A Portfolio Approach to Landscape Plant Production and Marketing

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Abstract

The ornamental horticultural industry continues to be one of the most rapidly expanding sectors in agriculture. This study examined a decision model for landscape plant production based on portfolio analysis. A quadratic programming model was developed to generate an optimal crop portfolio for a selected southeastern nursery. Empirical results indicate opportunities exist for modest diversification to offset income variability in landscape plant production and marketing.

Key Words: landscape plants, quadratic programming, portfolio analysis, risk management.

The ornamental horticultural industry continues to be one of the most rapidly expanding sectors in agriculture (D. Johnson, 1989). "Grower sales of greenhouse and nursery crops accounted for 10 percent of all crop cash receipts in 1990" (D. Johnson, 1991). In 1991, grower cash receipts of greenhouse and nursery products were expected to total $8.7 billion, and the 1992 outlook was for receipts to grow to $9.5 billion (D. Johnson, 1992). Furthermore, when examined in the context of net value added per dollar of gross income, the greenhouse and nursery industry ranked second behind vegetables among all commodities examined by Jinkins and Ahern. Net value added provides a broad measure of a commodity's contribution to the general economy by emphasizing the income generated for a wide array of people who contribute to the commodity's production and distribution (Jinkins and Ahern).

While this industry has grown rapidly, research in pricing, marketing, and management has been scarce compared with other agricultural sectors. Economic research on landscape plant production and marketing presents many challenges, largely due to the variety of plants and inconsistent data collection procedures. Government programs and futures markets, commonly used to shift commodity price risk, are unavailable to the nursery industry. Thus, producers need alternative decision analysis tools to help them with complex production and marketing decisions.

Production cost research for ornamental crops has been conducted in various climatic zones (Alyesworth and Gartner; Badenhop, Einert, and S-103 Technical Committee; Dickerson, Badenhop, and Day; and Hall, Phillips, Newman, and Laiche). Although most research has been regional and focused on a limited number of genera or species, the studies have provided guidelines for beginning and established firms. With a large number of species available and more being brought into production, continued research is needed to encompass more data on costs and returns. Insufficient economic information, particularly knowledge concerning production trends and prices, greatly hinders managerial decision analysis. While a producer is generally interested in a relatively small number of genera, there exist many possible combinations of species to grow in the expectation of profit.

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This study examined a decision model for landscape plant production based on portfolio analysis. The objective was to produce an optimal plant combination to achieve minimal price risk for given rate of return.[1] A quadratic programming model is developed to ascertain an optimal crop portfolio for a selected nursery resource situation in Climatic Zones 8 and 9 (which includes much of Texas, Louisiana, Mississippi, Alabama, Georgia, Florida, and South Carolina), given a producer's preference between risk and return.

Portfolio Theory

Portfolio analysis was first introduced to evaluate investment opportunities within the context of diversification and the pricing of capital assets (Markowitz, 1952). Markowitz (1959) was later credited with pioneering an investment selection model based on expected utility and mean-variance theory, commonly termed portfolio theory. The principles of portfolio theory have been suggested as a useful methodology to analyze uncertainty in farm planning (Camm; S.R. Johnson; McFarquhar; Pyle and Turnovsky; and Stovall).

The objective function specified for this analysis was designed to maximize net returns for given levels of risk aversion. The objective function is specified:

$$\text{MAXIMIZE } EU(R) = P'X - \lambda X'MX \quad (1)$$

Subject to:

$$AX \leq B$$
$$X \geq 0$$

where EU(R) is expected utility as a function of net returns, P' is a row vector of net returns per species, X is a column vector of activities (species), λ is the coefficient of risk aversion, M is a symmetric variance-covariance matrix of activities (species), A is a matrix of technical (input-output) coefficients for the activities (species), and B is a column vector of resource levels and other constraints.

The QP model used in this research was formulated to determine efficient combinations of species to produce and market, while maximizing expected utility as a function of expected income and market risk. While linear resource constraints (B) generally include operating capital, land, labor, marketing, operating inputs, and machinery capacity, Markowitz (1959) constrained his original portfolio model by one restriction, capital for investment. The present model includes several production and marketing restrictions to illustrate a nursery operation.

The objective function consists of both a quadratic (X'MX) and a linear (P'X) component. The linear component consists of gross returns and costs associated with each activity (species) and measures the expected income from an operation given the constraints (B) and the transformations on the activities (species) (X) in the QP program. Values for expected gross returns can be calculated using historical time-series data or by budgeting procedures (Musser, Mapp, and Barry). The quadratic component includes the variance-covariance matrix, which is commonly derived by using historical estimates of expected returns, variances, and covariances. Historical data are typically used because subjective estimates are difficult to obtain and have questionable accuracy (Musser, Mapp, and Barry).

Procedures for obtaining optimal portfolios in this study were developed using a mean-variance criterion applied through quadratic programming. Several alternative methods are available in portfolio selection, including the capital asset-pricing model, a single index model, and MOTAD and Target MOTAD. Development of appropriate indexes and a lack of relevant data precluded the use of the first two methods in this study. Since the MOTAD and Target MOTAD methods have linear objective functions and constraints, they may be solved using linear programming (LP) risk evaluation techniques (Hazell; Tauer). The mean-variance criterion applied with quadratic programming was employed in this study because information generated in the variance-covariance matrix of returns helps illuminate portfolio selection.

Data and Procedures

Eight wholesale nurseries were selected from a list of 150 certified nurseries in Georgia, based on computerization of accounting and inventory functions, type of stock produced, number of years in business, and price and cost records (Turner and Mixon). Nurseries with good business records were assumed more likely to possess the necessary time-series data needed for a portfolio study. A letter and sample questionnaire were mailed to each nursery. This was followed with a personal interview. Of the eight nurseries, four participated in this study and were personally interviewed during June and July of 1990. Nurseries interviewed derived virtually all revenues from wholesale container production.

Species (e.g., Gumpo Pink) were used as decision variables rather than genera (e.g., Azalea) in order to provide a more realistic production set. A total of 197 different plant species were obtained after data aggregation. However, this total group of species was restricted to five genera in order to develop a tractable model. Genera selection for the species was based on two criteria: (1) cost data was readily available from previous studies, (2) the five genera represented a large volume of total sales. This procedure resulted in the inclusion of 64 plant species (Appendix table 1).

Nominal price data for each plant species were collected for the years 1985 to 1989. The prices used in this study were from one nursery. This was the only nursery that had consistent, accurate, and reliable data over the 1985 to 1989 period. Secondary data (Hall) were used for costs (adjusting costs for each year of this study using the Producer Price Index) and a per plant budget is presented in table 1. The selected set of plant species was analyzed over the five years to obtain expected returns and variances. Covariances between all possible species pair returns were also computed.

Model Specification

The four main parts of the model are the objective function, the variance-covariance matrix, the constraint levels, and the input-output matrix. Each component is discussed, in turn, in some detail.

Objective Function and Variance-Covariance Matrix

The model reflects the 1989 production year, the latest year for which complete data were collected. Prices were calculated from total revenue and total sales quantity of each plant species provided by the previously identified nursery operation. Costs were entered separately to provide greater flexibility in changing the cost of a particular input without the need for recalculating net returns. This method allows a producer to obtain a prospective plant bundle based on the cost of one input changing while holding others constant or changing all input costs simultaneously. Cost figures were assumed constant with zero variability.

Risk analysis of all possible plant species combinations was considered through the use of covariance elements in the QP matrix. After the net returns per plant for each of the five years were determined, their variances and covariances were calculated. Standard deviations are reported in tables.

Constraints

To derive the constraints of the program, the resource availability of a hypothetical nursery in the study area was examined. The example nursery selected was the 12-acre, container-plant nursery of Hall et al., 1987. Land classification was divided into specific areas prior to input. Production space excludes land allocated to roadways, parking space, and permanent buildings from total area. Eight acres are devoted to producing approximately 288,000 one-gallon plants. The remaining area includes potential room for future expansion.

Marketing restrictions often require production of a minimum number of plants from certain genera (i.e. azalea) in order to meet customer demands. At the same time, concern about the market consequences of oversupply restrict production of certain genera to a maximum level. The impetus for genera restrictions evolved from observations of nursery operations (Hall, 1988).

Labor availability is important for a labor-intensive operation such as nursery production. In the first two scenarios of this study, labor was not constrained. The third scenario assumed a restriction of 3,000 labor hours per month. These labor restriction levels were similar to those used in Hall et al., 1991.

A nursery operation has variable capital demands during the year. Reserves are strained during peak demand periods, while other months are

Table 1. Per-plant Labor Requirements and Costs[a] of Producing Selected Landscape Plants in Climatic Zones 8 and 9, 1989

Item	Azalea	Ilex	Crape Myrtle	Photina	Juniperus
Labor	(hours)				
Propagation	0.018	0.022	0.019	0.019	0.024
Field	0.044	0.051	0.041	0.044	0.047
Total	0.062	0.073	0.059	0.063	0.072
Costs					
Variable	(dollars)				
Propagation	0.311	0.289	0..322	0.322	0.367
Field	0.789	1.056	0.778	0.789	0.900
Fixed	0.411	0.411	0.411	0.411	0.411
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Total	1.512	1.757	1.512	1.512	1.679

Source: Hall et al., 1987.

[a] Cost figures were adjusted with the producer price index in order to represent 1989 costs.

less capital intensive. Therefore, monthly capital accounting was incorporated to provide flexibility and realism.

The Input-Output Matrix

A schematic section of the constraint matrix used in the model is presented in table 2. For expository purposes, the portion presented depicts one genera (Azaleas) with several species. Remaining components differ only in requirements of each plant type. The structure is rather straightforward. The columns section of the table represents 64 production activities, with resource requirements divided into land, labor, and capital. In addition to major resource requirements, marketing requirements and accounting rows were incorporated into the model.

Looking at the rows sections of the tableau, FIELDSP constrains field space capacity to eight acres, or a maximum of 288,000 one-gallon plants. The rows JANL, FEBL, ..., DECL constrain monthly labor resources and act as accounting rows for the total labor required in the event a restriction is non-binding. The coefficients account for total labor required to produce and harvest a finished plant.

Rows JANC, FEBC, ..., DECC account monthly capital resource requirements used during the annual production cycle. Capital outlays are only for variable costs per month. If capital is unconstrained, they act only as accounting rows which total the amount of capital used each month. Interest on operating capital is incorporated into the total cost per month for each plant during the production process.

Rows AZALEAM, AZALEAX, ..., PHOTX introduce marketing and production constraints on the minimum and maximum number of genera produced. This row section applies to plant genera and not plant species, allowing the model to select from a plant genera without binding individual plant species. Following the genera accounting/restriction rows are the individual species within each genera. These rows may either be constraining or non-constraining. If unconstrained, each row tracks numbers of each plant species used in the bundle. These particular rows were left unbounded so that the QP analysis could choose based on risks and returns.

Table 2. Schematic Section of the Input-Output Matrix.

Rows	---Columns---							Constraint
	AZD1	AZG2	AZG3	AZG4	AZG5	AZG6		
FIELDSP	1	1	1	1	1	1	≤	288,000
JANL	.00187	.00187	.00187	.00187	.00187	.00187	≥	0
FEBL	.00372	.00372	.00372	.00372	.00372	.00372	≥	0
:								
DECL	.00188	.00188	.00188	.00188	.00188	.00188	≥	0
JANC	.02106	.02106	.02106	.02106	.02106	.02106	≥	0
FEBC	.04440	.04440	.04440	.04440	.04440	.04440	≥	0
:								
DECC	.02116	.02116	.02116	.02116	.02116	.02116	≥	0
AZALEAM	1	1	1	1	1	1	≥	51,200
AZALEAX	1	1	1	1	1	1	≤	76,800
ILEXM							≥	76,800
ILEXX							≤	115,200
CRAPEM							≥	12,800
CRAPEX							≤	38,400
JUNIPM							≥	25,600
JUNIPX							≤	51,200
PHOTM							≥	38,400
PHOTX							≤	76,800
AZD1M	1						≥	0
AZD1X	1						≥	0
AZG2M		1					≥	0
AZG2X		1					≥	0
AZG3M			1				≥	0
AZG3X			1				≥	0
AZG4M				1			≥	0
AZG4X				1			≥	0
AZG5M					1		≥	0
AZG5X					1		≥	0
AZG6M						1	≥	0
AZG6X						1	≥	0

Model Assumptions

The assumptions made throughout the QP analysis include:

(1) Eight acres of bed space available to the nursery, the capacity for 288,000 one-gallon plants.

(2) No limit was set on monthly capital availability--rows used for accounting only.

(3) Selling prices were obtained from a grower located within Climatic Zones 8 and 9.

(4) Market demand constraints on the minimum and production constraints on the maximum number of each genera that could enter the product mix were as follows:

	Minimum	Maximum
Azalea	51,200	76,800
Ilex	76,800	115,200
Crape Myrtle	12,800	38,400
Photinia	38,400	76,800
Junipers	25,600	51,200

(5) All sales were assumed to take place during the year.

(6) The time frame for the model was one year and all plants were sold as one-gallon products.

Analyses Performed

Once the QP model was formulated, three increasingly restrictive scenarios were analyzed. An initial unconstrained, excepting land, solution was obtained. In addition, there were no minimum or maximum plant genera constraints. Several solutions were generated by consecutively increasing the risk parameter. The effects of changing the risk aversion parameters on plant species selection, as well as changes in monthly resource demands, were analyzed.

The other two scenarios imposed minimum and maximum quantities of genera so that the nursery would be attractive to a variety of buyers. Marketing and production constraints were first imposed on the five plant genera while allowing labor and capital to remain unconstrained. Risk parameters were increased to detect changes in the species bundle and resource demands. The third and last scenario limited labor to 3000 hours per month. Changes in the product mix, monthly capital usage, monthly labor usage, net returns, and variance were then analyzed for each model. GAMS/MINOS (Brooke, Kendrick, and Meeraus) was used to solve the quadratic program.

Results

Empirical results will be discussed starting with the least restrictive model. As the analysis progresses to the increasingly constrained second and third scenarios, notable effects and changes in the production/marketing mix are discussed.

Unconstrained Nursery Model

Returns, standard deviations, and product mix for each specified λ for the model nursery with minimum constraints are shown in table 3. λ was chosen at extremely small intervals starting at zero and increasing until variance became constant or an infeasible solution occurred. The linear programming (LP) solution ($\lambda=0$) for this model yields 288,000 Juniperus *Procumbens Nana* (JUP60) with a total net return of $209,140. Juniperus *Procumbens Nana* (JUP60) and Juniperus *Virginia* (JUV63), which generate relatively unstable incomes, are the dominant activities in solutions with high levels and variability of expected incomes -- i.e., near risk neutral. However, when λ is increased, indicating a higher level of risk aversion, variability decreases rapidly while maintaining relatively high net returns. Product mix becomes more diversified from the initial solution of two activities to five in the final solution set. Photinia *X Fraseri* (PHT64) appears in the solution at the beginning only briefly, while Crape Myrtle *Lagerstromia Potomac* (CRP27) and Juniperus *Chinensis Blue Vase* (JUC44) enter the solution in relatively small numbers and continue to increase as risk aversion increases. As expected, diversification decreased risk significantly, while expected income levels stabilized at approximately $195,000. The empirical results demonstrate that risk reduction can be achieved successfully through plant diversification while maintaining high net returns.

These results can be explained partially by the variance-covariance matrix of returns associated with this product mix. Juniperus *Virginia* (JUV63) has negative covariances with the other activities of table 3, making it a desirable plant to include in a producer's portfolio. That is, when the price of JUV63 is high the price of many other plants are low, and thus price movements tend to offset each other. In contrast, Photinia *X Fraseri* (PHT64) has a significant degree of variance combined with positive covariances between three other activities included in table 3, making it somewhat less desirable in the product mix at lower risk levels. Juniperus *Procumbens Nana* (JUP60) also remains in the solution, because it provides relatively high returns with low variability and a negative covariance with Juniperus *Virginia* (JUV63) and Juniperus *Chinensis Spiny Greek* (JUC49).

Total annual labor usage remained relatively stable over the (E-V) frontier, changing only 1140 hours. However, as the product mix becomes more diversified, annual labor actually decreases while producing the same total plant number. This counter intuitive result is due to the optimal solution including species with lower labor requirements as risk aversion increases. Labor requirements are highest in the spring, when sales occur simultaneously with propagation and potting activities. A second peak occurs in the summer, due to propagation periods for certain plant species.

Table 3. Changes in Product Mix, Total Net Returns, and Standard Deviations for a Nursery with Minimum Constraints at Different Risk Levels (λ).

λ Values	Activity[a] Sets	Amount Produced	Total Net Returns	Standard Deviation
			------------($1000)------------	
.000052	JUP60	193083	208.66	9.7441428
	JUV63	94917		
.00026	CRP27	5874	200.34	3.0294388
	JUC44	21106		
	JUP60	119046		
	JUV63	125479		
	PHT64	16495		
.00050	CRP27	66160	198.21	1.715016
	JUC44	22498		
	JUC49	1579		
	JUP60	82914		
	JUV63	114848		
.00134	CRP27	73263	196.37	.63992968
	JUC44	23144		
	JUC49	8190		
	JUP60	71593		
	JUV63	111811		
.018	CRP27	77175	195.36	.0476445
	JUC44	23500		
	JUC49	11832		
	JUP60	65355		
	JUV63	110138		

[a] Activities are identified in Appendix Table 1.

A third peak in labor required occurs in the fall, around November, when sales again compete for labor.

Capital demands remain fairly stable over a 12-month period. However, when the λ parameter increases, more capital is utilized in March and May. Capital utilization peaks in November, but increasing risk aversion reduces capital use in November slightly.

Marketing Constraints Imposed

Optimal solution levels with marketing and production constraints are presented in table 4. The LP solutions for the marketing constraint models selected the species in each genera with the highest net return; AZG5, CRP27, ILX42, JUP60, and PHT64. For example, the LP model with marketing but no labor constraints selected: 51,200 AZG5 for net returns of $18,520; 38,400 CRP27 for net returns of $26,290; 76,800 ILX42 for a net return of $38,430; 51,200 JUP60 for a net return of $37,180; and 70,400 PHT64 for a net return of $46,450. The total net return was $166,870.

The activities that appeared in the unconstrained model also appear in this case, with the exception of Juniperus *Chinensis Pry Spiny Greek* (JUC49). However, differences in the total number of species entering and their quantities are quite striking. Standard deviations for this constrained model are much higher for each given return level than in the unconstrained case. This frontier also has a dramatically different response tradeoff where risk decreases at a much slower rate under $150,000 net returns.

The results provide insight into the impacts that market and production constraints have on the

Table 4. Changes in Product Mix, Total Net Returns, and Standard Deviations for a Nursery with Marketing Constraints at Different Risk Levels (λ).

λ Values	Activity[a] Sets	Amount Produced	Total Net Returns	Standard Deviation
			($1000)	
.000052	AZG5	51200	166.37	15.648233
	CRP27	38400		
	ILX42	76800		
	JUC44	904		
	JUP60	8066		
	JUV63	42230		
	PHT64	70400		
.00020	AZG5	3901	147.80	7.3116093
	AZH8	47299		
	CRP27	38400		
	ILX40	10286		
	ILX42	98514		
	JUC44	8306		
	JUV63	42894		
	PHT64	38400		
.00112	AZH8	51200	141.99	6.1866073
	CRP27	38400		
	ILX40	13708		
	ILX42	22737		
	ILX43	72355		
	JUC44	9291		
	JUV63	41909		
	PHT64	38400		
.00144	AZH8	51200	133.91	5.6823771
	CRP27	21941		
	ILX40	13316		
	ILX42	28528		
	ILX43	73356		
	JUC44	9485		
	JUV63	41715		
	PHT64	38400		
.007	AZH8	51200	109.55	4.2648388
	CRP27	12800		
	ILX40	10941		
	ILX42	357		
	ILX43	65503		
	JUC44	9267		
	JUV63	41933		
	PHT64	38400		

[a] Activities are identified in Appendix Table 1.

model. The initial solution (λ=.000052) has a plant combination containing seven activities with a high standard deviation and a net return of $166,370. When the risk parameter (λ) is increased (λ=.0002), the optimal solution changes from seven to eight activities. Azalea *Glen Dale Treasure* (AZG5) enters the solution at modest risk levels (λ≤.0002) but drops out as λ increases. Overall, the model provides a substantial reduction in risk without drastically reducing net returns. Tradeoffs between return and risk are demonstrated with standard deviation decreasing by $11,383.39 and net returns declining by $56,820 as λ increases from .000052 to .007. Most of the decrease in variance occurs in the change from λ = .000052 to λ = .00020.

Again, the results can be partially explained by the variance-covariance matrix of returns. Azalea *Glen Dale Treasure* (AZG5) and Azalea *H.H. Hume* (AZH8) have a negative covariance. But, as λ is increased, Azalea *Glen Dale Treasure* drops out due to its higher variance in proportion to net return. The genera restriction on Ilex begins with Ilex x *Attenuata Savannah* (ILX42) and diversifies into three specie activities. Ilex *x Nellie R. Stevens* (ILX40) enters the solution at relatively lower risk levels and contributes to a dramatic decrease in risk. This activity selection can be explained by its low variance and low covariances associated with other production activities. Photinia *x Fraseri* (PHT64) enters the model at high levels of acceptable risk. However, this activity declines quickly as risk aversion increases and eventually becomes the minimum genera constraint.

Labor demands during the twelve-month period have three peak periods, as in the previous model. However, labor demands are more consistent over all risk levels. Labor decreases consistently, with peak period demands diminishing relative to other months. Capital demands are similar over the E-V frontier as risk aversion increases. Results demonstrate that as risk decreases, capital requirements decrease proportionately more between February and October than in the remaining four months.

Labor and Marketing Constraints Imposed

Results of the 3000 labor hour and marketing and production constraint analysis are presented in table 5. Ilex *x Attenuata Savannah* (ILX42) dominates species production at high levels of acceptable risk. As in the unconstrained case, very little diversity takes place with the exception of Juniperus. The genera restrictions force the model to choose at least one species from each genera group. However, as λ increases, shifts in the bundle and risk change dramatically. Azalea *Glen Dale Treasure* (AZG5) is replaced by Azalea *H.H. Hume* (AZH8), which becomes the dominant activity for the azalea constraint. Ilex *x Attenuata Savannah* (ILX42) decreases, while becoming diversified into Ilex *Crenata Tiny Tim* (ILX40) and Ilex *x Nellie R. Stevens* (ILX43). The Juniperus constraint begins with two species, Juniperus *Procumbens Nana* (JUP60) and Juniperus *Virginia* (JUV63), and changes magnitude and composition when risk aversion becomes an increasing consideration. Overall, the solutions provide an diversified portfolio that will decrease risk under consideration of the labor limitation imposed.

As risk aversion increases, plant combinations become more diverse within each genera or change to a species with less price risk (as defined by variance). For example, Ilex *x Attenuata Savannah* (ILX42) is produced in large numbers at the beginning in order to gain a high return but is accompanied by a relatively high variability. Its numbers decrease as risk aversion increases in importance. Photinia *x Fraseri* (PHT64) in this model never changes from 38,400 plants, the minimum genera constraints, while Juniperus *Procumbens Nana* (JUP60) drops out and Juniperus *Virginia* (JUV63) changes little over the efficient solution sets.

March is the constraining month for labor. Total annual labor demands are relatively consistent over the efficient frontier, changing only 1313 hours. As in scenario two, three peak labor demand periods occur during the year. As risk levels decline in this model, labor requirements decrease each month between March and October. November labor increases as risk levels decrease. Total capital costs decline $24,845 while maintaining high net returns and low risk levels. Capital requirements remain consistent during the year, with the exception of November. Capital requirements increase when risk levels decrease and plant combinations shift to other activities that require more capital during this month.

Conclusions

Nursery crop production in the United States has grown considerably over the last 10 years. The general objective of this study was to develop a quadratic programming model to ascertain optimal species combinations for a selected nursery resource situation in Climatic Zones 8 and 9.

The first scenario analyzed the case where all resources were unconstrained except field space. As risk aversion became a factor, variability decreased dramatically and returns stabilized. Diversification among activities (species) also

Table 5. Changes in Product Mix, Total Net Returns, and Standard Deviations for a Nursery with 3000 Labor Hours Per Month and Marketing Constraints at Different Risk Levels (λ).

λ Values	Activity[a] Sets	Amount Produced	Total Net Returns	Standard Deviation
			($1000)	($1000)
.000052	AZG5	51200	123.09	12.217537
	CRP27	12800		
	ILX42	103917		
	JUP60	1798		
	JUV63	23802		
	PHT64	38400		
.00014	AZG5	27970	115.75	8.8398009
	AZH8	23230		
	CRP27	12800		
	ILX40	9179		
	ILX42	94738		
	JUC44	2616		
	JUV63	22984		
	PHT64	38400		
.00112	AZH8	51200	102.61	5.0143514
	CRP27	12800		
	ILX40	14036		
	ILX42	41286		
	ILX43	21478		
	JUC44	6304		
	JUV63	31769		
	PHT64	38400		
.00166	AZH8	51200	101.94	4.9641031
	CRP27	12800		
	ILX40	13097		
	ILX42	25836		
	ILX43	37867		
	JUC44	6384		
	JUV63	31689		
	PHT64	38400		
.008	AZH8	51200	100.84	4.9235546
	CRP27	12800		
	ILX40	11554		
	ILX42	441		
	ILX43	64805		
	JUC44	6516		
	JUV63	31558		
	PHT64	38400		

[a] Activities are identified in Appendix Table 1.

became important as risk levels were decreased over the efficient set.

A second nursery scenario imposed minimum and maximum constraints on plant genera and reflected a marketing and production constraint. E-V frontiers obtained by varying risk demonstrated that efficient solution sets became more diversified overall but at a higher risk level due to the added restrictions. In the last scenario, with labor (3000 hours per month) and marketing and production constraints, results changed dramatically. Decreasing monthly labor caused production to shift while risk increased and returns decreased for each specified risk aversion parameter.

Empirical results of this research indicate that opportunities exist for modest diversification to offset income variability in landscape plant production and marketing, given resource availabilities, input costs, and wholesale prices in Climatic Zones 8 and 9. Risk programming can assist nurserymen in this decision process. With the large number of plants to choose from in ornamental production, quadratic programming can provide insights into which plants and how many to produce or delete from year to year.

Nursery realism was an important factor in model development. Genera or marketing requirements and labor constraints have a marked effect on optimal product mix. If no marketing and production constraints were placed on the model, the solution levels would produce a small number of different plant species over the E-V frontier. Yet, nurserymen often produce certain minimum quantities of each genera to be more attractive to buyers. They also limit production of some species to avoid oversupply. Nurserymen can reduce risk while maintaining positive net returns. Analysis of tradeoffs between risk and return imply a wide range of options. The models presented provide an illustration of how a portfolio approach to nursery production and marketing could be used for more profitable decision-making.

The results of this study are limited by the assumptions. A major limitation restricts the model to one production period, assuming that a plant was produced and sold in a 12-month period. A multi-period production system including continuous sales throughout each period would be a desirable next step. Another assumption limited production to one-gallon plants, when generally a container nursery produces multiple container sizes. Additional labor and material costs also may be incurred by holding plants longer than anticipated in the one-year period studied. Such an extension would be feasible in a multi-period context.

Quadratic programming itself has limitations in that it is not capable of projecting prices and demand, only indicating the resource requirements to produce a combination of plants given a producer's projected prices, variances, and costs. Quadratic programming also cannot estimate physical production (input-output) relationships. Nursery operators must supply estimates of these data. Despite these limitations, the nursery QP model produces useful results for managerial decision-making. Further refinements in risk programming could prove beneficial to nurserymen.

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Appendix Table 1. Genera Species (activities) Included in the Quadratic Programming Model.

Genera Species Symbol (activity)	Genera Species Name
AZD1	Azalea *Delaware Valley White*
AZG2	Azalea *Glen Dale Copperman*
AZG3	Azalea *Glen Dale Fashion*
AZG4	Azalea *Glen Dale Glacier*
AZG5	Azalea *Glen Dale Treasure*
AZG6	Azalea *Gumpo Pink*
AZG7	Azalea *Gumpo White*
AZH8	Azalea *H.H. Hume*
AZI9	Azalea *Indica Formosa*
AZI10	Azalea *Indica George Tabor*
AZI11	Azalea *Indica G.G. Gerbing*
AZK12	Azalea *Kurume Christmas Cheer*
AZK13	Azalea *Kurume Coral Bell*
AZK14	Azalea *Kurume Hershey Red*
AZK15	Azalea *Kurume Hinodegiri*
AZK16	Azalea *Kurume Mothers Day*
AZK17	Azalea *Kurume Pink Pearl*
AZK18	Azalea *Kurume Sherwood Red*
AZK19	Azalea *Kurume Snow*
AZM20	Azalea *Macrantha Orange*
AZM21	Azalea *Macrantha Pink*
AZM22	Azalea *Massasoit*
AZP23	Azalea *Pink Ruffle*
AZS24	Azalea *Stewartstonian*
CRP25	Crape Myrtle *Lagerstromia Muscogee*
CRP26	Crape Myrtle *Lagerstromia Natchez*
CRP27	Crape Myrtle *Lagerstromia Potomac*
CRP28	Crape Myrtle *Lagerstromia Watermelon*
ILX29	Ilex *Cornuta Burfordi*
ILX30	Ilex *Cornuta Dwarf Burfordi*
ILX31	Ilex *Cornuta Needlepoint*
ILX32	Ilex *Cornuta Rotunda*
ILX33	Ilex *Crenata Compacta*
ILX34	*Ilex Crenata Convexa*
ILX35	Ilex *Crenata Greenlustre*
ILX36	Ilex *Crenata Helleri*
ILX37	Ilex *Crenata Hetzi*
ILX38	Ilex *Crenata Mycrophyllum*
ILX39	Ilex *Crenata Rotundifolia*
ILX40	Ilex *Crenata Tiny Tim*
ILX41	Ilex *Vomitoria Schillings*
ILX42	Ilex *X Attenuata Opaca Savannah*
ILX43	Ilex *X Nellie R. Stevens*
JUC44	Juniperus *Chinensis Blue Vase*
JUC45	Juniperus *Chinensis Compacta Pfitzer*
JUC46	*Juniperus Chinensis Hetzi Glauca*
JUC47	Juniperus *Chinensis Nicks Comp Pfit.*
JUC48	Juniperus *Chinensis Old Gold*
JUC49	Juniperus *Chinensis Pry Spiny Greek*
JUC50	Juniperus *Chinensis Sargent Green*
JUC51	Juniperus *Chinensis Sea Green*
JUC52	Juniperus *Communis Irish*
JUC53	Juniperus *Conferta Blue Pacific*
JUC54	Juniperus *Conferta Shore*
JUH55	Juniperus *Horiz Andorra Compacta*
JUH56	Juniperus *Horiz Bar Harbor*
JUH57	Juniperus *Horiz Blue Rug*
JUH58	Juniperus *oriz Prince Of Wales*
JUP59	Juniperus *Procumbens*
JUP60	Juniperus *Procumbens Nana*
JUP61	Juniperus *rocumbens Variegata*
JUS62	Juniperus *Squamata Parsoni*
JUV63	Juniperus *Virginia 'skyrocket'*
PHT64	Photinia *X Fraseri*

Endnotes

1. Production (yield) risk is not considered in this study. Various methods (irrigation, chemical application, etc.) are used to manage these risks. Many of these operations were directly included in the production regime and budgets of this modeling process.