traditional rotations. Rev. Agr Econ. 13:185-200.
14. King, R. P. and L. J. Robison. 1981. An interval approach to measuring decision maker preferences. Amer. J. Agr. Econ. 63:510-20.
15. Layne, R. E. C. 1994. *Prunus* rootstocks affect long-term orchard performance of 'Redhaven' peach on Brookston clay loam. HortScience 29:167-171.
16. Layne, R. E. C., H. O. Jackson, and F. D. Stroud. 1977. Influence of peach seedling rootstock on defoliation and cold hardiness of peach cultivars. J. Amer. Soc. Hort. Sci. 102:89-92.
17. Layne, R. E. C. and P. Y. Jui. 1994. Genetically diverse peach seedling rootstocks affect long-term performance of 'Redhaven' peach on Fox sand. J. Amer. Soc. Hort. Sci. 119:1303-1311.
18. Layne, R. E. C. and G. M. Ward. 1978. Rootstock and seasonal influences of carbohydrate levels and cold hardiness of 'Redhaven' peach. J. Amer. Soc. Hort. Sci. 103:408-413.
19. Layne, R. E. C., G. M. Weaver, H. O. Jackson, and F. D. Stroud. 1976. Influence of peach seedling rootstocks on growth, yield, and survival of peach scion cultivars. J. Amer. Soc. Hort. Sci. 101:568-572.
20. Maynard, L. J., J. K. Harper, and L. D. Hoffman. 1997. Impact of risk preferences on crop rotation choice. Agr. Res. Econ. Rev. 26:106-114.
21. Pennsylvania Agricultural Statistics Service. 1986-1992. Statistical summary and Pennsylvania Dept. of Agriculture annual report. Harrisburg, PA.
22. Penn State Cooperative Extension. 1992. 1992-1993 Tree fruit production guide. University Park, PA: Penn State, College of Agricultural Sciences.
23. Pratt, J. W. 1964. Risk aversion in the small and in the large. Econometrica 32:122-136.
24. Raskin, R. and M. J. Cochran. 1986. Interpretations and transformations of scale for the Pratt-Arrow absolute risk aversion coefficient: Implications for generalized stochastic dominance. West. J. Agr. Econ. 11:204-210.
25. Ritter, C. M. 1978. Planning and planting orchards. Pennsylvania Fruit Notes No. 9. University Park, PA: Penn State College of Agriculture.
26. Warmund, M. R. and J. V. Slater. 1988. Hardiness of apple and peach trees in the NC-140 rootstock trials. Fruit Var. J. 42:20-24.
27. Wheaton, T. A., J. D. Whitney, W. S. Castle, R. P. Muraro, H. W. Browning, and D. P. H. Tucker. 1995. Citrus scion and rootstock topping height and tree spacing affect tree size, fruit quality and economic return. J. Amer. Soc. Hort. Sci. 120:861-870.
28. Williams, J. R., G. L. Carriker, G. A. Barnaby, and J. K. Harper. 1993. Crop insurance and disaster aid designs for wheat and grain sorghum. Amer. J. Agr. Econ. 75:435-447.
29. Williams, J. R., J. K. Harper, and G.A. Barnaby. 1990. Government program impacts on the selection of crop insurance in Northeastern Kansas. Nor. Cent. J. Agr. Econ. 12:207-221.

New Russian Rootstocks

The following 7 rootstocks were tested: 3-17-38, 3-17-12, 2-46-43, 4-46-112, 3-3-3, 3-5-44, and 2-19-385. All the new rootstocks were more productive than on the seedling control. Productivity per unit of trunk area ranged from 0.6 to 2.0 kg.cm^2 while the trees on seedling produced 0.4 kg. Tree size of 4 of the selections were similar in size to trees on M.9 and these dwarfing stocks had higher Ca content in their fruit. Fruits on trees on rootstocks 2-46-43, 3-17-38, 2-46-112 and 3-5-44 had the best level of mineral elements and were less susceptible to storage diseases.

From Ivanova. 1994. ISHS Hort Congress Abstracts P-22-25 p. 246.