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Spray Applications to Citrus: Survey of Current Practices in the Indian River Area[1]

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Introduction

Foliar sprays are used to control many important pests in the Indian River citrus growing region. While fruit grown for processing may only require one or two sprays each year, fresh market citrus typically receives additional sprays to reduce fruit blemishes. Grapefruit represent 59% of fresh citrus shipped from this region (Florida Dept. of Ag. and Consumer Services, 2000) and these fruit are especially susceptible to several diseases that affect rind appearance. These diseases typically result in a substantial proportion of fruit (15%-20%) being rejected for packing as fresh fruit (Miller and Burns, 1992), with less than 50% of annual production suitable for fresh sales in the current market (Florida Agricultural Statistics Service, 2000).

Aerial application, using fixed-wing aircraft or helicopter-mounted sprayers, is used for some sprays when good coverage is less important (sulfur applications for mites or nutritional sprays) or for occasional sprays when wet water furrows prevent use of ground equipment. However, almost all foliar applications to commercial grapefruit are made using air-assisted sprayers pulled through the groves by tractors. Therefore, current practices using tractor-drawn sprayers are the focus of this report.

Several factors encourage re-assessment of spray application practices. Oversupply of grapefruit permits buyers to demand unblemished fruit in the fresh pack, making spray effectiveness crucial for premium markets, while low overall prices encourage scrutiny of all production costs. In addition, concern about surface water contamination with some spray materials has focused attention on off-target deposition. This survey of current spray practices was conducted as a first step in identifying opportunities for improving economic efficiency and reducing potential environmental impact in the Indian River Citrus Region.

Survey Methods

Forty growers and spray-contractors, were interviewed from March through May 2001using a standard survey format. Because spray-contractors service many individual groves, the survey actually represents practices for a total of 191 individual growers. The data were collected for commercial groves in Indian River, St. Lucie, Martin, and Palm Beach counties, making up more than 90% of the

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grove area in the legally defined Indian River Citrus Production Region (Florida Agricultural Statistics Service, 2000). According to the State of Florida's figures there are 214,028 bearing citrus acres in these four counties and 80,983 bearing grapefruit acres (Florida Agricultural Statistics Service, 2000). The data collected represent production practices on 128,936 acres or 60% of the total citrus acreage and 59,084 acres of grapefruit or 73% of the total bearing grapefruit acreage in these counties and 71% of all Indian River grapefruit acreage (Florida Agricultural Statistics Service, 2001).

The survey included a broad array of questions relating to foliar spray practice components as well as information identifying area and types of citrus farmed by the respondents. Most questions focused on spraying of grapefruit acreage since these fruit are grown primarily for the fresh market and receive more sprays than oranges which are produced primarily for juice. Grapefruit trees also tend to be larger than other Indian River citrus trees, and good fruit coverage is more difficult since a higher proportion of grapefruit are located inside the tree canopy compared to sweet oranges. Questions asked included: acres in citrus; number and type of spray machines; typical nozzle number and sizes; ground speed and pressure used for sprayers; gallons per acre used on various fresh grapefruit sprays; practices for spraying row ends; weather conditions necessary to alter or postpone sprays; approaches used for tailoring sprays to specific blocks; and use of tree sensor technology. The responses were examined for natural clustering of data and categorized into groups, therefore, in this study very low-volume spraying was defined as application at 25-35 gallons per acre (gpa); low-volume as100-170 gpa; mid-volume as 200-380 gpa; and high-volume as 450-750 gpa.

These interviews were conducted in part to aid the implementation of pesticide best management practices (BMPs) for the Indian River citrus region, so additional issues were discussed relating to the survey questions, and growers often chose to explain the rationale for their practices. In these discussions, additional information was collected that suggested important trends but lacked the broad representation obtained for survey questions. Thirty seven of the original 40 respondents provided further information about number of sprays containing copper, amount of copper used per acre, tree size and age, and use of tower sprayers. This information is also reported in the analysis.

Types of Spray Equipment Used

Description of Sprayers

Three main types of sprayers are used in commercial Florida citrus production. Two types of airblast sprayer are standard for mid- and high-volume applications: the engine-driven and the power-take-off (PTO) airblast sprayers. These are essentially identical in function but differ in power source. Considerations in selecting between engine-driven and PTO sprayers include: 1) perceived need for higher air volume and velocity produced by engine-driven sprayers to spray large trees; 2) preference for a sprayer with air oscillation, found only in engine-driven units; and 3) lower costs for purchase, operation, and maintenance of PTO machines. The third type of sprayer has low-volume output and is represented in this survey exclusively by Curtec machines. The Curtec is also an air-assist sprayer but differs from the airblast machines in several important ways. Curtecs produce a much narrower range of smaller droplets (volume median diameter or VMD of ~120 um) than standard airblast sprayers (droplet size range of 5-600 um). The air delivery system is also different in that the air is directed at the canopy by three or four stacked cross-flow fans instead of radiating outward from one axial-flow fan. The fans and accompanying rotary atomizers are arrayed on booms ranging from 15.5 to 16.8 feet in height in the Curtec sprayer. While airblast tower-sprayers are available, only two respondents use such equipment.

Sprayer Usage

Engine-driven and PTO airblast sprayers were reported with equal frequency and accounted for 89% of spray machines, with very low-volume (Curtec) machines making up the remainder. Forty percent of respondents had more than one type of sprayer, while the remaining 60% had a single type of sprayer. Twenty-five percent of respondents used both the Curtec and one or more of the airblast sprayer types. Frequently, growers with more than one

sprayer type used specific sprayers for different types of sprays or for different varieties, based on importance of greater coverage or reduced fill-up time or lack of confidence in a sprayer type to be effective on a certain variety. In addition, the depth and condition of the water furrows may be a factor in choosing a specific sprayer type since weight, center of gravity, and tire flotation can all affect the ability to enter, exit, and drive through wet and/or deep furrows.

Growers with both Curtec and airblast sprayers used each type of machine for different sprays. Four out of the ten who use both types use the Curtec sprayer for most of their fresh grapefruit sprays. It should be noted that two of these growers own packing houses, are keenly aware of fruit blemish concerns, and are satisfied with results from low-volume applications. The other six growers with both Curtec and airblast machines largely reserve the Curtec sprayers for juice oranges since they have experienced significant burn or reduced pack-out when low-volume machines were used for copper applications on fresh fruit. However, these growers report use of Curtec machines for fresh fruit sprays where good coverage is not needed or spray burn is not likely. Growers who confidently use Curtec machines for fresh fruit see lower application cost per acre as a major advantage. Their responses indicate a higher tolerance for experimenting to overcome problems and admitted to some “disasters,” but made adjustments and found satisfactory solutions. Interestingly, one grower who has both sprayer types praised the cost efficiency of using the Curtec machine but felt that the use of airblast sprayers at 100 gpa (still relatively low-volume) gave good coverage with less spray burn.

There are some difficulties in interpreting these responses, since grower perception of burn severity can be highly subjective, with individuals varying widely in both their interpretation of likely economic consequences and tolerance of risk. In addition, the extent of burn is likely to be exaggerated when viewed in the grove, since most burn symptoms occur on exterior fruit exposed to both high levels of spray materials and sunlight. Comparing percentage of fruit accepted for fresh sales (pack–out) can also be misleading, since growers seldom compare different spray programs in otherwise identical groves in the same year, and many things can effect pack-out that are independent of spray practices. For example, fruit size, shape and texture can affect pack-out, and tolerance for all imperfections can vary according to individual market demands and fruit availability.

Spray Volumes Used

Overview

Growers were asked to specify the gallons per acre used in three general spray periods focusing on fungal pathogens for fresh grapefruit: dormant, post bloom and summer oil. These periods were chosen because they provide the basic framework for the fresh grapefruit spray schedule. Additional sprays for mites, insects, and nutritional purposes may also be applied as need is indicated by scouting reports, and may even be applied by aircraft or with a lower volume than used for the principal fungicidal sprays. The first fungicide spray in most grapefruit blocks is primarily directed toward citrus scab and may be omitted in blocks with little evidence of this disease (Timmer, 2001b). This spray is applied around two-thirds petal fall. Some growers begin their copper sprays at this time in order to cover the few small fruit that are already exposed to melanose. Most fresh grapefruit growers use two to five post bloom sprays to control melanose from petal fall to early July when the fruit becomes less susceptible (Timmer, 2001a). Often the last melanose spray includes the first greasy spot spray, since one to two sprays of copper with oil are typically applied to control greasy spot in the summer. Copper fungicides have been the mainstay for all of these sprays, supplemented by petroleum oils in the summer. Since copper acts as a protectant it must be applied prior to the infection period and it must be distributed uniformly throughout the canopy on both leaves and fruit. Hence, the concern for all fresh grapefruit growers through spring and summer is to use the machine, spray volume, and conditions that provide the best coverage.

Selection of spray volume involves a balance of several factors. For any spray equipment, more acreage can be covered per day by reducing spray

volume rate and thus increasing the proportion of time spraying vs. filling the sprayer. However, efficacy of materials requires adequate volume for coverage of fruit and foliage in the actual field conditions during the spray, and is strongly influenced by canopy architecture, environmental conditions, sprayer design, and sprayer set-up. As recently as 1975, a standard spray application for Florida citrus was 2000 gallons per acre for large trees. All respondents were well below this value. Growers interviewed varied widely in the spray volumes used, with their selections based on their individual equipment, tree size, experience, and tolerance for risk. Interestingly, surveys indicated that almost half of the acreage does not receive a uniform spray volume throughout the year.

Percentage of Acreage at Different Spray Volumes

Spray volume use for grapefruit production was reported (Table 1) with less than 8% of acreage sprayed at 25-35 gpa for all sprays; 4% sprayed at 100-170 gpa for all sprays; 15% sprayed at 200-380 gpa for all sprays 28% sprayed at 450-750 gpa for all sprays; while 44% of grapefruit acreage is sprayed with different volumes as the season progresses. This last category can be further broken down into three sub-categories: 34% of grapefruit acreage is sprayed at 200-380 gpa for dormant and/or post bloom but higher for oil; 4% of grapefruit acreage is sprayed at 100-170 gpa for dormant and/or post bloom but higher for oil; and 6% of grapefruit acreage is sprayed at 25-35 gpa for dormant and/or post bloom but higher for oil. Mid-volume sprays (200-380 gpa) are used by most of the contract sprayers interviewed, resulting in utilization by a large number of growers with smaller acreage per operation.

Growers who vary spray volume per acre attempt to balance spray volume with adequate coverage to control the principal pests in each spray period. Many growers/applicators indicated that full coverage is less critical on the first spray, directed mainly at scab, and therefore lower spray volumes are often used. The second set(s) of sprays, for melanose control, utilize higher volume since good coverage of interior fruit is considered important for this disease. Finally, many growers reported even higher volumes for summer oil sprays. Some growers who used Curtec sprayers for other sprays shifted to airblast sprayers for summer oil applications, which are directed at mite and scale control in addition to greasy spot. Since petroleum oil controls these arthropod pests by functioning as a suffocant, higher volume applications are considered necessary for thorough coverage. Details are listed in Table 2.

Many growers using mid- to high-volume applications have tried lower gallonage but reported poor coverage or lower pack-out and remain skeptical of spray volume reduction. Since controlled comparisons of practices are rare in the commercial citrus industry, some of these experiences may have reflected problems unrelated to spray volume, such as differences in environmental conditions, pest pressure, or market demands. Interestingly, one third of the operations routinely using low-volume for their scab and melanose sprays also pack the fruit that they produce. It is possible that disconnection between industry components may hamper shifts into less proven technology. One division manager of a large company is cautiously reducing his spray volume over a period of several years on part of his acreage, and is closely monitoring any complaints that might come from the packing house.

Acreage Per Sprayer as Influenced by Typical Spray Volume

One rationale for use of lower spray volumes is that fewer spray machines may be needed to cover similar acreage. The ratio of spray machines to grapefruit acreage was compared across spray volume categories for the post bloom sprays, since this is the period when sprayer use is most intensive. Several atypical respondants were excluded, such as owners of small acreage with a single sprayer. The breakdown by volume categories for post bloom sprays is indicated in Table 3.

Examination of acres per sprayer suggests that the greatest difference is between users of Curtec sprayers and airblast units. Overall, operations using engine and PTO-driven airblast sprayers for post-bloom sprays averaged one sprayer for every 244 acres of grapefruit, while those who used Curtec sprayers averaged one machine for every

435 acres. In the most extreme case, one grower replaced 5 airblast sprayers with a single Curtec machine for post bloom sprays. Driven by these efficiencies in application, the trend is clearly toward lower spray volumes, with several growers expressing frustration at not being successful in their attempts to move from mid- to low-volume.

Copper Usage Per Acre as Influenced by Typical Spray Volume

There was tremendous variability in number of copper sprays applied post bloom (2-5) with some mid- and high-volume users spraying more often than some of those using lower volume. Growers spraying at high-volume (450-750 gpa) used an acreage-weighted average of 3.5 copper sprays per year while growers spraying at very low- and low-volume (25-170 gpa) used an average of 5 sprays, with intermediate number of applications for those spraying at mid-volume.

Informal discussions during the survey interviews indicated a strong tendency for less total copper application in organizations that used low-volume sprays. Thirty-seven growers (representing 96% of surveyed acreage) provided additional information on copper use. All values were expressed as pounds of Cu per acre, to avoid confusion over different levels of active ingredient (Table 3). Two growers severely limited spray application for economic reasons, using 2-3 pounds total copper per acre per year and these atypical values were excluded from the following calculations. On an acreage-weighted basis, the very-low-volume spray growers averaged 8.1 lbs. of copper per acre per year with a range of 5.8 lbs-10.6 lbs and low-volume spray growers averaged 9.9 lbs. of copper per acre per year with a range of 9.4 lbs-12.0 lbs ; the mid-volume spray growers averaged 9.3 lbs. of copper with a range of 5.5 lbs-16.0 lbs; and the high-volume sprayers averaged 13.3 lbs with a range of 7.5lbs-16.7lbs.

Overall the average copper utilization by growers spraying at very low- through mid-volume was 30-34% less than by high-volume spray growers. A regression of gallons per acre for postbloom sprays vs. pounds copper per acre was significant and positive but the correlation was only moderate (r=0.41). Interestingly, the weighted average for all acreage in the survey was 10.1 lbs per grove acre, which is centered within the guidelines recommended for control of fungal diseases on Florida grapefruit (8-12 lb Cu / acre/ year) (Timmer, 2001a).

Growers using very low-volume sprayers indicated that they reduced copper concentrations to control spray burn. More frequent sprays are then considered necessary to maintain coverage following weathering and to compensate for deposition variability associated with low spray volume. There may be several additional benefits from this approach. Melanose control depends on sufficient copper coverage of fruit prior to infection-triggering rain events, and lower rates with more frequent applications should reduce the proportion of time in which fruit are unprotected. It is also argued that lower-volume spray applications should permit equal efficacy with lower chemical rates because of better distribution from small droplet sizes and reduced run-off from foliage.

Chemical Cost per Acre

Growers were asked to provide their chemical cost on a per acre basis for the previous years fresh grapefruit crop (Table 3). Some growers did not share cost data and others provided an estimate. Responses ranged from $65 to $350 per acre and averaged $248 on an acreage-weighted basis. Four growers reported chemical costs between $65 and $100 per acre and were excluded from further analyses as being atypical. Growers spraying at very low-volume reported an acreage weighted mean of $200 / acre: vs. $294 for low-volume ; $258 for mid-volume; and $293 at high-volume. The broad cost ranges reported probably reflect differences in materials used such as more expensive newer materials vs. sprays of copper, oil, and sulfur only. A published estimate for spray material costs for 1998-99 Indian River grapefruit was $196.90 per acre, based on 5 typical sprays (Muraro et al., 1999). In this survey, the relationship between chemical cost per acre and spray volume per acre in the post bloom period was positive and significant (p=0.04) but overall correlation was moderate (r=0.42). Lower costs reported by Curtec users appears to largely

explain this correlation, and appears to be consistent with a philosophy of tolerating some risks to reduce production costs.

Correlation Between Spray-Volume and Tree Size

Comments during the initial survey revealed many growers using high-volume applications on tall trees (18-22 ft.), while growers using lower spray volume were often controlling tree height by topping at 12-14 ft. More information on tree height was collected from survey participants and indicated some relationship between grower management of tree size and spray volume, but considerable variability. All growers that reported spraying trees taller than 20 feet sprayed in the mid or high volume range. However there were low-volume sprays applied to trees up to twenty feet and some growers sprayed at a high-volume on trees less than twenty feet. One respondent illustrated the variability in grower spray practice quite well: he sprayed his own trees up to twenty feet tall at low-volume, but as a custom applicator, sprayed much shorter trees at high-volume, with both sets of trees receiving similar amounts of total copper. Several high-volume spray users indicated that they determined appropriate spray volumes by visual assessment of penetration and coverage of grove blocks while machines were spraying.

Ground Speed, Nozzles, Pressure

Spray volume is determined by ground speed, nozzle (disc and core sizes), number of nozzles and pump pressure. Fifty percent of interviewees changed spray volume by adjusting both nozzle output (size and number) and ground speed, 25% percent adjusted only nozzles, 15% adjusted only speed, while only 5% adjusted pressure, speed, and nozzling. Of the 36 respondents who reported sprayer pressure values, 92% used pressures between 120-200 psi. Only one grower used pressure greater than 200 psi and two utilized 100 psi. Growers using Curtec machines use the integrated computer to adjust volume or shut off groups of nozzles.

The range of ground speeds used for spraying fresh grapefruit was quite limited. All mid- and high-volume fungicidal applications to fresh grapefruit were reported at 1-2 mph, except one small acreage grower who uses 0.75 mph. With the Curtec sprayers all applications were made at 3-3.5 mph. For nutritional sprays and sulfur applications, where good coverage is considered less important, speeds were often greater than 2 mph even with high-volume sprayers.

The way growers nozzle their airblast sprayers was varied but within a limited range (nozzles are not adjusted on Curtec sprayers). Differences within a spray-volume class were as great as differences between low-, middle-, and high-volume spray classes (Table 4). Number of nozzles and disc diameter can vary 2-3-fold within a volume class. Configuration of nozzles depends on the growers priority. For example, some growers prefer a “fog” to achieve their ideal spray, requiring small diameter discs. Other growers prefer larger nozzles for better coverage of tall trees. Plugging problems with smaller nozzles constrains minimum nozzle size, with few growers using discs smaller than a TeeJet #4. Thirty-two percent of growers using airblast sprayers maintain uniform disc and core sizes across the entire sprayer manifold for each specified volume. However, most growers vary nozzle output across the manifolds on their machines, using from two to four disc sizes and from one to three core sizes for each sprayer set-up. All growers who mix nozzles use greatest output from the upper manifold positions, because they feel that larger droplets and more spray volume directed at tree tops improves coverage on tall trees, and several indicated that larger droplets directed at the canopy tops reduce drift. None of the growers interviewed followed the older recommendation of directing two-thirds of the spray at the top half of the tree. Most growers said they made an effort to fit the nozzle constellation to the foliage distribution in the tree. This included routinely shutting off nozzles for shorter trees, and since Indian River citrus groves are often planted with two rows per bed, adjusting nozzle output distribution differently for spraying bed-tops vs. furrows. Some larger operations designated different sprayers for the bed tops and the water furrows to minimize nozzle adjustment needs. Growers reported adjusting sprayers differently between bed-tops and water furrows on 85% of acreage.

Since there were so many combinations of nozzle number, disc size, core selection, ground speed, and pump pressures used by the growers, it was not possible to discern much of a relationship with spray-volume categories. There was a 25% decrease in the number of nozzles from high- to mid- and low-volumes and there was a drop in the range of disc and core sizes between mid- and low-volume sprays.

Sprayer Calibration

Like other practices assessed in this survey, calibration methods varied widely. There were three primary approaches used. For Curtec machines, respondents indicated that calibration was achieved simply by entering designated values into the associated computer (14% of acreage). Otherwise, growers were evenly divided between measuring ground speed and adjusting delivered gallons per minute to achieve desired gallons per acre (44% of acreage) or assessing the time required to empty the sprayer over a known acreage (42% of acreage). Concerning frequency of calibration: respondents representing 33% of acreage reported daily assessment and adjustment of calibration as needed; on 27% of acreage calibration was reported to be adjusted for every block (this includes all Curtec users); and on 38% of acreage it was reported that a more formal calibration was conducted 2-5 times a year. The remaining 2% of acreage reported calibration from twice a week to every two weeks. Many growers record tanks applied per block and adjust calibration when either too few or too many tanks are sprayed. Calibration was not actually assessed in this survey, however, a study conducted on sprayer calibration in the New York apple industry identified considerable potential savings from improved calibration.

Spraying Row Ends and Shutting-Off On Dead or Missing Trees

Methods of spraying trees at row ends is important in Indian River groves, because groves are surrounded by ditches, with exposed surface water often twenty feet or less from row ends. Most growers want to get good tree coverage using practices that minimize pollution with spray materials. The first option is to spray to the end of the row and leave the inside nozzles on as the turn is made (8.2% of the sample acreage used this method). On 29.6% of the reported acreage, sprays are continued until the end of the row and both sprayer sides are shut off on the turn. On 55% of reported acreage, growers sprayed to the trunk on the last tree and then single side “wiped” the ends, by spraying perpendicular to the rows along the row ends. On 7% of the acreage, growers varied their practices based on turning radius and distance to ditches in each block. A substantial acreage (20%) received spray to the end of the row and then a follow-up wipe perpendicular to the rows. The practice of spraying to the trunk and wiping row ends has been promoted by University of Florida extension for about two years and the high level of adoption indicates the rapidity of BMP adoption.

Indian River citrus trees historically have displayed loss rates of 3.5% per year (Muraro et. al., 1999), but loss rates have recently accelerated because of citrus tristeza virus (Brown and Spreen, 2000), diaprepes root weevil, and poor matching of rootstock to soil type (Stover and Castle, 2001). As a result, missing and dead trees are very common in Indian River groves. Shutting off sprayers on dead and missing trees was the routine practice for 82.8% of the acreage represented in this survey. However, on 37.3% of acreage this practice was only engaged for two or more adjacent trees, because the growers involved have either experienced poor coverage on the next healthy tree when single-tree shut-off has been used, or expressed a fear of that possibility.

Use of Precision Spray Technology

Precision technology, which results in spray application only where there is tree canopy present, could provide more efficient spraying of groves with missing or irregular trees. This approach uses sensor-activated control systems so that no spray is applied where trees are missing or not yet grown together, and only lower nozzles emit spray where there are shorter trees. From the survey, 14.7% of the acreage was sprayed using this technology, and practitioners felt that resultant savings easily compensated for the additional maintenance problems. Growers representing 21% of the survey

acreage have tried these systems but experienced too many problems and so abandoned use of this equipment, some as long ago as ten years. However, even this latter group expressed an interest in adopting precision spray technology if it becomes more reliable. Growers with small acreage indicated that the technology is too expensive for the amount of acreage they spray so the cost would not be made up by any savings.

Night Application

Wind speeds are typically much lower at night in the Indian River region and night spraying has been proposed as a way of reducing spray drift. Fifteen percent of the grapefruit acreage represented in our survey was sprayed at night. This acreage was being sprayed at 250 gpa or less, and all practitioners felt that the use of smaller droplet size made avoiding high wind more important for both drift reduction and good spray coverage. However, not all growers using low spray volume sprayed at night, and some growers using very low-volume sprays (25-35 gpa) sprayed during the day. Several growers reported that they tried spraying at night, but considered the potential for accidents too great or felt that additional expenses were unwarranted for night-time shift management personnel. The growers most committed to night sprayers were those with large acreage who employed dedicated night spray crews, small growers with only one spray machine, and some of the contract sprayers. Of surveyed acreage, 7.6% was sprayed at night using sensor control technology, and almost all of these acres were sprayed with Curtec machines.

Weather Conditions that Interfere with Spraying

Growers reported no defined protocol for stopping spraying when weather becomes unfavorable. They indicated that they would stop spraying when rain threatened, or when wind visibly prevented good deposition. Some growers noted that they sometimes moved spray operations to mature groves with larger trees in high wind conditions, because the high canopy density in such plantings greatly reduces wind speed and appears to permit good spray coverage. Measurement of wind speed as a component of spray management was not reported by any interview participants.

Conclusions

Diversity within the industry was reported for all aspects of foliar spray application. This diversity is a result of numerous factors, including characteristics of different sprayers and perceived differences in spray requirements for larger trees. However, the most important issues may be the ongoing evolution in spray technology and the ways in which the citrus industry has responded to these changes. Standard spraying was at very high volumes twenty-five years ago and many current growers developed their conceptions of fruit production during that period. Although financial concerns encourage experimentation for greater efficiency, and new technology has been developed, people vary in their rapidity and degree of acceptance of new technologies. Much of this may be due to individual risk tolerance, but it is also apparent that many growers have had negative experiences when using newer practices like lower spray volumes and precision spraying.

Research and extension literature on citrus spraying rightly focuses on the complexity of predicting effects of spray practices on distribution of materials within trees, even in controlled experiments. Consequently, recommendations from authorities often provide limited guidance to growers. This forces the industry to explore spraying as an art, in which changes are attempted on an ad-hoc basis and either rejected or continued based on individual experience or reports from peers. The tremendous range of grower spray practices appears to reflect the current status of this ongoing, largely independent, experimentation by individual growers.

With this assessment of current spray practices, we can more clearly see the extension and research efforts needed to help growers efficiently and effectively apply foliar materials to citrus trees. It appears likely that many failures reported when growers shifted from established spray practices resulted from use when environmental conditions were adverse to lower volume sprays (Stover et al, 2001a). While traditional high-volume spraying may provide acceptable results across wide environmental conditions and grove characteristics, there are considerable disadvantages to this approach. No

single spray practice will be ideal for all situations and extension recommendations must do a better job of clarifying the limitations and advantages for each spray option. In addition, this survey provides valuable information for the current effort to formulate and implement surface water protection BMPs for the Indian River area.

In subsequent reports, the information collected in this survey is assessed within the context of current literature on the spray application process (Stover et al., 2002a), and is used to identify opportunities for greater efficiency and efficacy, improved efficiency / efficacy balance, and reduced potential for environmental contamination (Stover et al., 2002b).

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Table 1. Spray volumes reported for Indian River grapefruit production in 2001 survey. This represented 76% of all grapefruit acreage in Indian River, St. Lucie, Martin, and Palm Beach counties, comprising a majority of the grove area in the legally defined Indian River Citrus Production Region.

Spray volume reported (gpa)	Percent of grapefruit acreage	Percent of growers
Very low (25-35) for all sprays	7.6	1.5
Low (100-170) for all sprays	4.2	1.5
Medium (200-380) for all sprays	15.3	56
High (450-750) for all sprays	28.2	13
Varying among spray periods	44.5	28

Table 2. Spray volumes for individual spray periods reported for Indian River grapefruit production in 2001 survey representing 76% of all grapefruit in Indian River, St. Lucie, Martin, and Palm Beach counties.

	Percent of grove acreage receiving reported spray volume			
	Very low spray volume 25-35 gpa	Low spray volume 100-170 gpa	Medium spray volume 200-380 gpa	High spray volume 450-750 gpa
Spray period				
Dormant (prebloom to 2/3 petal fall)	13.9	27.4	30.0	28.0
Postbloom	13.8	8.4	50.7	28.0
Summer oil	7.6	4.2	21.0	66.5

Table 3. Spray machines per acre, pounds metallic copper, and total foliar pesticide cost (excludes herbicides) per acre per year reported for Indian River grapefruit production in 2001 survey.

	Spray machines per acre		Pounds fungicidal copper applied per acre per year[z]		Foliar pesticide costs per acre per year	
	Acreage-weighted average	Range	Acreage-weighted average	Range	Acreage-weighted average	Range
Overall	259	85-1078	10.1	5.5-16.7	$248	$150-350
Very low-volume 25-35 gpa	435	333-1078	8.1	5.8-10.6	$200	$150-280
Low-volume 100-170 gpa	201	125-620	9.9	9.4-12.0	$294	$250-300
Mid-volume 200-380 gpa	236	85-528	9.3	5.5-16.0	$258	$180-350
High-volume 450-750 gpa	304	100-382	13.3	7.5-16.7	$293	$230-350
P value for regressions[y]	0.06		0.01		0.03	

Table 4. Nozzle configurations reported for airblast sprayers in the 2001 survey of Indian River grapefruit producers.

	Number of nozzles per side	Range in nozzles per side	Range in disc sizes (TeeJet #)	Range in nozzle core hole number
Overall	14	8-27	3-10	2-5
Low-volume	13	8-20	3-5	2-3
Mid-volume	13	8-27	3-10	2-5
High-volume	17	10-24	3-9	2-4