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# Investigating Producer Preferences for Crapemyrtle (*Lagerstroemia indica* L.: Lythraceae) & Their Perceptions Regarding Crapemyrtle Bark Scale

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**Abstract:** Crapemyrtle (*Lagerstroemia indica* L.: Lythraceae) is the most popular summer flowering tree in the U.S. Its total value sold has almost doubled since 1998. Consumers prize crapemyrtles for their beauty and pest resistance. However, current crapemyrtle production and use is being threatened by crapemyrtle bark scale (*Acanthococcus lagerstroemiae* (Kuwana, 1907)) (CMBS), which has been confirmed in 12 U.S. states after its first sighting in Texas in 2004. Our survey results indicate that producers anticipate a significant decrease in the value of crapemyrtle due to CMBS, in the magnitude of 29.93% and 33.79%, in our 2018 and 2019 surveys respectively. Our findings indicate industry demand for CMBS control. We used a non-parametric test to compare the producers' responses to several questions regarding CMBS-control, among the different producer categories included in our sample. Incorporated businesses showed the most support, followed by partnerships, and family/individual operations were the least supportive of science-based CMBS control research. Large businesses predicted a more serious decrease in crapemyrtles' value as compared to smaller businesses. More businesses with high volume of crapemyrtle-related business considered the benefits of CMBS-control to be higher than its cost, as compared to other businesses. We also used a relative importance index to illustrate the ranking of different attributes of crapemyrtles that producers consider while making decisions about growing/purchasing the plants. Flower color was found to be the most important attribute, followed by disease resistance. If the issue of CMBS gets out of control, the industry might need to find potential replacements to crapemyrtle. The most popular landscape plants that can potentially replace crapemyrtle, in the opinion of producers we surveyed, are vitex (Texas lilac) and magnolia.

**Keywords:** Crapemyrtle (*Lagerstroemia indica* L.: Lythraceae); Crapemyrtle Bark Scale (*Acanthococcus lagerstroemiae* (Kuwana, 1907)); flowering tree; pest; producer survey; relative importance index

## 1. Introduction

Crapemyrtle is the most popular flowering tree in the U.S. [1, 2, 3]. The total value of crapemyrtles sold has almost doubled since 1998, from approximately \$32.3 million in 1998 to almost \$66 million in 2014 (annual wholesale values) [1, 2, 3]. It is produced in 33 states most of which are located in the southern part of the continental U.S., according to the 2014 USDA NASS Census of Horticultural Specialties [3, 4]. The total number of crapemyrtles sold rose sharply by 152.6%, from approximately 1.9 million in 1998 to over 4.8 million in 2014 [1, 2, 3]. The reason why crapemyrtles are so popular in the U.S. is not only that they are relatively easy to grow, it is also because they offer a lot of variety with respect to color, size, growth habitat, and their use [5]. Consumers prize crapemyrtles for their beauty, but they are also, relatively speaking, fairly pest resistant [6].

Crapemyrtle bark scale (CMBS) (*Acanthococcus lagerstroemiae* (Kuwana, 1907)) is a novel pest affecting crapemyrtles in the U.S. [7]. Biologically, *A. lagerstroemiae* is a sexual dimorphic [8]. For most of its lifetime, the adult female is sessile on the bark [8, 9]. The scale secretes honeydew, which encourages sooty mold growth on the plants [8]. Not only does this limit the plants' photosynthesis, it also reduces their aesthetic value [8]. Additionally, if the infestation gets out of control the sooty mold can coat the bark, which can be a huge concern for growers [7]. CMBS may result in sooty mold covering the bark, branch dieback, sparse flowering, and smaller flowers [10]. In some cases, it may also result in stunted growth, or even fatality of the plants [10]. Several characteristics of plants such as size, overall visual quality, and photosynthesis rate, are significantly affected due to CMBS infestation [11]. CMBS is native to East Asia and poses a serious threat to several plants such as persimmon, pomegranate, and crapemyrtles [10]. However, current crapemyrtle production and use is being threatened by CMBS [10]. It has been confirmed in 12 U.S. states (Alabama, Arkansas, Georgia, Louisiana, Mississippi, New Mexico, North Carolina, Oklahoma, Tennessee, Virginia, and Washington), after it was first sighted in north Texas in 2004 [10].

A few insecticides, particularly neonicotinoids, that control CMBS to some extent, pose a high risk to pollinators [12]. The Pest Management Strategic Plan for Container and Field-Produced Nursery Crops in FL, GA, KY, NC, SC, TN, and VA: Revision 2015, mentioned that there is no known biological control for CMBS [13]. Even though currently there are no reported instances of CMBS in California, the California Department of Food and Agriculture has given CMBS a rating of 14 in its pest-rating proposal, on a scale of 1 to 15 (the highest). Furthermore, it also mentions that CMBS can widely spread across California [14]. Even though it has a moderate host range, it has high reproduction as well as dispersal potential, due to which it can have an impact on the environment and cause economic repercussions in California [14].

Production of, and landscaping with, crapemyrtles is expected to continue since a majority of stakeholders of the green industry (e.g. growers, retailers, consumers and landscape professionals) are unaware of the CMBS problem. This study aimed at investigating how CMBS affected landscape plant industry in general and the crapemyrtle growers in particular.

## 2. Materials and Methods

In this study, we conducted in-person interviews of businesses at the Texas Nursery/Landscape EXPO in 2018 and 2019. The survey participants were provided with a paper survey that they filled out themselves. The survey administrator was available to answer questions that the participants had. The participants were not provided any monetary compensation to take the survey. We have surveyed 32 and 47 businesses, in 2018 and 2019 respectively, from eight states- Alabama, California, Florida, Georgia, Louisiana, Mississippi, Tennessee, and Texas. Out of the 79 respondents, 75 were growers. The other four businesses included a wholesaler, re-wholesaler, nursery, and a broker. These surveys provided us with knowledge about the crapemyrtle production. The business representatives answered several questions regarding their knowledge of CMBS, their thoughts and concerns about CMBS, and details about their business and sales. The questions were presented using a Likert scale; the questions are listed in Table 2.

Based on the responses in the surveys, we were able to divide the businesses into different categories based on several parameters such as their legal status, and the gross annual sales of the operation (Table 1).

**Table 1:** Classification of producers based on business types in the crapemyrtle survey sample

Parameter	Categories [number in each]	Number of Businesses Surveyed
Legal status	Family or individual operation, and Partnership	36
	Incorporated under state law	37
Gross annual sales value of the operation	\$1,000,000 or more	50
	Under \$1,000,000	18
Gross annual value of crapemyrtle-related business for the operation	\$100,000 or more	26
	Under \$100,000	32

We used the Kruskal-Wallis test to compare the producers' responses to several questions among the different producer categories included in our sample (Table 2) [15]. The Kruskal-Wallis test is a distribution-free nonparametric approach [16] to the one-way analysis of variance (ANOVA) [15]. It is used to compare different groups based on a dependent variable measured by the ordinal level. It helps in testing whether different population distributions are identical; it does not assume that the distributions are normal. The test statistic is given by

$$H = \frac{(N-1)}{N} \sum_{i=1}^g \frac{n_i[\bar{r}_i - (N+1)/2]^2}{(N^2-1)/12}, \quad (1)$$

where  $g$  is the number of sample sets,  $n_i$  is the number of observations in set  $i$ ,  $N$  is the total number of observations (all sets combined),  $\bar{r}_{ij}$  is the mean of the  $n_i$  ranks from set  $i$ ,

$\bar{r}_i$  is the mean of the  $n_i$  ranks from set  $i$ :  $\bar{r}_i = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i}$  [15]. The null hypothesis states that the difference between medians of the groups within the sample is not statistically significant. Therefore, if the  $p$ -value  $\leq \alpha$  (significance levels: 0.01, 0.05, 0.1), we reject the null hypothesis and conclude that the difference between groups is statistically significant. On the other hand, if the  $p$ -value  $\geq \alpha$ , we fail to reject the null hypothesis and conclude that the difference between groups is not statistically significant.

In the survey, we also asked the business representatives about the importance of different attributes of crapemyrtles when they are making decisions about growing/purchasing the plants. The relative importance index can be used to see the ranking of all the attributes based on their respective importance [17]. It has been commonly used in project management and engineering research (e.g. [18, 19, 20, 21, 22]). The relative index (RI) is calculated by the following formula [23]:

$$RI = \sum_{A \times N} \frac{W}{A} \quad (2)$$

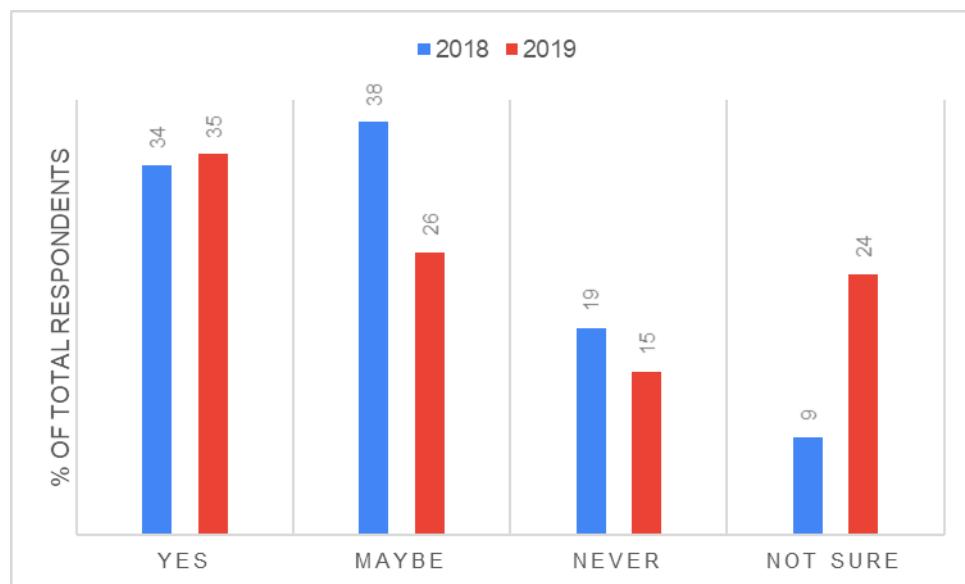
Here,  $W$  is the 'importance' assigned by the survey respondents, on a scale of one to four (1 = least important, 4 = highest in importance),  $A$  is the value for highest importance and  $N$  is the total number of respondents [18, 23].

### 3. Results

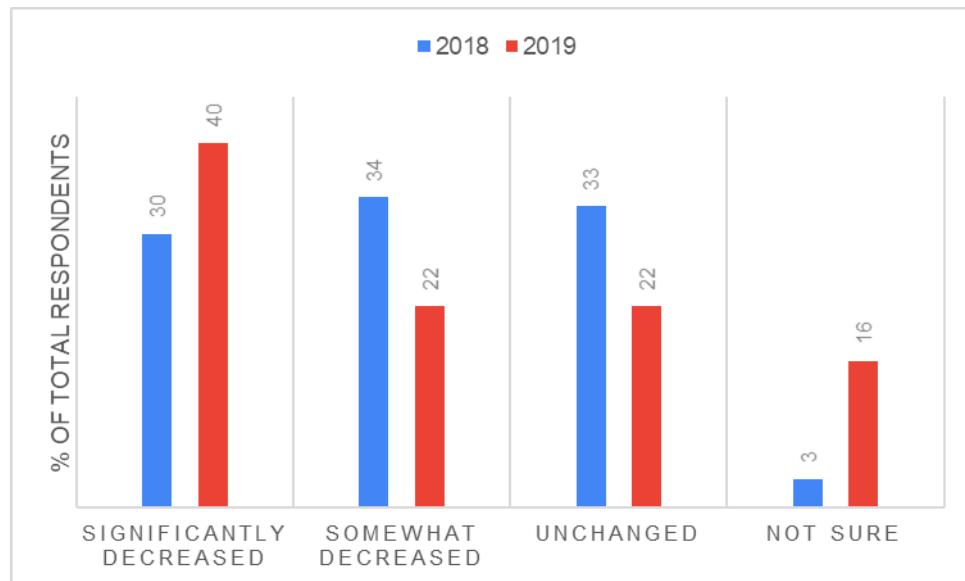
#### 3.1. Survey Responses

According to the producers we surveyed, the three cultivars with the greatest sales are Natchez, Muskogee, and Tuscarora. Additionally, the three most popular sizes for crapemyrtles are 15gal, 30gal, and 45gal. These sizes refer to the volume of the containers in which the plants are potted. Our survey results indicate that producers anticipate a significant decrease in the value of crapemyrtle due to CMBS, of the magnitude between 29.93% and 33.79%, in our 2018 and 2019 surveys, respectively. This is an alarming number, especially since crapemyrtle production is an important part of the horticulture industry.

Quite a number of the producers interviewed (72% and 61% in 2018 and 2019, respectively) also anticipated a decrease in the sale and use of crapemyrtles, in general, if the CMBS problem persists (Figure 1). Their willingness to grow crapemyrtle would also decrease if it were infested by CMBS. For example, 30% of the producers interviewed in 2018, and 40% of the producers interviewed in 2019 mentioned that their willingness to grow crapemyrtle would be significantly decreased if it were infested by CMBS. Another 34% and 22% of the producers in 2018 and 2019, respectively, mentioned that their willingness to grow crapemyrtle will be somewhat decreased if it were infested with CMBS (Figure 2). This shows that CMBS presents a very serious threat to the landscape plant industry in general, and the crapemyrtle production in particular. If the issue of CMBS gets out of control, it will become important to find potential replacements to crapemyrtle. The most popular landscape plants that can potentially replace crapemyrtle, in the opinion of producers we surveyed, are *Vitex agnus-castus* L. (Texas lilac), *Magnolia* spp. and *Hibiscus* spp.



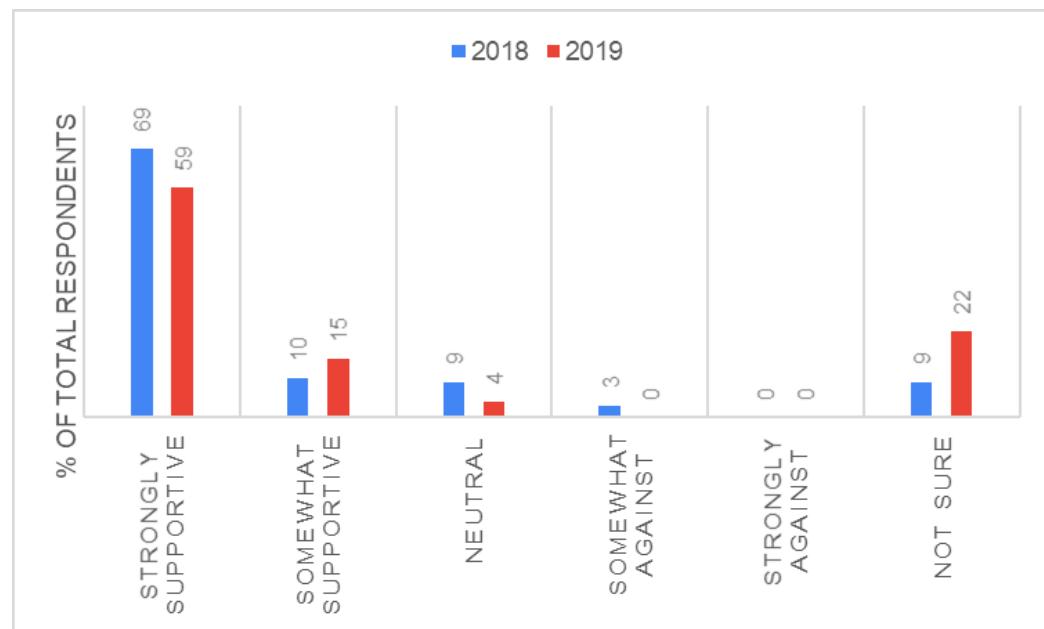
**Figure 1.** Producers anticipating a significant drop in sales and use of crapemyrtle (in %)



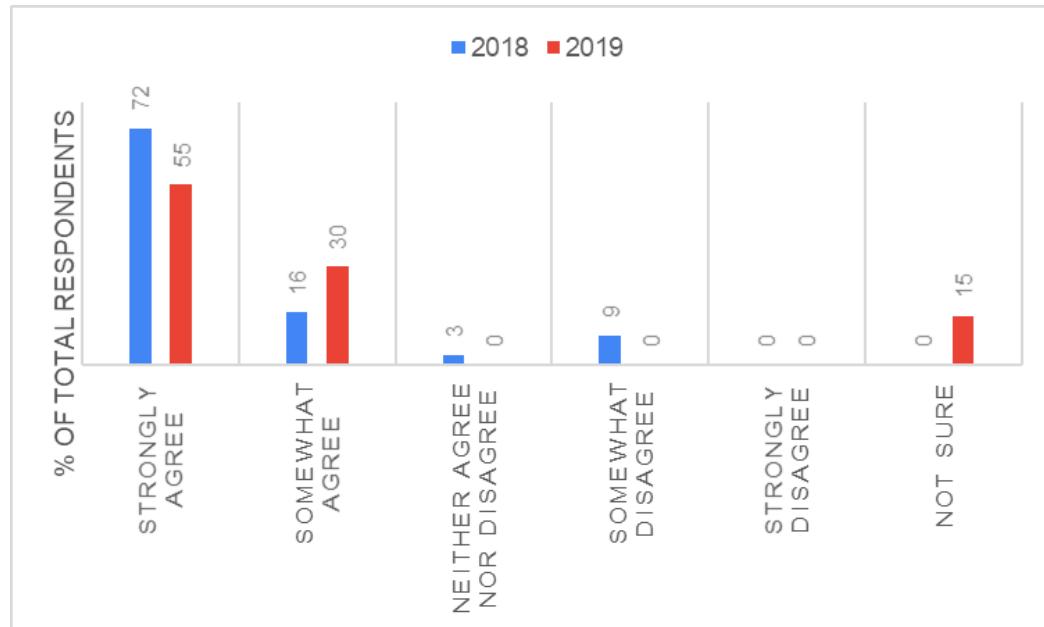
**Figure 2.** Decline in willingness to grow crapemyrtle if infested by CMBS (in %)

However, CMBS can be controlled using a variety of methods including physical cleaning/washing of plants [6]. Systemic strategies are also useful for its control, and in fact shown the most promise in experiments [6]. Soil-applied neonicotinoids were found

to suppress CMBS to a significant extent [6]. The producers demonstrated support for systemic and scientific control strategies. Scientific control strategies include sustainable chemical control, the use of biological control agents, and other environmental-friendly methods such as the development of insect-resistant cultivars [9, 24, 25, 26, 27]. A total of 69% of the producers interviewed in 2018, and 59% interviewed in 2019, strongly supported the development of systemic strategies for CMBS control (Figure 3). Another 10% and 15% of the producers interviewed in 2018 and 2019 respectively were somewhat supportive of systemic strategies. 72% of the producers interviewed in 2018, and 55% interviewed in 2019, strongly supported science-based CMBS control (Figure 4). Another 16% and 30% of the producers interviewed in 2018 and 2019 respectively were somewhat supportive of science-based CMBS control. Science-based pest control refers to deterring pests through strategies developed by extensive research into pest biology.



**Figure 3.** Producer support for development of systemic strategies for CMBS control (in %)



**Figure 4.** Producer support for science-based CMBS control research (in %)

### 3.2. Kruskal-Wallis Test and Categorical Comparison

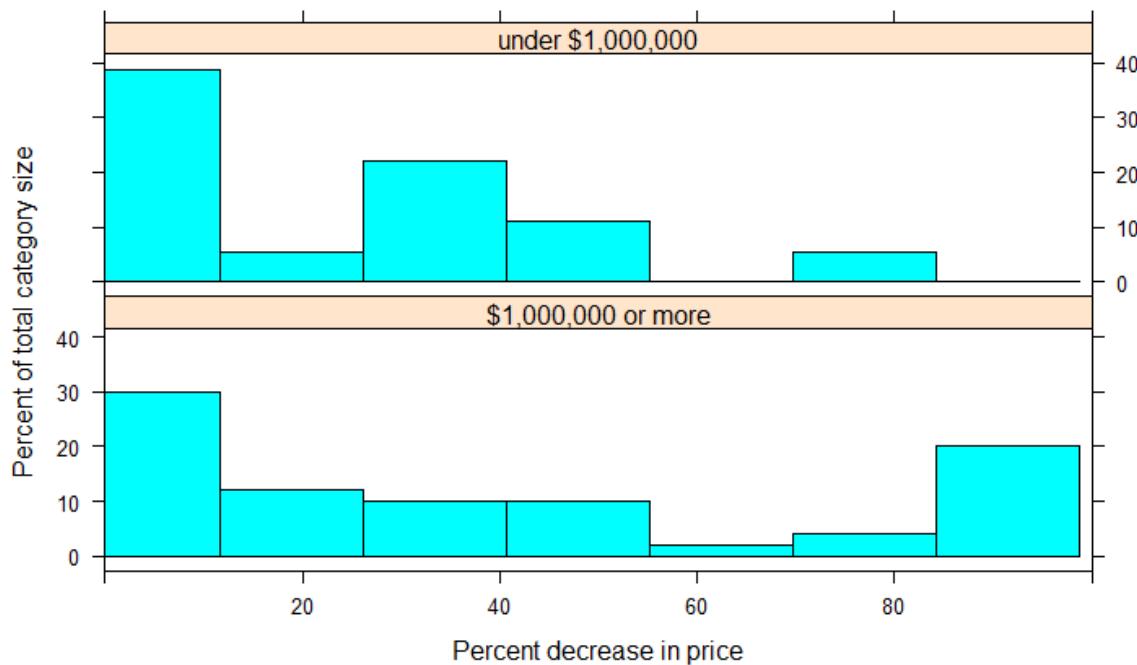
Table 2 shows the Kruskal-Wallis test's p-values for producers' responses to several questions among the different producer categories included in our sample. The significant values have two important implications.

**Table 2:** Kruskal-Wallis test statistics (p-values) for comparison of producers' responses to CMBS survey, among different business types and categories

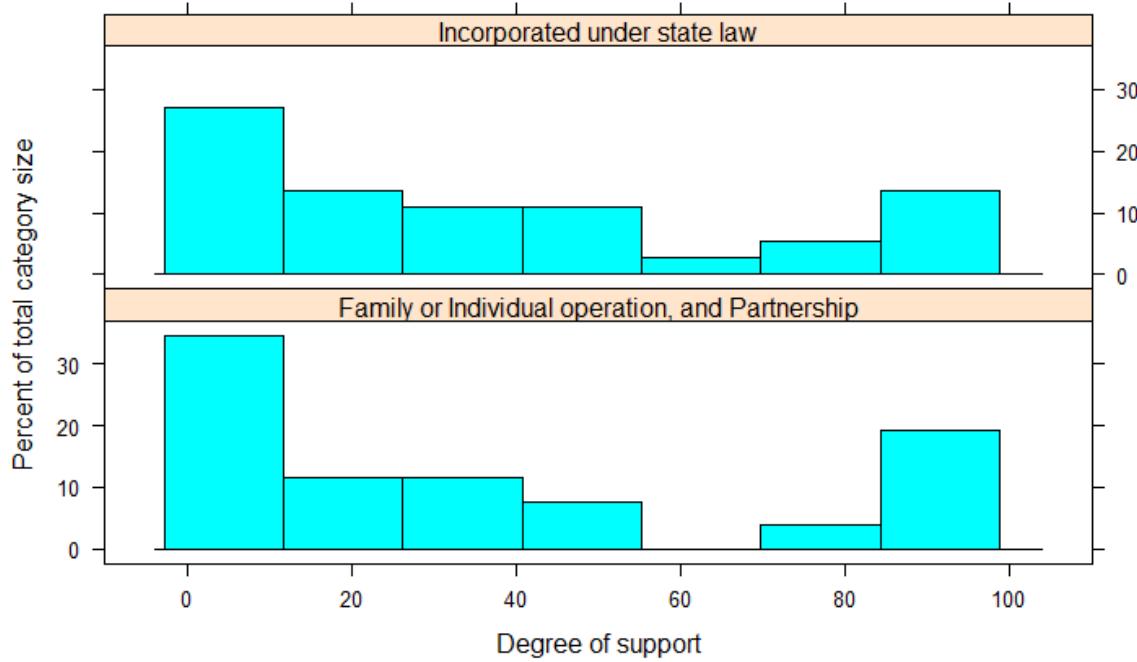
Survey question	Classification		
	Legal status	Gross annual sales value	Gross annual value of crapemyrtle-related business
Anticipate that CMBS will result in a significant drop in sales and use of crapemyrtles in your area.	0.369	0.171	0.353
Magnitude by which the price value for crapemyrtles will decrease if it is infested by CMBS.	0.832	0.081*	0.101
Change in your willingness to grow crapemyrtles will if it is infested by CMBS.	0.509	0.894	0.150
General opinion about developing systemic strategies to control CMBS.	0.690	0.605	0.969
Do you think that your operation will benefit from science-based CMBS control strategies?	0.064	0.869	0.966
Do you think the overall benefits from CMBS control will be higher than the cost of CMBS control?	0.872	0.229	0.046**

\*, \*\* significant at  $p \leq 0.05, 0.01$ , respectively

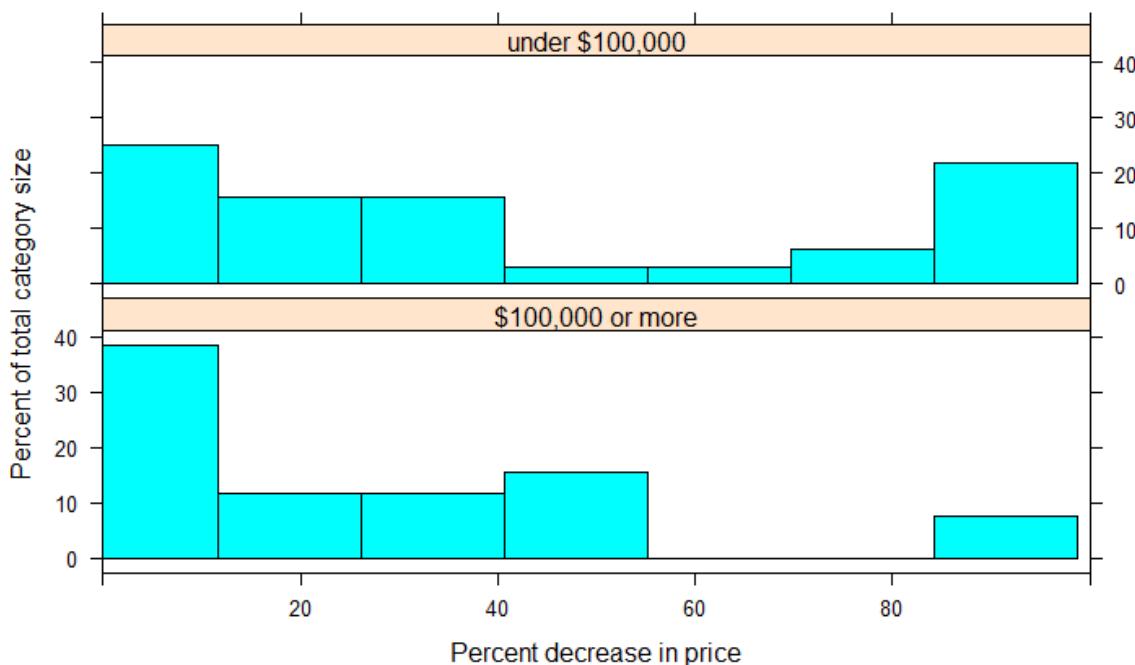
First, there was a significant difference among different producer types based on gross annual sales regarding their thoughts on the magnitude by which the price value for crapemyrtles will decrease (in %) if it is infested by CMBS (Figure 5). Less than 6% of the businesses with under \$1,000,000 gross annual sales value thought that the value of crapemyrtles would fall by more than 60%. On the other hand, 26% of the businesses with more than \$1,000,000 gross annual sales value thought that the value would fall more than 60%. In conclusion, large businesses (with more than \$1,000,000 gross annual sales value) predicted a more serious decrease in crapemyrtles' value as compared to other businesses (with less than \$1,000,000 gross annual sales value). The difference was not statistically significant for different categories based on the other two parameters- legal status, and gross annual crapemyrtle sales (Figures 6 & 7). The comparison is illustrated in Figures 5-7.



**Figure 5.** Magnitude of decrease in the price value for crapemyrtles will decrease (%) if infested by CMBS vs. different producer types (gross annual sale)

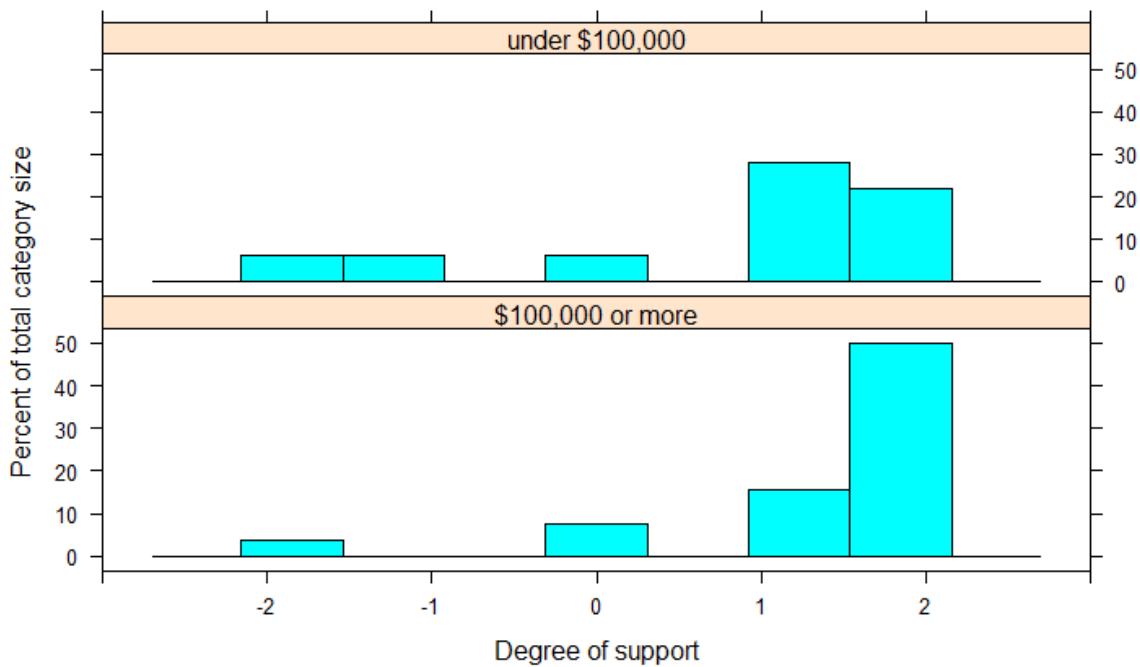


**Figure 6.** Magnitude of decrease in the price value for crapemyrtles (%) if infested by CMBS vs. different producer types (legal status)



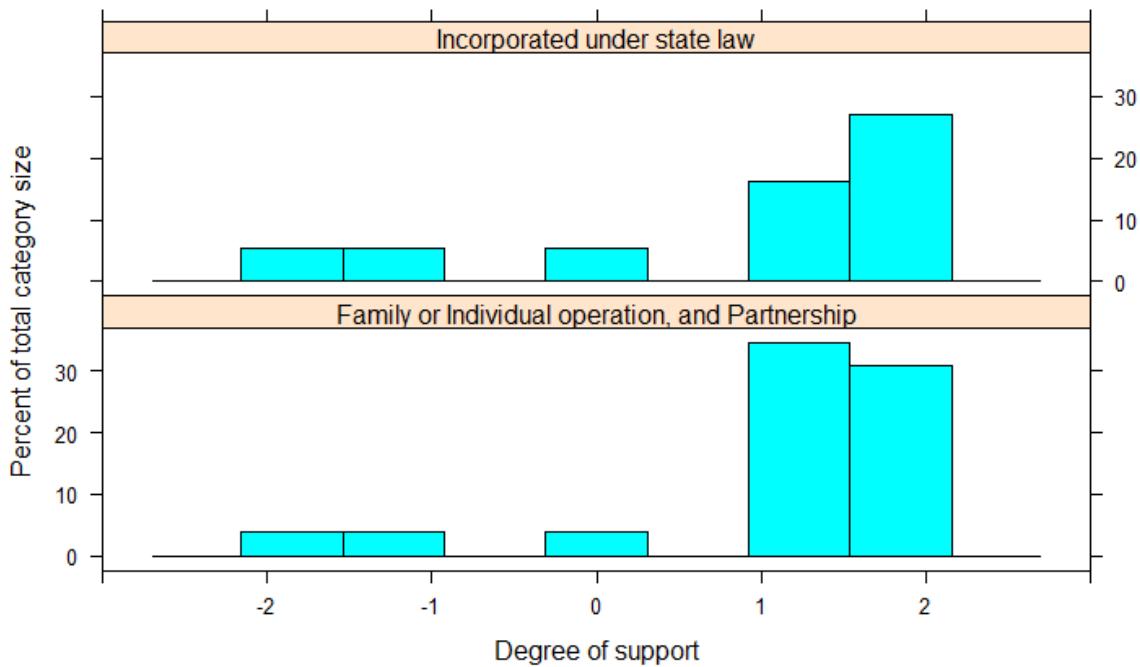
**Figure 7.** Magnitude of decrease in the price value for crapemyrtles (%) if infested by CMBS vs. different producer types (gross annual crapemyrtle-related sales)

Second, there was a significant difference among different producer types based on gross annual value of crapemyrtle-related business, about their thoughts on whether the overall benefits from CMBS control will be higher than the cost of CMBS control. Approximately 65% of businesses with over \$100,000 worth of crapemyrtle-related sales agreed that overall benefits from CMBS control would be higher than its cost; less than 4% disagreed with that statement. On the other hand, 50% of the businesses with under \$100,000 worth of crapemyrtle-related sales agreed that overall benefits from CMBS control would be higher than its cost; 12.5% disagreed with that statement (Figure 8). In summary, more businesses with high volume of crapemyrtle-related business (over \$100,000 in gross sales) considered the benefits of CMBS-control to be higher than its cost, as compared to other businesses (under \$100,000 in gross sales). The difference was not statistically significant for different categories based on the other two parameters- legal status, and gross annual sales (Figures 9 & 10). These three findings suggest an immediate need for CMBS control. Our surveys indicated that overall, most producers believe that benefits of CMBS control are higher than the costs (Figure 11). This implies that there is industry demand for CMBS control.



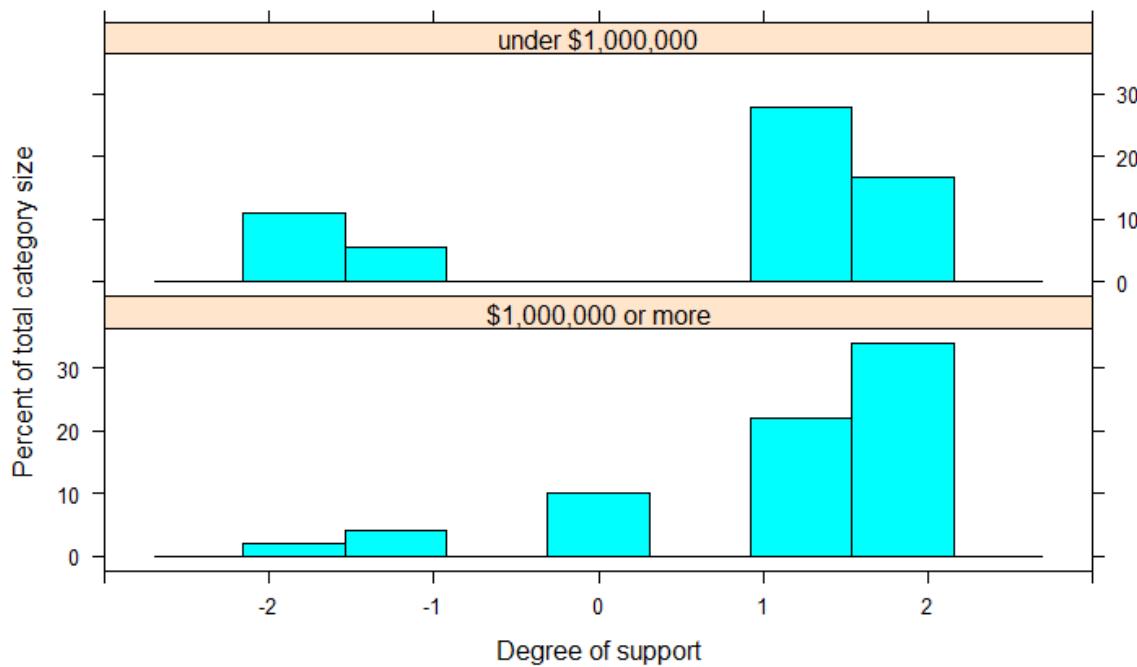
(-2 = Strongly disagree, -1 = Somewhat disagree, 0 = Neither agree nor disagree, 1 = Somewhat agree, 2 = Strongly agree)

**Figure 8.** Overall benefits from CMBS control higher than its cost vs. different producer types (gross annual crapemyrtle-related sales)



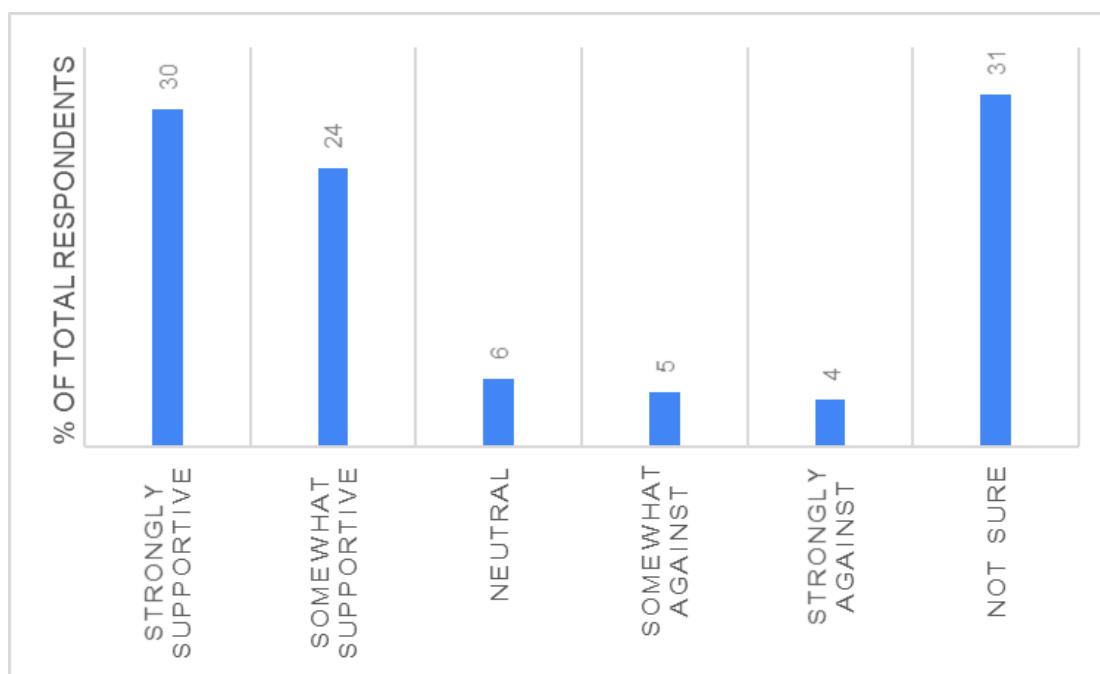
(-2 = Strongly disagree, -1 = Somewhat disagree, 0 = Neither agree nor disagree, 1 = Somewhat agree, 2 = Strongly agree)

**Figure 9.** Overall benefits from CMBS control higher than its cost vs. different producer types (legal status)



(-2 = Strongly disagree, -1 = Somewhat disagree, 0 = Neither agree nor disagree, 1 = Somewhat agree, 2 = Strongly agree)

**Figure 10.** Overall benefits from CMBS control higher than its cost vs. different producer types (gross annual sale)

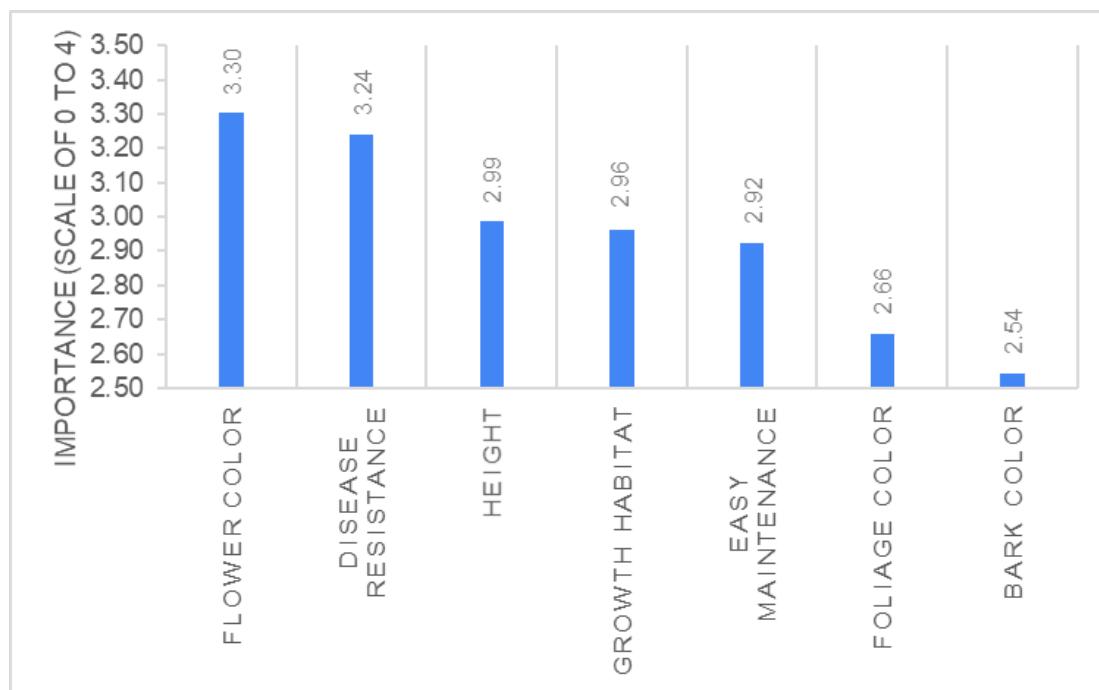


**Figure 11.** CMBS control: benefits higher than cost (in %)

### 3.3. Relative Importance Index

Business representatives ranked the importance of different attributes of crapemyrtles that they consider when they are making decisions about growing/purchasing the plants (Figure 12). The relative importance indices for different attributes are shown in Table 3. Flower color was found to be the most important attribute. This result is intuitive,

since the producers would choose what colors to grow based on the consumers' demand in the previous years. Flower color was followed by disease resistance. This is an important finding. It implies that once the producer makes the decision regarding which color crapemyrtle to grow, the next attribute that holds the highest importance is disease resistance. This suggests how important CMBS control is for producers. We used the Kruskal-Wallis test to compare the rankings between the two years included in our sample [15]. There was no significant difference in the relative importance of attributes between 2018 and 2019. The relative index (RI) can be used to assign the importance levels to the attributes. There are five levels corresponding to the relative index values: a.  $0.8 \leq RI \leq 1$ : high (H), b.  $0.6 \leq RI \leq 0.8$ : high-medium (H-M), c.  $0.4 \leq RI \leq 0.6$ : medium (M), d.  $0.2 \leq RI \leq 0.4$ : medium-low (M-L) and e.  $0 \leq RI \leq 0.2$ : low (L) [28]. In addition to a comparative analysis, this importance level helps in identifying the individual importance of each attribute (Table 3). In our analysis, flower color, disease resistance, height, and growth habitat were determined to be of 'High' importance level. In addition, easy maintenance, foliage color, and bark color were determined to be of 'High-Medium' importance level. This suggests that all of the attributes are extremely important while making purchasing/growing decisions.



**Figure 12:** Importance of different attributes (on a scale of 0 to 4)

**Table 3:** Relative Importance Index (RII) of plant attributes for producers when making crapemyrtle purchasing decisions

Attribute	2018	2019	Mean RII	Rank	Importance level
	RII	RII			
Flower color	0.90	0.91	0.91	1	High
Disease resistance	0.85	0.87	0.86	2	High
Height	0.84	0.82	0.83	3	High
Growth habitat	0.82	0.81	0.81	4	High
Easy maintenance	0.76	0.80	0.78	5	High-Medium
Foliage color	0.75	0.75	0.75	6	High-Medium
Bark color	0.69	0.72	0.70	7	High-Medium

#### 4. Discussion

Previous research has looked into the causal organism and mechanism of bark scale [7, 8, 9]. Extant literature also provides some insights into ways to counter the issue- physical cleaning, systemic strategies, and scientific control strategies [6]. While previous research can be used to control the bark scale issue, there is an immediate need to analyze the economic impact of this pest. The issue of bark scale is associated with various economic costs. This includes financial loss due to plant fatality, or loss of commercially important attributes such as sooty black bark color and reduced flower density; it also includes the financial costs associated with the control of CMBS as well as the time and resources spent on researching more effective control strategies. Since crapemyrtle has enjoyed increased popularity over time, is produced in almost two-third of the states, and is a \$66 million industry, it is imperative to counter these economic impacts of CMBS.

If the issue of CMBS gets out of control, it might have two serious implications. First, it will result in a decrease in the demand for crapemyrtles, affecting several businesses of the crapemyrtle industry [3]. Second, the horticulture industry would need to find potential replacements to crapemyrtle. In essence, it may induce a shift in the demand of different products within the horticulture industry. Both of these shifts can potentially have a huge impact on businesses. Our findings are aligned with this possible outcome and indicate industry demand for CMBS control. Our results show that producers anticipated a decrease in crapemyrtle sales, as well as a decrease in its value. Our findings indicated that large businesses predicted a more serious decrease in crapemyrtles' value as compared to smaller businesses.

In summary, CMBS represents a significant economic cost. It is important to note here that this conclusion results indirectly from the subjective opinions of business owners based on our survey. Further analysis into direct economic indicators can be carried out as part of future research. An important finding of our research is that a majority of businesses support the development of more strategies for control of CMBS. In addition, more businesses with high volume of crapemyrtle-related business considered the benefits of CMBS-control to be higher than its cost, as compared to other businesses. These findings usher in optimism for researchers working on CMBS control, and it would motivate more projects researching control strategies. CMBS has serious implications on crapemyrtle production directly, and indirectly affects the whole landscape plant industry. It is therefore important to create effective communication and information material regarding CMBS and its control, tailored to different business types - growers, wholesalers, retailers, and landscapers. Our work provides insights into the diverse impact that CMBS has on different stakeholders of the horticulture industry. Therefore, our research can be used to design communication materials specifically customized for different stakeholders of the horticulture industry. Additionally, this research can be used for a wider study into the control of CMBS, since it provides insights into the extent of impact this issue has had on different businesses. Furthermore, this research design can be used to analyze the impact of other pests that have been an issue for the horticulture industry, and the field of agriculture.

**Author Contributions:** Conceptualization, Yu Yvette Zhang and Mengmeng Gu; methodology, Yu Yvette Zhang and Pulkit Marwah; software, Yu Yvette Zhang and Pulkit Marwah; validation, Yu Yvette Zhang and Pulkit Marwah; formal analysis, Yu Yvette Zhang and Pulkit Marwah; investigation, Yu Yvette Zhang and Pulkit Marwah; resources, Yu Yvette Zhang and Mengmeng Gu; data curation, Yu Yvette Zhang and Pulkit Marwah; writing—original draft preparation, Pulkit Marwah; writing—review and editing, Yu Yvette Zhang, Mengmeng Gu, and Pulkit Marwah; visualization, Pulkit Marwah; supervision, Yu Yvette Zhang and Mengmeng Gu; project administration, Yu Yvette Zhang and Mengmeng Gu; funding acquisition, Yu Yvette Zhang and Mengmeng Gu. All authors have read and agreed to the published version of the manuscript.

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