Sustainable Plant Protection Within Sustainable Fruit Growing - an American Experience

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ABSTRACT

Sustainability means many things to many people; it is an attempt to provide the best outcomes for man and the natural environment, both now and in the future. In sustainable fruit growing, the thee E's of sustainability, **E**nvironmentally sound, **E**conomically viable and socially **E**quitable must be combined with the three E's of crop protection, i.e. **E**ffectiveness, **E**fficiency and the **E**nvironment.

This paper details aspects of pesticide management within sustainable fruit production within the USA. The use of a workbook as an educational tool is discussed along with other methods of extension support such as bulletins and fact sheets. The introduction of a training course to ensure operators are aware of good spraying techniques is also highlighted. Application technology research at Cornell University is also presented, outlining methods such as reducing and directing airflow, and nozzle orientation to improve pesticide deposition and reduce drift.

Keywords: Crop protection, pesticide application, sustainable practices, air flow, adaption to canopy, USA

1. DEFINITION

Sustainability means many things to many people; it is an attempt to provide the best outcomes for man and the natural environment, both now and in the future. It is not a new word. In 1712, the German forester and scientist Hans Carl von Gilinscee, in his book *Sylvicultura Oeconomica*, discussed the concept of planting trees and used the words "sustained yield forestry". In 1989, the American Agronomy Society adopted this definition "A sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable and enhances the quality of life for farmers and society as a whole". The Lodi-Woodbridge Winegrape Commission (LWWC) in California, as well as much of the California wine industry uses the three E's of sustainability, **E**nvironmentally sound, **E**conomically viable and socially **E**quitable. In most cases, sustainable practices are used to produce quality grapes and wine based upon a mix of good viticulture and good business practices within a caring human and environmental framework.

Dr Norman Morgan of Long Ashton Research Station, University of Bristol, England, often, long ago, stressed the need to consider the three E's of crop protection, i.e **E**ffectiveness, **E**fficiency and the **E**nvironment. The challenge for the grower was to accommodate the three E's of crop protection and the three E's of sustainability within a market place of strong competition, a questioning and discerning public and in some areas, falling grape prices.

2. BACKGROUND

Over the past several years grape growers in the Western States of the USA, notably Oregon, California and Washington have adopted sustainable viticulture programmes. A number of reasons led to this development, mainly the need to pay attention to inputs which impact on soil and water, the growing spread of urbanization (in particular "educated" neighbours) and the development of audits or accountability within the general umbrella of produce marketing. "Eco-labeling" has become popular and, in Oregon, for example, the LIVE (Low Input Viticulture and Enology) program, Live (2007), allows producers to use a logo in their publicity and marketing. The Lodi-Woodbridge Winegrape Commission (LWWC) was established in 1991 in order to promote the area as a premium wine region, fund local research projects and implement environmentally sound farming practices (Ohmart 2003). The following year the LWWC sustainable viticulture program evolved based upon an IPM program. In 1995, a Biologically Integrated Farming System (BIFS 2007) was established and 40 growers representing 60 vineyards (948 hectares) joined the program. In the BIFS program data such as pest monitoring, pesticide use, and cultural activities such as pruning and mowing are detailed,. This is an on-going program now with 11 years of data. Following on from the success of the Lodi-Woodbridge experience, a Code of Sustainable Winegrowing in California, - was developed in 2001 by the Wine Institute and the California Association of Winegrape Growers (CAWG, 2007) to establish statewide guidelines for sustainable practices amongst winegrape growers under the umbrella of the California Sustainable Winegrowing Alliance.

This early work on the west coast resulted in the development of sustainability workbooks. Participants self-assess their vineyards and wineries and voluntarily contribute data to measure the adoption of sustainability. The workbook helps the grower identify and document practices which are sustainable, those that are not and those that can be improved upon. The workbook increases awareness of specific activities and aids in creating an action plan and timetable. The sustainability workbook is an excellent vehicle for educators to promote best practices and covers many sections that allow growers to assess areas such as:

Soil management –monitoring, nutrient management, soil quality and pollution prevention.

Pest and pesticide management – insect, disease and weed monitoring and management practices along with effectiveness and safety of their application practices.

Viticultural practices –vine balance through canopy management and crop development practices.

Water management –water management strategies, off-site water movement and irrigation practices.

Besides providing self-assessment for growers the workbook also contains assessments for vintners. Vintners can assess: Wine quality, energy efficiency, winery water conservation and quality, solid waste reduction and management, material handling and energy efficiency.

Each section contains specific questions on a given practice and then offers 3-4 alternatives; the grower chooses one answer which best fits his/her practice.

In New York State, in 2005, a workbook was created based upon the experiences gained from the west coast along with input from east coast industry leaders and academicians. Two standard reference publications frequently used by New York growers, the Agricultural Environmental Management Program and the New York and Pennsylvania Pest Management Guidelines for Grapes, were used as the basis of the workbook. The workbook will be used on a voluntary basis by growers throughout the state.

Growing world trade requires uniform technical regulations, and international standards help ensure a high standard of quality and uniformity. In Europe, as in many other countries, there is growing concern amongst the general public regarding pesticides in the environment and on food in particular. The understanding of, and skills associated with the correct application of pesticides, is being met via education and operator training legislation. There is concern however, that whilst training and certification may ensure the operator is competent, the application machine may or may not be operating to an acceptable standard.

Many New York apple growers export their apples to Europe and 2002 saw the introduction of EurepGAP standards for exporters (Internet reference). Growers responded well and their premises and practices were duly inspected. Fruit growers for the domestic market wished to become suppliers of high quality fruit, providing consistent fruit quality within an environmental and food safety framework. Under the EurepGAP checklist, growers are recommended to be involved in an independent calibration–certification scheme.

Sprayer testing offers growers an independent way to assess the reliability of their airblast sprayers and ensure pesticides are applied only to the target area. A correctly adjusted sprayer will reduce pesticide use, reduce environmental pollution and ensure maximum efficiency. It also reduces downtime during the busy season by ensuring reliability. Sprayer testing also provides evidence to customers of a commitment to keep machines in a sound, well serviced condition.

In 2006 a New York Integrated Fruit Production Protocol (IFP) for Apples was produced by academics and industry representatives, providing guidelines on the safe use of pesticides. In the IFP Protocol for New York, it states an annual inspection should include maintenance, mechanical condition and calibration. In order to aid sprayer accuracy, via a thorough mechanical check, a checklist for sprayers is included in the NewYork State Integrated Pest Management elements handbook.

3. SUSTAINABILITY IN PESTICIDE MANAGEMENT

Eliminating pesticides is unattainable for most fruit growers, an attempt to reduce reliance on pesticides is encouraged through monitoring the orchard or vineyard for insects/disease, practicing IPM, considering canopy growth for pesticide application volumes, selecting "soft" pesticides, ensuring the sprayer is well maintained and correctly setup to improve deposition and

Table 1. Example of a workbook self-assessment table – canopy sprayer design

Pesticide Application Equipment					
	1 (Best practice)	**2 (Good practice)**	**3 (Average)**	**4 (Bad practice)**	**SCORE**
What type of canopy sprayer is used?	Application equipment is used that **increases** target deposition, reduces drift, and allows for a reduction in the amount and/or rate of pesticides used. Examples: a) recycling sprayer, b) tower sprayer, c) directed deposition sprayer).	Application equipment is used that **improves** deposition and reduces drift. Examples: a) airblast sprayer with low drift nozzles such as air induction nozzles, b) modified airblast sprayer with deflectors, c) nozzle orientation adjusted to improve deposition).		The application equipment does **not** address drift (e.g. an unmodified airblast sprayer).	
The NY and PA Pest Management Guidelines, IPM (2007) provide an overview of spray drift management and nozzle types, including air induction nozzles. Air induction nozzles are well proven with herbicide applications and are recommended. Canopy application trials have been successful but further season-long trials are still needed. Top and bottom deflectors should be fitted to airblast sprayers to funnel the pesticide-laden air into the canopy. Correct nozzle orientation (to overcome the effects of the uneven airblast resulting from fan rotation) allows the spray plume to target the canopy.					

reduce drift, and ensuring the operator is well trained. Examples of worksheets used in the New York workbooks are provided in Tables 1 and 2.

These worksheets assist growers in determining how desirable their current practices are. For example, the Pesticide Management section (see Tables 1 and 2) contains worksheets on weed, disease and insect control. The grower determines which practice most closely matches their own and notes the associated score. A score of 1 indicates *best practice*, a score of 2 is *good practice*, 3 is *average* and 4 indicates *bad practice*.

Table 2. Example of a workbook self-assessment table – canopy sprayer calibration and environmental conditions

Pesticide Application Equipment					
	1 (Best practice)	**2 (Good practice)**	**3 (Average)**	**4 (Bad practice)**	**SCORE**
Is the canopy sprayer calibrated properly?	Sprayer is serviced and calibrated before the start of each season. *AND* Sprayer is recalibrated for major growth stages and/or different types of applications when amounts of air or liquid are changed and/or nozzle orientation is adjusted (e.g. spray directed at canopy vs. clusters). *AND* Calibration is repeated at least once during the growing season.	Sprayer is serviced and calibrated before the start of each season. *AND* Sprayer is recalibrated for different types of applications when amounts of air or liquid are changed or nozzle orientation is adjusted (e.g. spray directed at canopy vs. clusters).	Sprayer is serviced and calibrated before the start of each season.	Calibration is done infrequently or not at all.	
The annual NY and PA Pest Management Guidelines IPM (2007) provide an overview of sprayer calibration. This should be used in concert with recommendations from the sprayer manufacturer.					
Are environmental conditions considered before deciding to spray?	**No spraying** is done if winds are >10 mph unless using a sprayer that is designed/modified to improve deposition and reduce drift. If winds are >10mph, spraying is **only done** with a sprayer that is designed/modified to improve deposition and reduce drift.	Most of the time spraying is not done if winds are >10 mph unless using a sprayer that is designed/modified to improve deposition and reduce drift. If winds are >10 mph, **most of the time** spraying is only done with a sprayer that is designed/modified to improve deposition and reduce drift.		Spraying is done in conditions where significant drift will occur and sprayers are **not** designed to improve deposition or reduce drift.	

4. SUPPORTING SUSTAINABILITY

To support the workbook in New York, growers may call upon a number of resources. Local resources include Cornell University faculty and Cornell Cooperative Extension educators who regularly hold conferences, workshops and meetings. For example, in pesticide application, an annual pest management up-date is held in the spring and a sprayer demonstration is usually held in the summer. Applied research is often conducted in cooperating growers' orchards and vineyards and these sites provide excellent venues for demonstrating current projects. In the winter a research update is provided at the annual growers' conference. Cornell University web site, Cornell (2007) specifically covers fruit spraying. Obviously, access to the Internet gives growers a world-wide resource of information on application technology and sustainability.

4.1 New Mobile Patternators

Landers (2003) described methods used to demonstrate research results to fruit growers. A number of novel demonstration systems have been developed including safe tracers which can be clearly seen in daylight, and water sensitive strips to show penetration and deposition. A number of portable, field demonstration units have been constructed which use ribbons to demonstrate air movement, and tubes to create a standard canopy for comparing penetration and demonstrate droplet formation. The development of a portable patternator (Balsari, 2003) has dramatically improved deposition within the canopy and reduced drift. Simple adjustment of nozzle orientation, to take into account the non-symmetrical airflow due to the rotation of the fan has considerably improved spraying. To date, approximately 60 sprayers have been evaluated at numerous extension meetings.

While traditional methods of teaching are still extremely valuable, recent developments in technology provide an additional aid to teaching and learning, providing different ways of communicating, manipulating and handling information (Landers, 2003). The challenge is for researchers to cascade their valuable research information to the end-user with a degree of impact. In spring 2007, a new $1^1/_2$ day in-depth training course on better spray application techniques was introduced. The course improves grower's knowledge of spraying techniques. The current extension delivery system presents information in short, intense bursts. The grape industry, for example, is a rapidly expanding industry in New York, with many vineyards located in watershed areas. The course will help growers reduce pesticide use and improve their profitability via hands–on training. This innovative course is unique; it provides an intensive, applied, one-day course with a half-day demonstration follow-up in the early growing season. The courses are held in the grower's home regions.

Current spray practice in orchards and vineyards often use the same settings on the airblast sprayer, from the first application through to the last, irrespective of changes in canopy volume or density. Many growers may change application volume/hectare but generally few changes are made to air flow (speed, volume or direction) or forward speed. As the season progresses and the canopy fills, growers frequently drive too fast and often pay too little attention to drift and the deposition on leaves and fruit where disease or insects may occur. The objective in spray drift mitigation is to find the optimum combination of application parameters for different stages of canopy development to reduce drift while improving deposition (Landers, 2005).

Research at Cornell University has concentrated on improving pesticide deposition and reducing drift. Experiments have been conducted to ascertain the effects of airflow (speed and direction), nozzle type and nozzle orientation within the growing canopy. In some sectors, falling commodity prices over the past few years have encouraged growers to adapt their existing sprayers rather than purchase new.

The success of the MIBO mobile vertical patternator created a demand from New York fruit growers for an inexpensive patternator that could be built on the farm. In the Spring of 2006, two inexpensive patternators were constructed at Cornell University: the UPC patternator (Gil design) and the Cornell patternator (Landers design).

The UPC design, Figure 2, was created by Dr Emilio Gil, Universitat Politécnica de Catalunya (UPC), Barcelona, Spain while on sabbatical at Cornell University (Gil andBadiola, 2007). It comprises ten 152 mm PVC elbows, mounted in plastic frames attached to a 38 mm angle steel frame. Each elbow faced outwards and at the other end a plastic funnel was attached. A plastic hose connected the funnel to a box containing graduated measuring cylinders. The spray cloud entered the open end of the elbows, passed into the funnels and then ran down to the collection cylinders. A 2.7 m tall version was constructed and was very robust but quite heavy. It was decided that a taller version would be too difficult to erect due to the weight. The frame was constructed in two halves for ease of assembly.

Figure 1. Cornell University patternator

Figure 2. UPC patternator

The Cornell design, Figure 1, comprises nine 356mm x 1.2m wide fly screens connected via hooks to two 4.3m high, 100mm x 50mm wooden boards (Landers and Gil, 2006a). A small gutter was attached, at an angle, to the bottom edge of each screen. The gutter sloped to one end where a plastic hose was connected which ran down to a box containing graduated measuring cylinders. The spray cloud hit the fly screen; the air passed through while the liquid ran down the front of the screen, into the gutter and then, via the plastic hose into the collecting cylinders. The frame was constructed in two halves for ease of assembly.

A series of experiments were conducted to test the UPC and Cornell patternators to see if the new designs would be as accurate as the "standard" MIBO (Landers and Gil, 2006a). Three sprayers were tested: a Berthoud S600EX airblast sprayer, a Hardi Mercury airblast sprayer and a Turbomist with a tower. All sprayers were equipped to spray 500 litres/hectare and 3 repetitions were carried out for each trial. An experiment was conducted to measure the amount recovered by each of the patternators compared to the output of each of the sprayers. As shown in Figure 3, the Cornell patternator by far captured the most, averaging 68% of the applied spray with the three sprayers. This was followed by the UPC at 22% and the MIBO at 20%. The Cornell patternator also collected the absolute highest amount with the Berthoud sprayer when 88% was recovered.

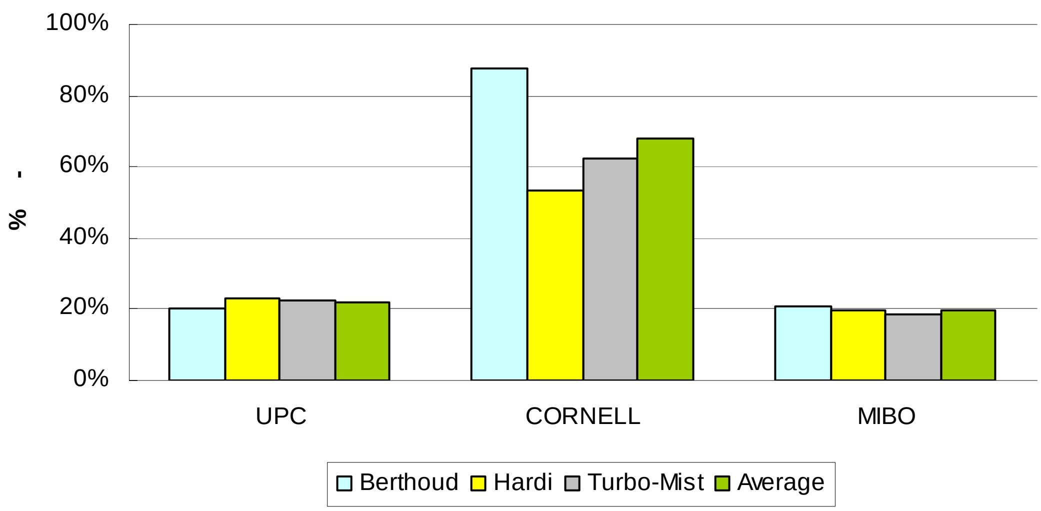

Figure 3. Percent recovery between three patternators and three sprayers

A second experiment was conducted to compare the symmetry recorded by each patternator. Good symmetry would be in the region of 90-95% of a sprayer output pattern occurring on both the left and right hand side of the sprayer. The results in Figure 4 show that the MIBO patternator gave the best indication of symmetry, with the UPC and Cornell patternators being similar in their ability to measure symmetry.

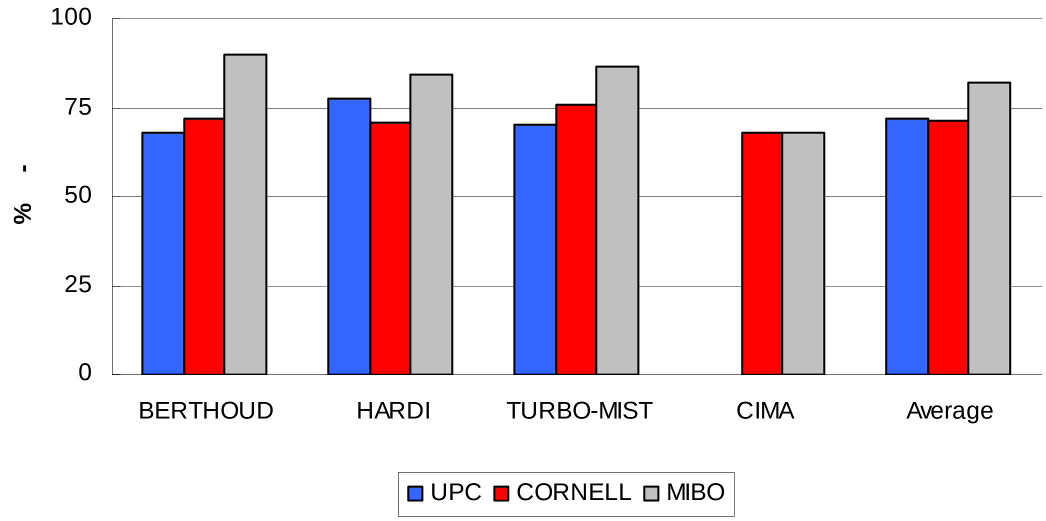

Figure 4. Symmetry of four sprayers as evaluated by 3 patternators

Experimental results show that the Cornell and UPC patternators perform very similarly to the MIBO in their ability to demonstrate where the spray plume is being deposited and the degree of symmetry being created with a range of sprayers. The Cornell patternator differs in that it has an extremely high capture efficiency, as is shown in Figure 3, resulting in less time being taken to conduct the tests. Thus, by using simple plans, growers are able to build their own economically viable patternator to aid in adjusting their sprayers for specific blocks on their farms. This will enable growers to reduce pesticide drift considerably (up to 90% in some cases) via better targeting. And it should lead to more effective pesticide application – more spray will hit the target and more effectively control insects/diseases, with possible pesticide reduction of up to 20%.

The mobile patternators have proven to be extremely useful extension tools. They vividly show growers the need to adjust the orientation of the airblast nozzles. Most growers in New York use traditional airblast sprayers which produce too much air and increase the profile of the spraying activity amongst the questioning public. Drift reduction is the key, if growers are to address crop protection within sustainable fruit production.

4.2 Airflow Deflectors

Another area of research and extension has been studies into airflow from airblast sprayers. Growers must direct the airflow into the canopy via correctly set deflectors, and attempt to alter airflow according to canopy development (Landers, 2002; Landers and Farooq, 2004). Reducing airflow via air restrictors (doughnuts) attached to the air intake, slowing down fan speed using hydraulic motor drives and simply shutting down PTO speed results in 25-35% improvement in deposition and up to 75% reduction in drift.

Directing air via deflectors or volutes has been shown to improve deposition. Modern sprayer design is good at directing air and liquid to the canopy. Unfortunately, not all growers can afford new sprayers necessitating modifications to existing sprayers. Simple deflector systems have been designed and tested over a number of seasons (Landers, 2002; Landers and Gil, 2006b). Results from a modified Kinkelder sprayer, using an air straightening deflector, showed a 25% improvement in deposition, Figure 5. Drift was greatly reduced. Water sensitive cards (Syngenta) were placed into the top, middle, bottom and centre of the dense *var. Concord* canopy. When dry, the cards were removed and a DropletScan (WRK, Cabot AR) image analysis system was used to measure the % area covered with droplets.

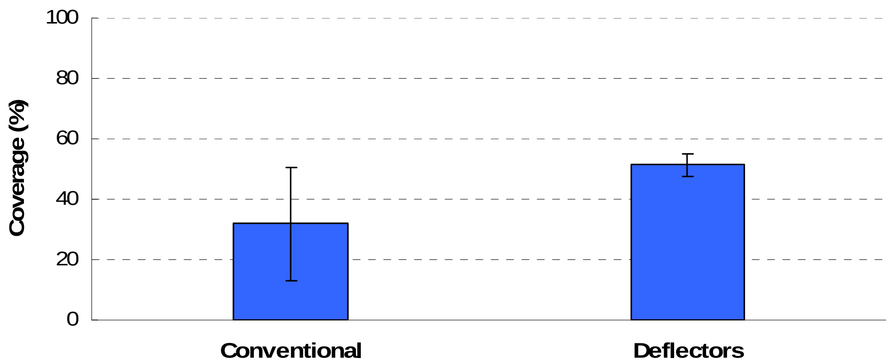

Figure 5. Comparison of % area covered (water sensitive cards) with droplets throughout the canopy between the conventional and modified (deflector) Kinkelder sprayer

5. SUCCESS

The success of a sustainability program must be measured by the number of growers "buying in" to the new program. In California, for example, the California Sustainable Winegrowing Alliance 2006 progress report, CAWG (2006), that since its inception in 2002, 1165 wineries and vineyards have been reached; 990 growers have undertaken the self-assessment representing 61,835 ha or 29% of California's 211,246 ha of grapes.

Sustainable viticulture has gained such popularity that local areas or regions have developed their own specific models. In the Central coast region of California for example, centered on Paso Robles, the Central Coast Vineyard team conducts research and extension towards sustainable practices, funded primarily via grower funds. In New York State, growers have just started to document and promote the use of production practices that reduce environmental risk while maintaining or improving economic viability.

6. CONCLUSIONS

Sustainable fruit production has developed rapidly in a very short time. Most growers are keen to conduct their businesses within a sustainable environment, taking care of their employees and ensuring they provide a good future for their families. Sustainable fruit production provides a golden opportunity for educators to support growers in attaining their goals. The ever-increasing demand for quality fruit ensures an on-going need for grower education. Research in application technology must be cascaded to the growers via interesting methods that, above all, make good business and environmental sense.

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