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Assessing the Impact of Integrated Dogwood Disease Management Practices on Labor Needs and Production Costs in Tennessee Nurseries

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Abstract. **Early and accurate detection of diseases, and implementation of efficient disease management practices are crucial to reducing the economic impact associated with plant disease outbreaks. Based on survey responses from dogwood nursery growers in Tennessee, USA, scouting was identified as an important disease management practice adopted by a majority of growers for disease management in field-grown, container-grown, and pot-in-pot production systems. Our results show a significant positive correlation between disease severity and scouting frequency for dogwood plants grown in container and pot-in-pot production systems. Our efficiency measure is a self-rated efficacy scale perceived by the nursery growers about their existing disease management system in nursery plants. A significant positive correlation was found between the efficacy of disease management and the number of workers involved in scouting and a negative association between the worker hours spent in scouting and the grower's experience/exposure to other disease detection methods. The majority of nursery growers followed a set spray schedule between May and October, with applications scheduled every other week. In addition, our results showed significant positive correlations between efficacy and spray-related factors, such as disease severity and worker hours spent in spraying; efficacy of disease management and spraying frequency in field-grown dogwoods; and foliar spray costs and efficacy of disease management. We estimated ≈$379/acre per year average costs for dogwood disease management, which the growers find to be one of the major components of the dogwood production budget. Moving to automated systems of disease scouting and management has the potential to reduce the cost of these labor-intensive disease management practices of dogwood production.**

The horticulture industry is the fastest growing segment of the US agricultural sector and it generated a total of $13.8 billion in sales, as reported in the *Census of Horticulture Specialties 2019* (US Department of Agriculture, National Agricultural Statistics Service 2020). In the same year, ornamental nursery production accounted for 33% of all horticulture sales, contributing a total annual sales value of more than $4.5 billion (US Department of Agriculture, National Agricultural Statistics Service 2020). The US ornamental nursery industry is estimated to generate ≈217,574 jobs (Hall et al. 2020). In Tennessee, USA, the nursery/greenhouse industry is one of the major components of the agricultural sector, with an estimated contribution of ≈$965 million to the state's economy (Jensen et al. 2020). In 2019, the Tennessee, USA, nursery industry reported total market sales of $116 million, which ranked 10th among all states in the United States (US Department of Agriculture, National Agricultural Statistics Service 2020).

Flowering dogwood is native to the northeastern and southeastern United States, from Maine to Florida, eastern Texas, and Missouri, and it is a valuable crop to southeastern US nursery producers (Wennerberg 2006). According to the total sales in the United States, flowering dogwood is ranked third among flowering trees, following crape myrtle and flowering cherry (US Department of Agriculture, National Agricultural Statistics Service 2020). In Tennessee, USA, dogwood sales were $7.4 million, accounted for 24% of the nation's sales, and the state ranked number one in dogwood production in 2019 (US Department of Agriculture, National Agricultural Statistics Service 2020).

The ornamental nursery industry has been going through rapid changes in type, technology, and location of production for the past several decades, and these changes have influenced and increased the importance of nursery disease management in the nursery industry (Gullino et al. 2015). Plant disease management is a primary concern for nursery crop producers, who often emphasize producing healthy plants to maintain a profitable business in the ornamental industry (Daughtrey and Benson 2005). Revenue loss resulting from diseases is a major setback for the nursery industry, and disease management requires large amounts of production inputs, such as labor, pesticides, and application equipment (LeBude et al. 2012). Scouting and correct identification of diseases of nursery crops are vital for effective disease management, as the accurate diagnosis of plant pathogens guides appropriate management (Rani et al. 2019). Chemical control plays an important role in ornamental plant disease management. The application of fungicides, a commonly used approach, is one component of the integrated disease management technique, which is implemented to reduce the economic losses of ornamental nursery crops (Daughtrey and Benson 2005).

Dogwoods are susceptible to several economically important foliar and root diseases (Hagan and Akridge 2007). Powdery mildew disease is one of the most damaging and economically important diseases in flowering dogwood (Hagan and Mullen 1995; Mmbaga and Sauvé 2004). With severe infection, powdery mildew can retard plant growth and cause seedling death, which leads to increased production costs and affects the aesthetic value of the plant. Because the combination of high humidity with dry leaves provides ideal conditions for powdery mildew development, this disease can be commonly found from late May to the first frost in Tennessee, USA (Baysal-Gurel and Gunter 2018; Halcomb et al. 2002). Therefore, continuous scouting is required during this period to effect the early detection of powdery mildew and implement effective management approaches to minimize economic losses. Spot

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anthracnose and dogwood anthracnose diseases are also important diseases in flowering dogwoods that can affect aesthetic value and marketability of the plants (Daughtrey and Hagan 2001; Mitchell et al. 2023). *Cercospora* leaf spot is considered to be a disease that does not reduce plant vigor predominantly, but can result in the formation of distorted flower bracts and young leaves (Hagan et al. 2008). Dogwoods are susceptible to canker infections and root rot, which cause major economic losses if left untreated (Brown et al. 2019; Mmbaga et al. 2018; Mullen et al. 1991). As a result of the greater susceptibility of dogwood plants to a variety of diseases, regular scouting is highly recommended. Therefore, the allocation of well-trained workers for regular disease scouting in dogwood is required for effective disease identification and management. Table 1 lists all the major diseases related to dogwoods and their causal agents.

Nursery crop disease management consumes a large amount of time and labor to be effective. Therefore, recent emphasis has been directed toward the use of alternative approaches, such as automated systems. Plant disease detection using unmanned aerial systems (UASs) has been developed during the past decade and has great research potential, particularly in the areas of increasing efficiency of scouting over traditional scouting methods (Hassler and Baysal-Gurel 2019; Neupane and Baysal-Gurel 2021). Also, UASs equipped for chemical spraying have many advantages, such as low fuel consumption, high productivity, low noise pollution, feasibility to reach terrain landscapes with limited access to ground sprayers, along with low a risk of chemical exposure to workers, which, collectively, is economically effective over traditional ground-based spraying methods (Pederi and Cheporniuk 2015; Xiao et al. 2019; Zhu et al. 2019).

To gain a better understanding of disease management of dogwood, including production practices, operational details, and challenges, a survey was developed and distributed to nursery crop growers in Tennessee, USA. The purpose of this survey was to understand the challenges, expenses, and perceptions of dogwood disease management among Tennessee, USA, nurseries. In addition, we estimated production costs and profitability of disease management in nursery crops to guide cost-effective approaches for nursery growers.

Materials and Methods

Sixty-two nursery crop growers were selected to participate in the study based on their involvement in dogwood production as growers or owners of nurseries located across Tennessee, USA. The survey was approved by the Institutional Review Board (IRB) at Tennessee State University (IRB approval no. HS-2020-4461). The survey was Web-based, and all potential growers were contacted via e-mail to participate in the survey. The survey questionnaire was designed using Dillman's Tailored Design Method (Dillman 2011). Participation in the survey was voluntary, and no incentives were provided when they completed the survey. Respondents were allowed to click on the link embedded in the e-mail and were directed to the questions maintained in Qualtrics (Qualtrics XM, 2024, Provo, UT, USA) if they agreed to participate. The survey e-mail was first sent on 1 Mar 2022. Additional follow-up e-mails and reminders were sent on 10 Mar 2022, 31 Mar 2022, 21 Sep 2022, 28 Nov 2022, and 8 Feb 2023 to enhance the response rate. Overall, complete responses from 18 dogwood growers were obtained out of the 62 sample growers contacted, resulting in a response rate of 29%. The respondent growers represented 19% of all dogwood nurseries in Tennessee, USA.

The survey consisted of 25 questions and it covered information on dogwood production including type of operation (field, container, or pot-in-pot), management practices, cost, and perceptions of dogwood disease management. Survey responses were recorded as multiple choice, open-ended, close-ended, and rating scale questions. Specific disease management statements related to dogwood such as the severity of the foliar diseases, confidence in the efficiency of current disease management practices, and experience in and exposure to any new methods of detection and control of dogwood diseases were ranked using a Likert scale of 1 to 5 points, where 5 points indicates most. Collected data were analyzed using a statistical analysis system (SAS v. 9.4; SAS Institute, Inc., Cary, NC, USA) and Microsoft Excel (Microsoft Excel 2016, Microsoft Corp., Redmund, WA, USA) analytical tools. To determine the strength and association between two variables, Spearman's correlation analysis method was used as a bivariate statistical test framework. Spearman's correlation coefficient (ρ or r_s), which is a nonparametric measure to determine the correlation based on rankings between dependent variables (disease severity of the foliar diseases, efficacy of current disease management practices, and experience in or exposure to any new disease detection and control methods of dogwood diseases), and independent variables (scouting and spraying frequencies of field, container, and pot-in-pot plants; number of workers and worker hours; and cost of scouting and spraying) that basically gives the measure of monotonicity of the relation between these variables. For the correlation between variables, the formula for calculating the sample Spearman's correlation coefficient is given by Eq. [1],

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)}, \quad [1]$$

where r_s represents Spearman's correlation coefficient, n is the number of samples, and d_i is the difference in the ranks given to the values of two variables for each data point.

Also, differences in scouting and spraying performance between the two groups of growers—those following a specific set spray schedule for dogwood diseases and those not following a spray schedule—were investigated using the Mann-Whitney U test. This is a nonparametric test that considers pairwise comparisons of the mean/median scores of responses between two groups. Because our sample sizes were small and the sample distributions were not normally distributed, the Mann-Whitney U test was performed as the suitable method to determine whether there is a statistically significant difference between the two groups of dogwood growers.

Results and Discussion

Dogwood production. Ninety percent of all respondents indicated they grow or maintain dogwood plants in their nurseries. Also, growers mentioned that they grow or maintain ≈23,317 (23,316.7 ± 32.934.6) dogwood plants on average each year. The average total acreage of a grower's nursery was estimated at ≈208 (207.9 ± 190.4) acres, which is greater than the average size of a farm in Tennessee, USA (≈154 acres) according to the *Farms and Land in Farms 2021 Summary* (US Department of Agriculture, National Agricultural

Table 1. Major diseases associated with dogwood production and their causal agents.

Disease	Causal organism	References
Powdery mildew	*Erysiphe pulchra* (Cook & Becke) U. Braum & S. Takamatsu comb. nov. (syn. = *Microsphaera pulchra*, *M. penicillata*) and *Phyllactinia guttata* (Wallr.) Lev. [syn. *P. corylea* (Pers.) P. Karst.]	Hagan and Mullen 1995; Li et al. 2007, 2009; Mmbaga and Sauvé 2004; Pfarr Moreau et al. 2022; Windham et al. 2003
Spot anthracnose	*Elsinore corni* (Jenkins and Bitanic)	Daughtrey and Hagan 2001; Mitchell et al. 2023; Trigiano et al. 2023
Dogwood anthracnose	*Discula destructiva* Redlin	Daughtrey and Hagan 2001; Mitchell et al. 2023; Trigiano et al. 2023; Windham et al. 2005
Cercospora leaf spot	*Pseudocercospora cornicola* (Tracy and Earle) Guo and Lin (syn. = *Cercospora cornicola*)	Hagan et al. 2008, 2011
Canker disease	*Lasiodiplodia theobromae* Griffon & Maubl and *Botryosphaeria* spp.	Brown et al. 2019; Mmbaga et al. 2018; Mullen et al. 1991
Phytophthora root rot	*Phytophthora cinnamomi* Rands	Brown et al. 2019; Mmbaga et al. 2018; Mullen et al. 1991

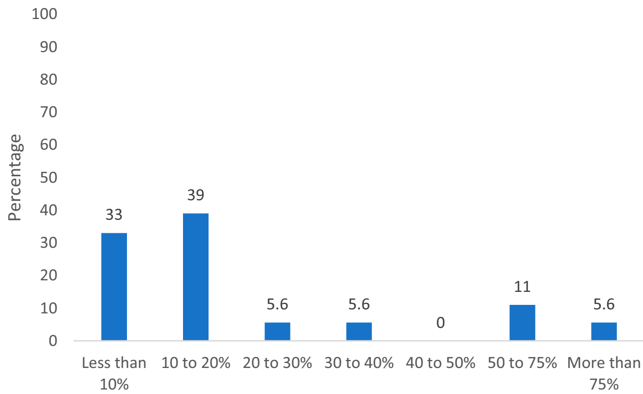

Fig. 1. Percentage of nursery operations with dogwood plants or area as a proportion of overall production (< 10%, 10%–20%, 20%–30%, 30%–40%, 40%–50%, 50%–75%, and > 75%).

Statistics Service 2022). Moreover, 39% of growers had a 10% to 20% portion of their total production in dogwood; 33% of growers had less than 10% of their total production in dogwood plants or areas in their nurseries (Fig. 1). In addition, 11% of growers had 50% to 75% of their total production in dogwood plants or areas (Fig. 1). The majority of growers (61%) produced dogwood as field-grown plants, followed by 30% as container-grown plants, and 9% as pot-in-pot plants. As a percentage distribution of area, 65% of nurseries produced field-grown plants, 30% produced container-grown plants, and 5% produced pot-in-pot plants. Table 2 provides the summary statistics of the variables used in the analysis. Dogwood production has decreased in Tennessee, USA, during the past decade. There were 806,036 dogwood plants in 2009, 1,455,236 plants in 2014, and 469,582 plants in 2019, leading to more than a 60% reduction compared with 2014 (US Department of Agriculture, National Agricultural Statistics Service 2020).

Field production is the most common method used for commercially grown flowering dogwood in Tennessee, USA (Halcomb et al. 2002). Plants can be harvested as either bare root or balled and burlap (B&B), depending on the plant size and intended use. Although field production is the least expensive method of growing flowering dogwood, the long production cycle and limited transplant window for B&B nursery stock have led to increased interest in growing flowering dogwood in containers (Witcher et al. 2019). In addition, the market for container-grown flowering dogwood has expanded as a result of year-round sales of plants and demands from garden centers and large retailers (Witcher et al. 2019).

Scouting procedure. Respondents were asked to mention the frequency of scouting for diseases of dogwood plants in their nurseries corresponding to the type of operation. Most growers (36%) scouted for diseases weekly, 21% scouted every other week, and 21% of growers scouted monthly in field-grown dogwood plants (Fig. 2). With regard to container plants, the majority of the growers (62.5%) scouted for diseases daily whereas 37.5% of growers scouted weekly (Fig. 2). For the pot-in-pot plants, the most common frequency of scouting was done weekly (75%); 25% of growers scouted daily (Fig. 2). In the questionnaire, information was requested on how many workers were involved and how many worker hours were spent by each worker throughout the scouting procedure in growers' nurseries. On average, at least three workers (2.6 ± 0.7) were involved in scouting session and ≈2 h (1.8 ± 0.7) were spent scouting by each worker during the scouting session.

Spraying procedure. Most of the growers (89%) indicated that they follow a set pesticide spray schedule for dogwood diseases throughout the year. The majority of growers began their pesticide program in May (43.8%), whereas 37.5% of growers started in April, and growers usually end the pesticide program in September (43.8%) or October (43.8%). Nursery crop growers who responded to the survey were also asked how frequently they spray pesticides to manage diseases in dogwood plants of each type of operation. For field-grown dogwood, 40% of growers sprayed every other week, 27% sprayed monthly, and 20% sprayed weekly (Table 3). In addition, 13% of growers rarely or never sprayed pesticides for their dogwood field production. For container-grown dogwood, most growers (62.5%) sprayed every other week, 25% sprayed weekly, and 12.5% sprayed monthly. For pot-in-pot plants, 66.7% of growers sprayed every other week and 33.3% were sprayed monthly to manage dogwood diseases (Table 3). So, the most common preference was every other week of spraying pesticides when all types of dogwood operations were taken into consideration. Respondents were also asked to provide how many workers were involved in pesticide spraying and how many worker hours were spent spraying. On average, at least two workers (2.4 ± 0.8) were involved in spraying and ≈8 h (7.8 ± 10.6) were spent each spraying session. because dogwoods are susceptible to several foliar diseases as well as canker and root pathogens, as mentioned previously, fungicides are applied routinely by nursery producers to minimize plant losses (Baysal-Gurel and Gunter 2018; Neupane et al. 2022). Several US Environmental Protection Agency–registered synthetic fungicides, biological control agents, and biorational products are available on the market for the effective management of economically important diseases of dogwood by spraying them on regular intervals (Daughtrey and Hagan 2001; Hagan and Mullen 1995; Mmbaga 2002; Mmbaga and Sheng 2002).

Nursery growers were asked to rank [1 (least)–5 points (most)] their opinions of dogwood disease management concerns (Table 4). Across all sampled nurseries, growers show a somewhat positive level of confidence (3.2 points) in the efficacy of their current dogwood disease management strategy,

Table 2. Summary statistics of grower responses to a survey on dogwood production in Tennessee, USA.

Variable	*n*	Mean	*SD*[i]	Minimum	Maximum
Total nursery area (acres)	18	207.9	190.4	5.0	700.0
No. of dogwood trees	18	23,316.7	32,934.6	1,000.0	100,000.0
Growing field nurseries (%)	18	60.9	43.4	0.0	100.0
Growing container nurseries (%)	18	30.5	50.0	0.0	100.0
Growing pot-in-pot nurseries (%)	18	8.6	32.3	0.0	100.0
No. of workers involved in scouting	18	2.6	0.7	2.0	4.0
No. of worker hours spent in scouting	18	1.8	0.7	1.0	3.0
Following a set pesticide spray schedule (Yes or No)	18	0.9	0.3	0.0	1.0
No. of workers involved in spraying	18	2.4	0.8	2.0	5.0
No. of worker hours spent in spraying	18	7.8	10.6	1.0	40.0
Grower perception for disease severity of dogwood-related foliar diseases (rating)	18	2.4	1.2	1.0	5.0
Confidence in efficacy of current dogwood disease management strategy (rating)	18	3.2	1.5	1.0	5.0
Experience or exposure to other disease detection and control methods (rating)	18	2.2	1.2	1.0	5.0
Dogwood sales income (US$)	18	336,944.4	502,579.1	20,000.0	2,000,000.0
Overall cost of foliar disease scouting per year in dollars (US$)	18	750.0	801.0	0.0	2,500.0
Overall cost of foliar disease spraying per year in dollars (US$)	18	2,320.0	1,230.0	1,000.0	5,000.0

[i] *SD* = standard deviation of the variables of the nursery growers' sample.

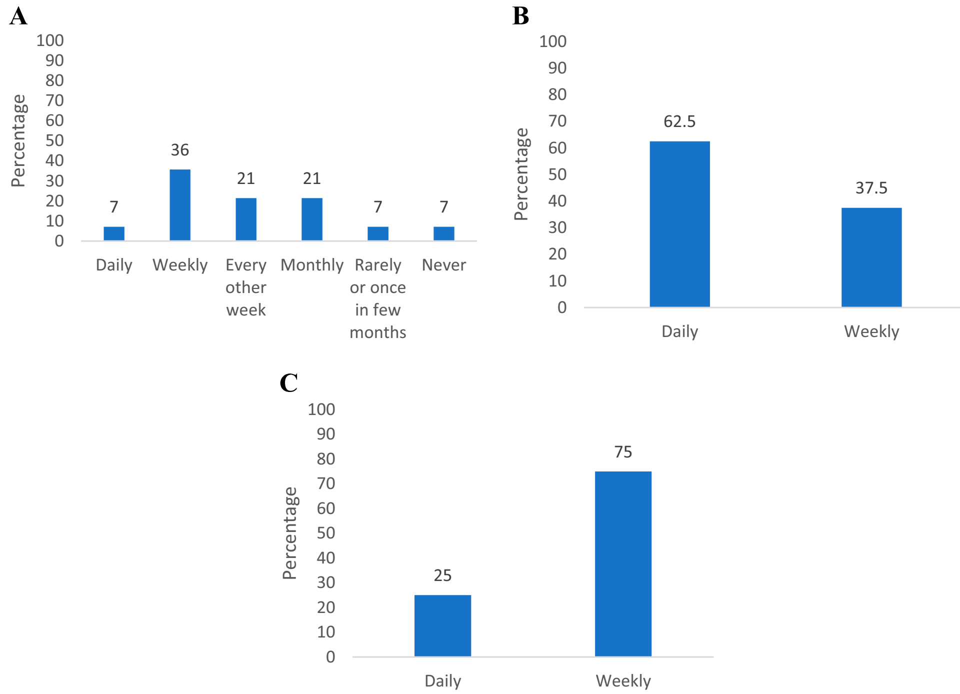

Fig. 2. Percentage of scouting frequency for diseases in dogwood plants according to the type of operation: (**A**) field-grown production, (**B**) container-grown production, and (**C**) pot-in-pot production.

even though dogwood-related foliar diseases were not severe in their nurseries (2.4 points). Also, growers rated their experience in or exposure to any new methods of disease detection and control of dogwood diseases as low (2.2 points) compared with current disease management practices. The necessity of continuous scouting and spray application to maintain the marketability of the dogwoods explains, in part, some positive level of confidence indicated by the respondents toward current management practices. This is also indicative of the requirement of exploring novel approaches for disease scouting and spray applications to minimize the costs associated with it, such as cultural sighting, treating for borers, rotating Fungicide Resistance Action Committee modes of action, using mefenoxam and propiconazole fungicides as a drench, and using resistant cultivars. There is a recent trend in using UASs for disease identification as well as for sprays in precision agriculture and ornamental nursery production (Hassler and Baysal-Gurel 2019; Neupane and Baysal-Gurel 2021). To identify the cost–benefit associated with the use of this kind of technique, the results found in out study will be highly beneficial. In addition, because growers' experience in or exposure to any new methods of disease detection and control was very low, according to growers' responses, outreach activities need to be conducted upon identification of effective alternatives to these traditional and costly disease management techniques currently used by dogwood growers.

Spearman's rank correlation coefficient values indicate significant positive correlations ($0 \leq r_s \leq 1$) between foliar disease severity and scouting frequency of dogwood container plants, foliar disease severity and scouting frequency of pot-in-pot plants, and foliar disease severity and worker hours spent in scouting and spraying (Table 5). Strong positive correlations (r_s = 0.6–1), included disease severity and scouting frequency for container plants (r_s = 0.95), scouting frequency for pot-in-pot plants (r_s = 0.98) at $P < 0.01$; number of worker hours spent in scouting (r_s = 0.69) at $P < 0.05$; and a moderate positive correlation (r_s = 0.4–0.59), was shown between disease severity and number of worker hours spent in spraying (r_s = 0.59) at $P < 0.1$ significance level. Also, the efficacy of disease management showed significant correlations with the number of workers involved in scouting (r_s = 0.46), overall cost of foliar disease scouting (r_s = –0.56), spraying frequency for field plants (r_s = 0.67), and overall cost of foliar disease spraying (r_s = –0.59). Experience in or exposure to dogwood disease detection and control methods showed a strong negative correlation with the scouting frequency of container plants (r_s = –0.95), a positive correlation with the number of worker hours spent in scouting (r_s = 0.53), and a negative correlation with spraying frequency for container plants (r_s = –0.83). Allocating more workers for disease scouting and spraying, and spending more money on disease management can reduce the damages caused by these diseases. But, when we consider the cost of labor and chemicals, and possible market losses resulting from these diseases, it is not economically feasible to growers.

Mann-Whitney *U* test results in Table 6 show that there are significant differences between the growers who follow and do not follow the pesticide spray schedule, mainly with number of workers involved in spraying (Z = 0.96, $P < 0.05$), overall cost of foliar disease spray (Z = 0.33, $P < 0.01$), efficacy of disease management strategy (Z = –1.98, $P < 0.05$), and experience in or exposure to other disease detection and control methods (Z = –1.63, $P < 0.1$). Dogwood growers who do not follow a pesticide spray schedule involve more workers for spraying and spend more money for spraying compared with growers who follow a pesticide spray schedule ($P < 0.05$ and $P < 0.01$, respectively). Also, growers who followed pesticide spray schedules seemed to be more confident in the efficacy of their current dogwood disease management strategy and had more experience in or exposure to other disease detection and control methods ($P < 0.05$ and $P < 0.1$, respectively). Number of workers, worker hours, and overall cost of scouting practices;

Table 3. Frequency of spraying pesticides to manage diseases in dogwood plants according to the type of nursery operation.

	Type of nursery operation (%)		
Frequency of spraying	Field-grown	Container-grown	Pot-in-pot
Weekly	20	25	0
Every other week	40	62.5	66.7
Monthly	27	12.5	33.3
Once in 3 or 4 months	0	0	0
Rarely/never	13	0	0

Table 4. Issues noted by nursery crop growers regarding dogwood disease management in their nurseries.

Perception of the issue	Mean[i]	*SD*[ii]
How severe is dogwood-related foliar disease in your nursery?	2.4	1.2
How confident are you in the efficacy of your current dogwood disease management strategy?	3.2	1.5
What is your experience or exposure to any other methods of disease detection and control of dogwood diseases?	2.2	1.2

[i] The mean rating is based on a scale from 1 to 5 points, where 1 point indicates least and 5 points indicates most.
[ii] *SD* = standard deviation of the perceptions of disease management of dogwoods.

worker hours of spraying; disease severity of dogwood foliar diseases; and dogwood sales income did not show any significant differences between grower groups based on the pesticide spray schedule. These results further confirm that creating a well-tailored pesticide program can benefit growers in managing dogwood diseases.

Cost assessment of dogwood disease management. Based on our estimates from the samples, our results suggest that overall cost of foliar disease scouting per year for dogwood in a nursery farm is ≈$750/year, whereas the overall cost of a foliar fungicide program for dogwood with chemicals, labor, and so on is ≈$2320/year. In a year, the nursery growers earned, on average, $938,000 from total sales of overall nursery plants and ≈$336,944 from the sale of dogwood plants. When the disease management cost for dogwood was calculated using the total cost of scouting and spraying and the total nursery area of dogwood production, the dogwood disease management average cost was found to be ≈$379/acre per year. In contrast, Fessler et al. (2021) reported that the minimal average disease management cost for flowering dogwood is ≈$769/acre per year ($1900/ha per year) as a result of currently recommended spray schedules in Tennessee, USA. Also, this management cost has surged from $120 to $1975/ha per year because of powdery mildew (Li et al. 2009; Trigiano et al. 2023). Our sample estimates could be the lower bound of the cost spectrum, because they suffer from a low sample size and perhaps miss some components of the costs. Nonetheless, our findings provide a projected greater cost with greater labor requirements inherent with the intensity of involvement for disease management in existing practices. In addition, it is recommended to find alternative solutions to reduce manual labor in disease management on woody ornamental nursery farms.

Table 5. Spearman rank correlation estimates between the perception of dogwood disease management and the management practices of dogwood nurseries.

Variable	Disease severity of foliar diseases	Efficacy of disease management	Experience/exposure to other disease control methods
Scouting frequency for field plants	0.29	0.11	0.47
Scouting frequency for container plants	0.95***[i]	0.30	–0.95***
Scouting frequency for pot-in-pot plants	0.98***	–0.87	–0.87
No. of workers involved in scouting	0.19	0.46*	0.03
No. of worker hours spent in scouting	0.69**	0.18	–0.53*
Overall cost of foliar disease scouting	0.36	–0.56*	–0.43
Spraying frequency for field plants	–0.07	0.67**	0.33
Spraying frequency for container plants	0.53	0.57	–0.83**
Spraying frequency for pot-in-pot plants	0.50	–0.87	–0.87
No. of workers involved in spraying	0.04	–0.34	0.02
No. of worker hours spent in spraying	0.59*	–0.12	0.38
Overall cost of foliar disease spraying	0.11	–0.59**	–0.19

[i] *, **, ***Significant at 0.10, 0.05, and 0.01, respectively.

Table 6. Summary of mean or median score differences, based on a Mann-Whitney *U* test, between management practices and dogwood nursery operations following or not following a pesticide spray schedule.

Variable	Following a pesticide spray schedule (mean/median score)	Not following a pesticide spray schedule (mean/median score)	Z value
No. of workers involved in scouting	9.00	13.50	1.18
No. of worker hours spent in scouting	7.32	5.25	–0.65
No. of workers involved in spraying	9.16	12.25	0.96**[i]
No. of worker hours spent in spraying	7.50	7.50	0.00
Overall cost of foliar disease scouting	5.25	6.50	0.40
Overall cost of foliar disease spraying	6.30	7.50	0.33***
Grower perception for disease severity of dogwood-related foliar diseases	6.25	7.71	0.38
Confidence in efficacy of current dogwood disease management strategy	8.42	2.00	–1.98**
Experience/exposure to other disease detection and control methods of dogwood	8.25	3.00	–1.63*
Dogwood sales income	9.53	9.25	0.00

The Mann-Whitney *U* test scores based on the measurement of two rank median/mean totals in each group.
[i] *, **, ***Significant at 0.10, 0.05, and 0.01, respectively.

Conclusion

Our study results provide important information regarding dogwood disease management by nursery crop growers in Tennessee, USA. Despite the availability of effective dogwood disease management approaches and identification of disease-resistant flowering dogwood cultivars, dogwood production is greatly affected by plant loss and costs associated with disease management. Therefore, identifying the production stages, often costlier to the growers, are important to guide growers in alternative cost-minimizing approaches. Based on the responses to our survey, most of the growers who responded produce or maintain dogwood plants. The majority of the nurseries were involved in field-grown dogwood production compared with container production or pot-in-pot production. Scouting was a crucial disease management practice; growers scouted weekly for diseases in field-grown and pot-in-pot plants, and scouted daily for diseases in container plants. We found positive correlations between disease severity and scouting frequency, and positive correlations between disease severity and the number of worker hours spent scouting for both container and pot-in-pot production systems. Also, the efficacy of disease management showed a significant positive correlation with the number of workers involved in scouting and a significant negative correlation with the overall cost of foliar disease scouting. When more workers are involved in the scouting program, the efficacy of disease management increases, and with an improved disease management program, overall cost of the scouting program decreases. Experience in or exposure to other dogwood disease detection and control methods showed a significant negative correlation with the scouting frequency of container plants and number of worker hours spent in scouting. When growers have more experience in or exposure to other disease detection and control methods, such as UASs, scouting frequency will be reduced in container plants, which would reduce worker hours spent in scouting.

Spraying for diseases also plays a major role in disease management in dogwood production. However, it gets costlier with the increase in nursery area. Our finding of a positive correlation between disease severity and the number of worker hours spent in spraying strongly indicates the increased cost of spraying led to more effective disease control. Likewise, the efficacy of disease management showed significant positive correlations with spraying frequency for field plants and the overall cost of foliar disease spraying. When growers spend more time to spray field plants and spend more money on a spraying program, it increases the efficacy of disease management. Experience in or exposure to other dogwood disease detection and control methods showed a negative correlation with spraying frequency in a container production system. More experience in or exposure to new disease detection and control methods helps growers reduce spending time for spraying in container production.

Nursery growers have little or no guidance by which they can minimize the costs associated with dogwood disease management. Therefore, they will benefit from the findings of our survey because they will increase their awareness regarding the economic aspect of the disease management approaches to which they currently adhere. Moving to automated technology has the potential to reduce the costs of most disease management practices. The results of our study regarding cost-intensive practices and correlated factors are expected to be useful in developing a disease management program using UASs, particularly by emphasizing those specific practices. This may be helpful not only to facilitate labor cost reductions in scouting, but also the costs of pesticide use, and the reduction of adverse environmental impacts resulting from over- or misuse of chemicals in nursery crops.

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