



How Much Should I Charge?

Applying Decision Analysis Tools to the Pricing of Flowering Dogwood Trees that are Resistant to Powdery Mildew



'Kay's Appalachian Mist' is a white flowering dogwood with creamy bracts that have reddish-purple clefts. The bracts are stiff and overlap. Flower petal color is yellow. The tree blooms at an early age. Berry color is red. 'Karen's Appalachian Mist' is very resistant to powdery mildew.



'Karen's Appalachian Blush' is a white flowering dogwood that has a pink blush along the edges of its bracts. The bracts are long, thin, and do not overlap. Flower petal color is yellow. Berry color is red. Fall foliage color is a vivid red. 'Karen's Appalachian Blush' is very resistant to powdery mildew.

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Abstract

In 1998, Tennessee's nursery industry income from retail and wholesale dogwood sales was \$6.1 million, and dogwoods made up 14.9 percent of Tennessee wholesale and retail nursery sales (Tennessee Agricultural Statistics Service). Nationally, Tennessee was ranked first in dogwood sales in 1998 (Tennessee Agricultural Statistics Service), with 23.2 percent of the nation's wholesale and retail dogwood sales (U.S. Department of Agriculture). Tennessee dogwood nurseries also produce seedlings which are sold to out-of-state nursery growers. Six counties in the State supply 80 percent of the country's dogwoods (Simmons).

The industry has been adversely affected by powdery mildew. Recent research at the University of Tennessee has fostered the development of a flowering dogwood tree that is resistant to powdery mildew. It is anticipated that the University will attempt to recover some portion of previous research and development expenditures through a fee or royalty. A simulated cooperative game was created to estimate a fee and predict the behavior of nursery growers and nursery product retailers. Results are based, in part, on a survey of consumers' willingness-to-pay for a resistant tree. Implicit in this approach is the assumption that point-of-sale information will be available at retail outlets where the trees are sold. The simulation suggests a fee of \$3.51, resulting in an average retail price premium for the resistant tree of \$10.41. At this price level the simulation predicts that 63% of all retail dogwood trees sold in the future would be a powdery mildew resistant variety. For example, if 1.475 million dogwood trees were sold nationwide, 914,500 would be the resistant to powdery mildew variety, resulting in \$3.2 million in revenue for the university. A below-optimal fee would not necessarily result in a lower retail price, as other players in the supply chain could increase their respective markups.

Keywords: Willingness to Pay, Monte Carlo Simulation, Cooperative Game Theory, Probability Distribution, Powdery Mildew, Flowering Dogwood.

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Introduction

Powdery mildew is a disease affecting flowering dogwoods that limits growth, detracts from plant aesthetics, and may cause plant decline and death (Windham 1998). The dogwood is an important source of revenue for Tennessee's nursery and landscape industry. In 1998, Tennessee's nursery industry income from retail and wholesale dogwood sales was \$6.1 million, and dogwoods comprised 14.9 percent of the Tennessee wholesale and retail nursery sales (Tennessee Agricultural Statistics Service). Additionally, Tennessee was ranked first in dogwood sales in the country (Tennessee Agricultural Statistics Service), accounting for 23.2 percent of the nation's wholesale and retail dogwood sales (U.S. Department of Agriculture). Another Tennessee role in the dogwood industry is that of producing seedlings which are sold to out-of-state nursery growers. Six counties in Tennessee supply about 80 percent of the country's dogwoods (Simmons).

The University of Tennessee has developed a series of dogwood trees that are resistant to powdery mildew and is considering their commercial introduction. The feasibility of introducing a series of resistant trees depends largely on consumer acceptance. Because the trees are not currently commercially available and growers require some indication of the demand before they are likely to produce the trees, estimates of the value that consumers place on the disease-free trees are needed. A study by Gardner *et al.* estimated the mean consumer's willingness to pay (WTP) premium for the resistant tree and concluded that the characteristics of a respondent's yard, landscape expenditures, criteria for selecting plants and trees, type of retail outlet where respondents shop for landscape materials, and the city where the outlet is located

had significant effects on the mean willingness to pay.

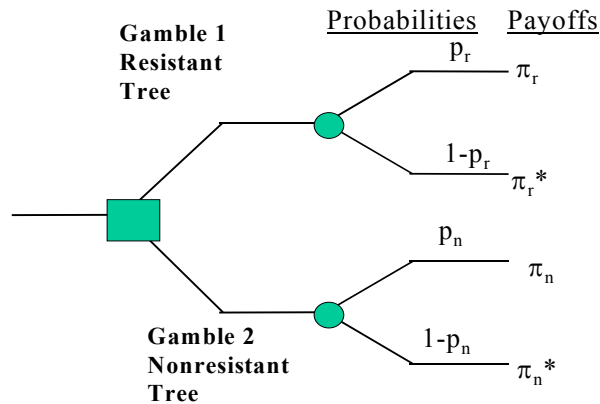
An additional consideration involves the return on research conducted by the university. The university is seeking opportunities to realize a “fair” return on research investment to support these activities in the future. The university would like to sell the right to grow the resistant tree, and the problem is determining a price that reflects the market’s valuation of the powdery mildew resistant dogwood at various stages in the distribution system. Ornamental horticulturists who developed the tree have speculated that the resistant tree could sell at the retail level for a \$2.00 or \$3.00 premium (Windham), a figure that is considerably less than the mean WTP estimated by Gardner et. al. of \$13.35.

Methodology

Utility Assessment

An accurate assessment of WTP hinges on the ability of survey respondents to assess risk and probabilities. Gardner *et al* describe a WTP survey that asks about respondents’ beliefs regarding the risks and costs associated with powdery mildew. Although it was not stated as such, respondents could be thought of as having been given a choice between two uncertain alternatives, or gambles. The decision tree is shown in Figure 1. Each dogwood tree has an unknown probability of not contracting powdery mildew. “Winning” is defined as a dogwood not contracting the disease. Let p denote the probability of winning and π represent the utility a person receives from a healthy dogwood. “Losing” occurs when a dogwood becomes infected with powdery mildew. The probability of losing is $(1-p)$, and π^* represents the utility associated with having a diseased tree in a homeowner’s yard. Subscripts r and n refer to the resistant and nonresistant varieties.

Figure 1. Survey Respondents' Decision Tree



The information provided during the survey had four components. First, the resistant tree had a higher probability of winning (p_r) than a nonresistant tree (p_n), or $p_r > p_n$. Second, for an additional maintenance cost, nonresistant trees can be sprayed with fungicide in order to prevent powdery mildew. Third, although the resistant tree is not immune to powdery mildew, respondents may have been led to believe that it is immune, or $p_r = 1$, so the resistant tree would be thought of as a certainty equivalent. Fourth, fungicides may provide the same degree of prevention as the resistant tree, or $p_r = p_n$, and the difference between the utility of the two trees is the disutility of spraying a nonresistant tree.

The probabilities and payoffs are unknown, and beliefs about these values are not fixed across respondents. The value of p_i , for example, can change depending on the growing conditions that any given respondent expects. π_i (π_i^*) is simply the satisfaction the respondent believes he or she will receive from owning a healthy (diseased) flowering dogwood. It is important to note that π_i and π_i^* are not monetary values, but satisfaction values. The utility any

single individual receives from π_i^* is merely less than the utility of π_i , holding everything else constant. π_i^* ranges from the utility received from the total loss of a tree to the utility received from stunted growth.

Subsequent decision making entails valuation of the risks associated with the two types of dogwoods contracting powdery mildew and the alternative's payoffs. The assessment process can be broken down into four conceptual parts. First, the respondent assesses the probabilities based on prior experience and information available to the respondent at the survey location. Second, expected utility values (EUV) are calculated for the types of dogwood. This is done by multiplying the probability of each outcome within a gamble by its respective utility. For gamble 1, the resistant tree:

$$EUV_1 = \pi_r p_r + \pi_r^* (1 - p_r).$$

For gamble 2, the nonresistant tree:

$$EUV_2 = \pi_n p_n + \pi_n^* (1 - p_n).$$

Third, the respondent develops a risk premium (RP). RP is the difference between EUV_1 and EUV_2 . This method for assessing an RP includes the time and disutility of spraying a nonresistant tree as well as the possible loss in utility due to powdery mildew. Fourth, the RP is converted from utility to dollars, and the respondent estimates WTP.

Probability Assessment

After the distribution of WTP has been estimated for a sample of landscape product consumers, it is possible to estimate the probability that a consumer, considered at random, will

purchase a resistant tree, θ , given a specific price premium or fee, at the retail level F_{Retail} . In order to assess this probability, a cumulative distribution function (CDF) can be generated based on the sample distribution. When graphing the CDF the axis representing WTP is reversed, starting at the largest value instead of the smallest. If $F_{\text{Retail}} = 0$ the probability of purchasing a resistant tree is 1, consumers would be able to receive RP without having to pay. There also is a F_{Retail} which is so high that no consumer would buy the resistant tree.

Game Simulation

Decision theorists use influence diagrams and decision trees to visualize problems that contain uncertainty. Figure 2 presents the influence diagram for a powdery mildew resistant dogwood. Circles represent unknown values, which can be approximated by probability distributions. The rectangle is an assumed fee charged by the university, $F_{\text{Univ.}}$, which is varied to assess the impact of different fees. The rectangle with rounded corners represents a calculation. In this case it is the market interaction of supply and demand in order to determine retail fees and the alternative probabilities of a purchase, θ .

A Monte Carlo simulation is used to model a known probability distribution. Here, the objective is to mimic a cooperative game among members of the dogwood supply chain. Figure 3 portrays the interaction between the university and a nursery in the first stage of the game. The upper and lower branches, labeled H and L, respectively, represent upper and lower bounds of the distributions. In actuality there is no bound on the distribution; however, extremely large or

Figure 2. Influence Diagram

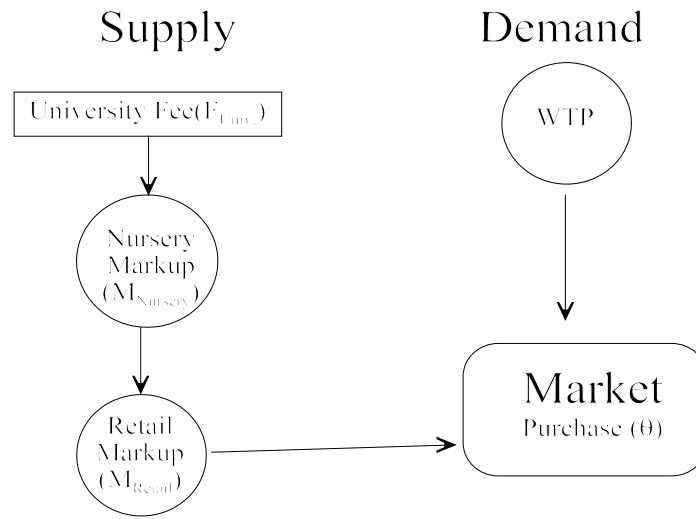
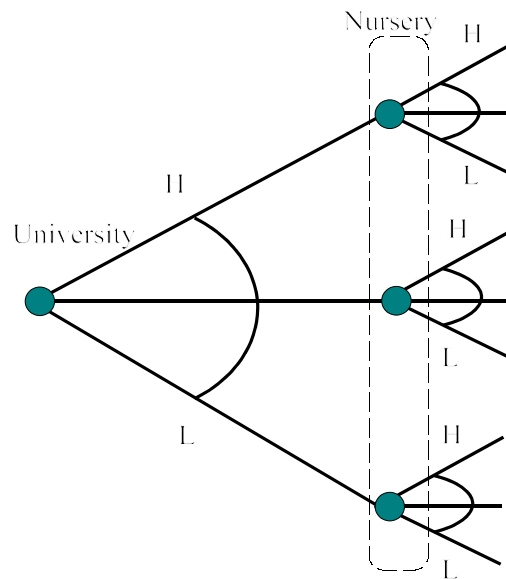


Figure 3. The Simulated Game



small values are neither realistic nor likely. Arcs in the diagram represent ranges of alternative fees. The university (as the owner of the patent) sells the trees to a nursery. The distribution of the subsequent players' actions is based on an expert opinion. The game tree for the remaining stages of the simulation would be similar to the one shown in figure 3. The simulation implicitly assumes that whatever mix of r plus n dogwoods is supplied to the retail market will be sold. That is, the analysis considers 1,000 hypothetical consumers who are assumed to purchase 1,000 dogwoods, and interest centers on the fee and the mix of trees.

The university is assumed to maximize revenue by cooperating with the supply chain, allowing the other players to make their normal profits on the resistant tree. The university begins distribution as a monopoly supplier of resistant dogwoods and charges a fee ($F_{Univ.}$). In the first stage nurseries purchase resistant seedlings and are charged $F_{Univ.}$ by the university. Producers are assumed to realize a per unit reduction in production cost (C) due to reduced fungicide applications and decreased tree loss. Consequently, the net cost per tree to the nursery is ($F_{Univ.} - C$). Savings are subtracted due to competition in the nursery industry. Nursery growers are assumed to use a percentage markup ($M_{Nursery}$) which can vary by nursery. Therefore, the percentage markup is modeled as a normally distributed random variable. The percentage markup is applied to the net cost of the resistant tree to arrive at the fee which is passed on to the next stage of the distribution system, $F_{Nursery} = (F_{Univ.} - C) * (1 + M_{Nursery})$.

In the second stage of the game, a retail store will set fees (prices) in a similar manner. The retail markup (M_{Retail}) is a percentage that can vary by outlet. Its distribution is based on an expert opinion, as noted below. Retail markups are multiplied by $F_{Nursery}$ to simulate the retail fee, $F_{Retail} = F_{Nursery} * (1 + M_{Retail})$.

In the final stage of the simulation the retailer faces the consumers' market demand. In the simulation a dogwood consumer enters a retail store at random and compares prices for regular dogwood trees and resistant trees. At this point it is important to note that a real consumer could purchase a resistant dogwood, a nonresistant dogwood, a substitute landscape product, or make no purchase. The simulation assumes the consumer will purchase a dogwood tree of some type. This is consistent with the way in which WTP data were collected (described below) where the respondent is queried about the premium, as opposed to whether any dogwood would be purchased.

Willingness-To-Pay

WTP data were collected at lawn and garden shows in four different cities: Knoxville, Tennessee; Nashville, Tennessee; Detroit, Michigan; and Jackson, Mississippi. Cities were chosen based on access to home and garden shows and the availability of Extension personnel and Master Gardeners¹ to conduct the survey. A display was designed in order to create a WTP setting. Materials consisted of pictures of diseased dogwood leaves, healthy dogwood leaves, a flowering dogwood in full bloom, and a brief description of powdery mildew. Respondents were then asked to complete a survey questionnaire².

The first question asked how much more one would pay for a typical³ dogwood tree that is resistant to powdery mildew, compared to a nonresistant tree. The questionnaire had a number

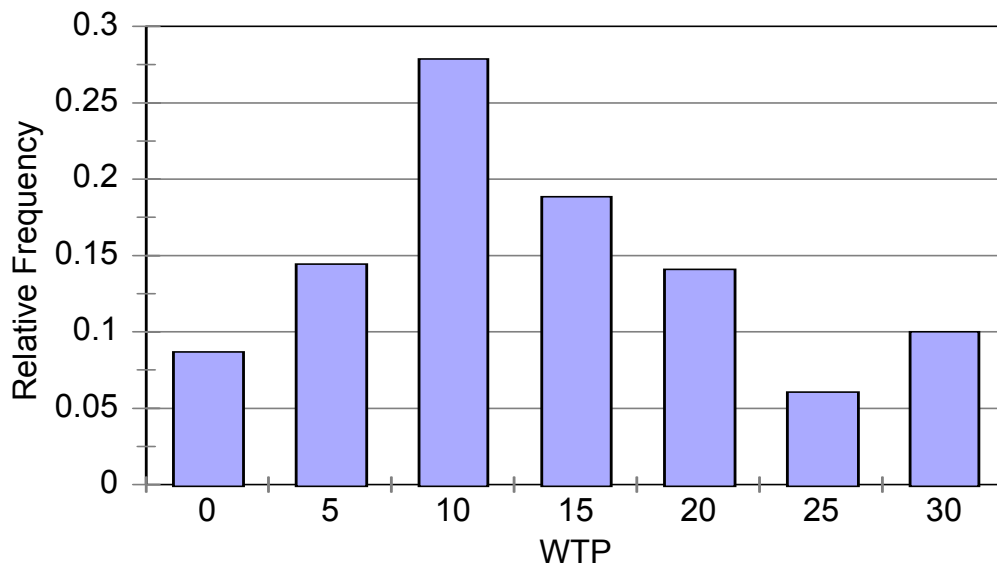
¹A volunteer who has taken part in Extension Service horticulture training, for example 35 hours at the University of Tennessee (Sams).

² The questionnaire and an analysis of the survey are available in Gardner *et al.*

³ The typical size tree is about 5 feet tall, with a 1-inch diameter trunk, and sold in a 5-gallon plastic container.

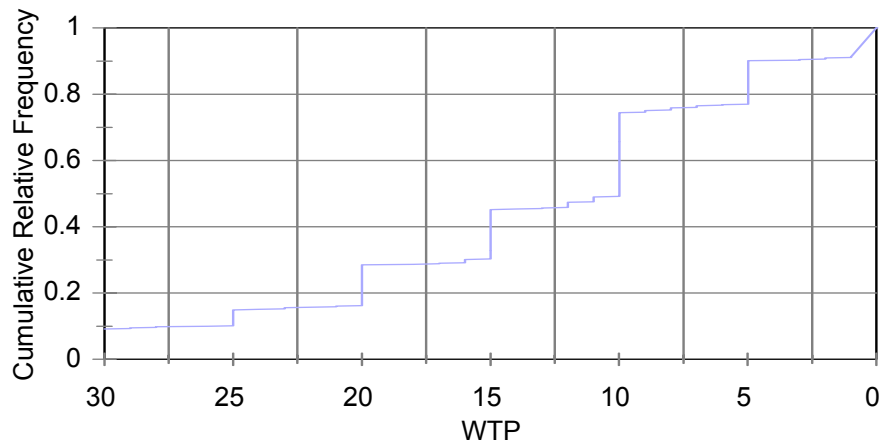
line that ranged from \$0.00 to \$30.00.⁴ One dollar increments were hatch-marked, and \$5.00 increments were numbered. Respondents had a tendency to indicate WTP in multiples of \$5.00 (Figure 4). This may reflect the way the number line was labeled as well as a possible tendency for respondents to evaluate in terms of \$5.00 increments. The mean and standard deviation were \$13.35 and \$8.43 respectively, while the most frequent response was \$10.00. Figure 5 shows the cumulative distribution of WTP.

Figure 4. Willingness-To-Pay, Relative Frequencies



⁴ For a discussion of alternative ways of gathering WTP responses, see Gardner *et al.*

Figure 5. Probability of Purchasing a Resistant Dogwood, Cumulative Distribution



Supply Chain Markup

No data are available on retail and nursery price markup rates. As an alternative, subjective probability assessments about the distribution of these variables were used (Clemen). Typically, nursery growers attempt to mark up products between 25 percent and 30 percent (Hall). Given this information M_N is assumed to be normally distributed with a mean 27.5 percent and a standard deviation of 5 percent. Based on expert opinions, M_R tends to range between 200 percent and 300 percent, with two-thirds of the retailers marking up products between 200 percent and 250 percent, and the probability of any given markup within its respective range is the same (Hall).

Costs

Powdery mildew increases growing and marketing costs for dogwood nursery stock producers and distributors. Costs are primarily due to the increased number of fungicide applications and the loss of trees. In 1984, the estimated cost of pest and disease control for one

acre of flowering dogwoods was \$290 over a three-year period. For 2000, this estimate was approximately \$1,075 per acre, with the increased cost largely due to powdery mildew (Klingeman et al.). After adjusting fungicide costs with the Producer Price Index for Fungicidal Preparations in order to account for inflation between 1984 and 2000, a nursery grower can save \$593.22 per acre (Bureau of Labor Statistics). The typical nursery grower produces 4,000 trees per acre (Badenhop, Witte, and Glasgow), and assuming a constant cost per tree a typical nursery can expect to save \$.148 per tree.

Results

Simulated Random Variables

The accuracy of the simulation is dependent upon how well the theoretical distributions used to create random variables replicate the real world. Therefore, it is useful to compare the distribution of simulated random variables with actual distributions of the variables that are being modeled.

In the first stage of the game, the nursery grower is assumed to add a markup M_N . The simulated distribution was nearly identical to the assumed distribution. It had the same mean, 27.5 percent and a slightly larger standard deviation of 5.2 percent. Figure 6 shows the relative frequency histogram for M_N . Because of the markup process, as F_{Univ} increases, $F_{Nursery}$ increases as does its variability (standard deviation).

Simulating the retail price markup presented a modeling challenge. Two uniform distributions, one between 200 percent and 250 percent and the other between 251 percent and 300 percent, were generated. Then a Bernoulli trial was used to pick a distribution, resulting in the representation of the simulated distribution (Figure 7). Sixty-seven percent of the simulated

markup distribution was contained in cells centered on 210 percent through 250 percent, with the remaining 33 percent in cells centered on 260 percent through 300 percent. The simulated average retail markup was 242 percent with a standard deviation of 1,030 percent.

Figure 6. Nursery Markup, Relative Frequencies

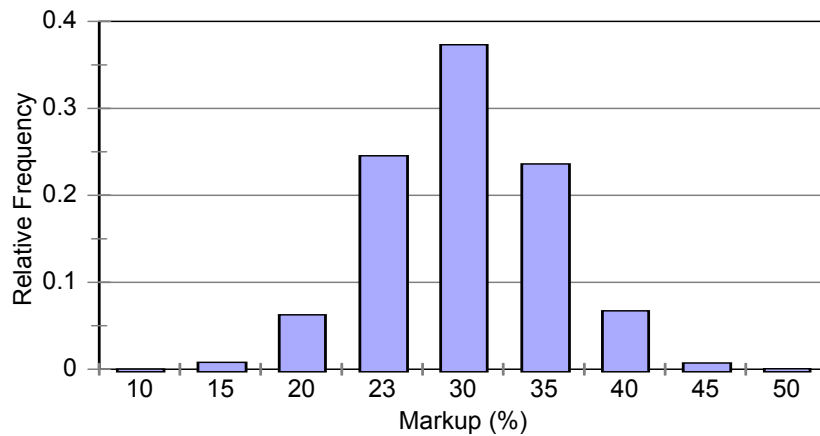
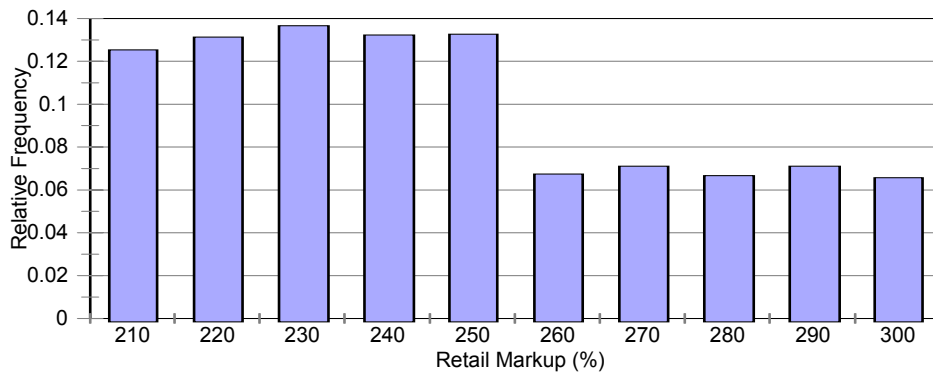


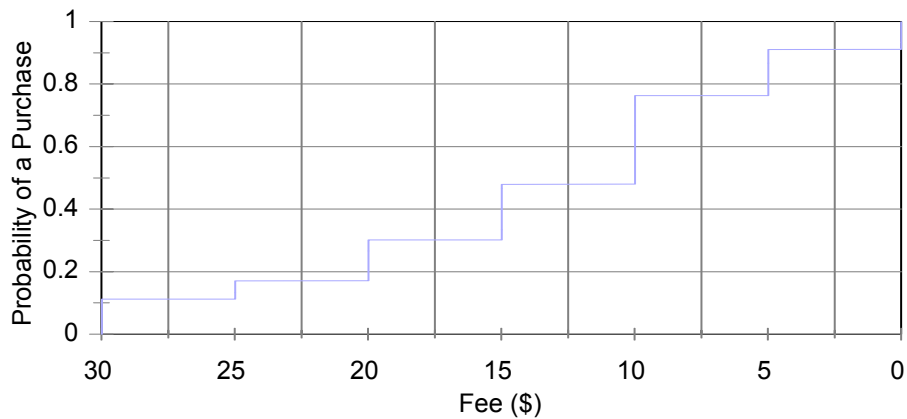
Figure 7. Retail Markup, Relative Frequencies



WTP was modeled using a discrete distribution. Dollar amounts were assigned a cumulative probability based on the actual WTP data. The simulated distribution had a mean of

\$13.69 and a standard deviation of \$8.63, compared to the actual sample mean, \$13.35, and standard deviation, \$7.78. Figure 8, the simulated WTP distribution, is comparable to the actual distribution shown in Figure 5.

Figure 8. Simulated Willingness-To-Pay, Cumulative Distribution



Simulation Results

Using the distributions described above, three scenarios were developed, and 1,000 simulation trials were run for each scenario. Results for all three scenarios are found in Table 1. It is important to keep the scenario context in mind when interpreting these results. The simulations attempt to predict if a random consumer would purchase a tree given a fee ($F_{Univ.}$ though F_{Retail}) that is determined by random supply chain markups. It is incorrect to think of each scenario in terms of a nursery that grows 1,000 resistant trees or multiples thereof, because the analysis is based on simulated demand, as opposed to actual sales. Rather, the simulation is directed toward analyzing a hypothetical level of demand for dogwoods in terms of mildew

resistant trees and traditional dogwoods.

Table 1. Simulation Results for Hypothetical Sales of 1,000 dogwoods

	Scenario 1	Scenario 2	Scenario 3
University Fee F_{Univ}	\$1.00	\$3.51	\$6.00
University Revenue R_{Univ} ¹	\$908.00	\$2,177.37	\$1,690.00
Nursery Fee $F_{Nursery}$	\$1.09	\$4.29	\$7.46
Nursery Revenue $R_{Nursery}$ ²	\$986.60	\$2,659.73	\$2,102.10
Retailer Fee F_{Retail}	\$2.64	\$10.41	\$18.13
Retailer Revenue R_{Retail} ³	\$2,396.46	\$6,460.52	\$5,106.04
Resistant Dogwood Sales ⁴	908	620	282
Percent of Total Dogwood Sales	91%	62%	28%

¹ $R_{Univ} = F_{Univ} \times X$ (Resistant Dogwood Sales)

¹ $R_{Nursery} = F_{Nursery} \times X$ (Resistant Dogwood Sales)

¹ $R_{Retail} = F_{Retail} \times X$ (Resistant Dogwood Sales)

⁴ Per 1,000 Total Dogwood Trees Sold

Scenario 1 simulates the effects of $F_{Univ} = \$1.00$. In this scenario 1,000 random consumers of dogwood trees each visited a random retailer; 908 of them purchased resistant dogwood trees. The remainder is assumed to have purchased nonresistant dogwoods. The retailer sells approximately 9 resistant trees for every nonresistant tree, and the industry should, therefore, produce the trees in such a ratio. The university's simulated return is \$908.00.

Assuming the wholesale nursery fee is a normally distributed random variable with mean \$1.09 and standard deviation \$0.04, the average nursery would receive a return of \$986.60=(908*\$1.09). Given a normally distributed F_{Retail} with mean \$2.64 and standard deviation \$0.34, retailers' expected return is \$2,396.46=(908*\$2.64).

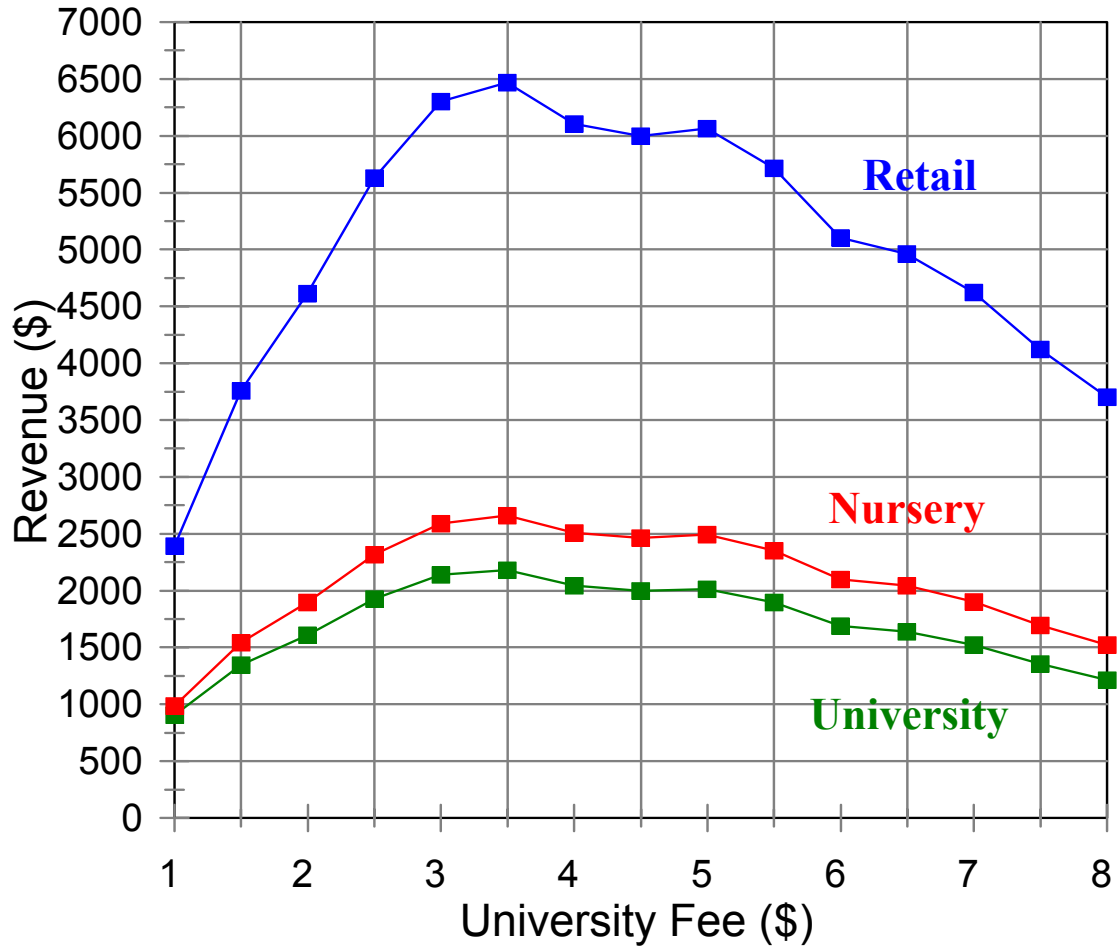
A \$6 fee is used in scenario 3, resulting in the purchase of 282 resistant dogwood trees out of 1,000 total trees. The university would expect a return of \$1,690.00. $F_{Nursery}$ has a mean of \$7.46, and standard deviation \$0.29. Nurseries would expect a return of \$2,201.10. F_{Retail} has a

mean of \$18.13 and standard deviation \$2.32, with an expected return to retailers of \$5,106.04.

The effects of other fees were simulated. Figure 10 shows how $F_{Univ.}$ affected $R_{Univ.}$, $R_{Nursery}$ and R_{Retail} . In each stage of the simulated game revenue behaves the same way. That is, a fee that maximizes $R_{Univ.}$ also maximizes $R_{Nursery}$ and R_{Retail} . The diagram can be interpreted two ways. First, if the objective is a target rate of return per 1,000 trees (e.g., \$2,000 for the university), then there is a range of $F_{Univ.}$ values consistent with this objective (e.g., \$2.59 to \$5.10). If the objective is to maximize the revenue then a specific $F_{Univ.}$ is used. In Scenario 2 for example $F_{Univ.} = 3.51$, and there are 620 simulated purchases of resistant dogwoods. Roughly 6 out of every 10 dogwood trees sold are resistant. Expected return to the university is \$2,177.37. Mean $F_{Nursery}$ is \$4.29, with a standard deviation of \$0.17. Nurseries would expect a return of \$2,659.73. Mean F_{Retail} is \$10.41 and standard deviation \$1.33, with an expected return to retailers of \$6,460.52.

Figure 10 displays revenue, not cost or profit. The nursery (retailer) curve lies above the University (nursery) curve due to the fee being marked-up as the trees move through the distribution channel. Since retailers have the highest mark-up, vertical distance between the Retail and Nursery curves is the largest.

Figure 9. Revenue vs. University Fee



Conclusions and Implications

By varying the fee charged by the university and running the simulation multiple times, the estimated optimal simulated fee is \$3.51. This fee maximizes revenue to the university, the nursery industry and the retail industry. U.S. sales of dogwoods in 1998 were 1.475 million trees (1998 Census of Horticulture Specialties). If the simulation assumptions hold and retail sales remain at the 1998 level, the university could expect a return of \$3,209,895 from the sale of 914,500 resistant dogwoods. For the revenue maximizing producer and retailer, an important result is the ratio of resistant to nonresistant trees, because producing non-optimal quantities will reduce revenue. In the optimal scenario, this ratio is approximately 6 resistant trees out of every ten total dogwoods. If the nursery industry as a whole were to produce too many resistant trees then the excess supply would drive prices down, resulting in a loss of revenue.

A simulation such as this can be quite useful if the results are interpreted with caution. The actual cost savings and price markups may be different from those used in the simulation; therefore, the actual optimal technology fee may be different. Care must also be taken when interpreting the results. As stated above the simulation does not model a grower who produces 1,000 resistant trees, but instead 1,000 dogwood tree consumers who may or may not purchase a resistant tree. These simulations assume that consumers who buy nonresistant dogwoods, which subsequently contract powdery mildew, understood the risk and would consider replacement of a diseased tree with another dogwood.

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