ABSTRACT
Strategies to reduce potential food safety risks need to start in the paddock or orchard with the horticulturist. Although Commonwealth and State food safety legislation is not directed at regulating inside farm gate activities, the market itself is demanding that fruit and vegetable growers, packers and distributors apply the Hazard Analysis Critical Control Points (HACCP) methodology within their quality management systems to prevent, eliminate or reduce the food safety risk to an acceptable level.

The identified food safety risks in horticulture include chemical (agricultural chemical residues in produce and soil, cleaning agents etc.), physical contamination (sticks, stones, glass, plant matter etc.) and microbiological (bacteria, fungi, viruses and parasites). These three food safety risks have the potential to harm humans.

HACCP has made a significant impact in the reduction of foodborne illness relating to the consumption of fresh (and processed) horticultural produce. It has also led to improvements in the consistency and quality of produce. However there is emerging concern that HACCP, particularly when applied at the grower level, is not truly addressing potential excess chemical residue contamination.

This paper explores the Codex Alimentarius Commission Guidelines for HACCP and its application in the horticultural industry, focusing on small horticultural enterprises (SHE), in ensuring maximum chemical residue limits are not exceeded.

Keywords: Quality Systems, Horticulture, Hazard Analysis Critical Control Point (HACCP), Maximum Chemical Residues Limits (MRL), Small Horticultural Enterprises (SHE)

1.0 Introduction
Australian horticulturalists are amongst the most efficient in the world. On average, each farmer produces enough food to feed over 80 people compared to ten people in 1940 (Day, Hock & MacAlpine, 1997, p. 1.17). This increase in productivity is due to many factors including the breeding of more productive plant varieties, better soil management, the introduction of sustainable agricultural practices, improved mechanisation and the development and more efficient use of farm chemicals.

Insecticides can improve the quality and quantity of horticultural produce. They can also protect crops from destructive insects and reduce the transmission of disease organisms by arthropod and vertebrate pests. Herbicides used to control weeds help to reduce plant competition for moisture, light and nutrients. Fungicides prevent or contain outbreaks of fungal diseases that cause injury to plants (Day et.al, 1997, p. 1.17).

1.1 Economic Benefits
The economic, social and environmental benefits of agricultural chemicals are many. The Food and Agriculture Organisation of the United Nations (FAO) estimates that 20 to 40% of the world's agricultural production is lost annually because of the effects of weeds, insect pests and diseases (Day et. al, 1997, p. 1.17). It is broadly accepted that if all farm chemicals were withdrawn, agricultural production would be likely to fall by around 30%. Farm chemicals directly contribute at least $3000 million a year to agricultural production in Australia.

The future of Australia's fruit and vegetable industry rests with the assurance that we grow and harvest produce that is natural, food safe and wholesome. Consumers want to be confident that minimal or no chemicals are being used. When chemicals are used, consumers want to be sure that they have been used responsibly - label instructions and withholding periods followed.

Few horticulturalist take the use of agricultural chemicals for granted and often underpin such use with a wider strategy, an integrated pest management plan. In many cases farm chemicals are used because it is the most appropriate way of dealing with a potential or actual problem - a pest or disease threatening to destroy the crop, or
the weather conditions facilitating the development of mildews. Purchase and associated labour costs, the time involved, the wait to see if the application has worked, and the all too often worry that chemical residue limits may be exceeded place undue stress on growers. Their position is further exacerbated when an unregistered chemical is applied.

1.2 Pesticides For Minor Crops

Many minor crop growers face the problem that when they want to use pesticides, no chemicals are registered for their line of produce. The problem stems from the fact that due to the small size of the market, minor crops are often not considered when pesticide products are being developed and registered (NRA, 1998, p. 35). Growers have three choices:

- They can decide not to use chemicals.
- They can apply to the National Registration Authority to have the minor use approved.
- They can take the risk and use unapproved sprays.

In many cases horticulturalists are damned if they do, and damned if they don't. Damned that they have to use a chemical to control the problem in the first place. Damned that all too often the chemical used is not registered for use with that particular crop (few registered chemicals are available for many minor crops). Damned if they don't because if ignored, the problem can get out of control and ruin the produce.

2.0 Methodology

The research problem became apparent to the author whilst undertaking an action research project with a group of berry growers. The growers were somewhat perplexed as to which quality system they needed to implement to meet the needs of their customer base and how they were going to manage their food safety and quality process. Possible systems included the Woolworths Vendor Quality Management Standard, SQF 2000 Safe Quality Food Code: 1997, AS/NZS ISO 9002, horticultural industry ISO 9002 variants and Hazard Analysis Critical Control Points (HACCP) Verification.

As grower understanding of the principles and application of the HACCP framework increased, they became more aware of the potential weaknesses and pitfalls relating to their new food safety and quality management system.

The following paper shares information that was forthcoming through a number of focus group discussions with those growers and how they might reduce the potential food safety risk relating to agricultural chemical application.

3.0 Some Background to the Problem

Pesticides are used for agricultural purposes to control unwanted insects, mites, fungi, rodents, weeds, nematodes and other pests and to control diseases in crops. Pesticides have been used in world agriculture for many years and provide higher yields, year-round availability and improved quality and variety in our food supply. Contamination may be either naturally occurring substances or environmental pollutants. Unlike pesticides, contaminants are not deliberately added to food or crops (ANZFA, 1998, p. 2). Ingestion of excessive levels of pesticides and contaminants can have detrimental health effects on consumers.

3.1 How Significant is the Chemical Residue Problem?

The Australian Market Basket Survey (AMBS) monitors pesticide residues and contaminants in food and estimates the level of dietary exposure in Australia. The survey is conducted every two years. The data provides information for the development of standards in the Food Standards Code and is also used by the National Registration Authority for Agricultural and Veterinary Chemicals during the clearance and registration process undertaken for pesticides. This survey of table-ready foods is a tool that allows Australia New Zealand Food Authority to highlight potential problems that exist in the Australian food supply and to deal with areas of concern (ANZFA, 1998, p. xi).

The 1996 AMBS (p. xiv) stated:

'results indicate that Australians can be confident that the food they eat is very low in pesticide residues and contaminants'.
This result is also supported by the Victorian Department of Natural Resources and Environment (DNRE) research published in Victorian Produce Monitoring (Results of Residue Testing 1997 and Program Summary Report 1987-96) the national study:

'Overall, 1.7% of analysis results were above the relevant maximum residue limits (MRL), while 82.8% of results were below the limit of detection for the analysis method used. The results for pesticide residues display a high level of compliance with good agricultural practices' (Dunn & Roberts, 1998, p. 1).

'A targeted sampling strategy was used, whereby DNRE officers selected chemical and produce combinations specifically chosen to investigate emerging or potential residues. Such a strategy would be expected to produce a higher rate of violations than a random sampling program. Despite this targeted approach, the 1997 program results reveal a very low violation rate, confirming the clean, green image of Victorian agriculture' (Cook, 1998, p. 9).

Although the results were very encouraging, monitoring authorities have openly expressed their concern that a single violation can have a severe impact on the health of consumers and that growers needed to do more to ensure that their farm chemical applications will not exceed stated residue limits.

### 3.2 Residue Testing

Residue studies are conducted for the proposed method of application on crops. These tests determine how much of the compound or its metabolites remains on or in a crop when the proposed treatment is under good farming practices relating to crop production.

The Acceptable Daily Intake (ADI) for humans is derived from feeding studies carried out on laboratory animals. The no-effect level found in such studies in the most susceptible species of laboratory animals is divided by a safety factor which may vary from 100 to 2000 (Day, Hock & MacAlpine, 1997, p. 1.15). The ADI is the cornerstone of toxicological evaluation. The Maximum Residue Limit (MRL) is the yardstick by which residues in food are measured.

### 3.3 Safety Factors

There are a number of safety factors built into the ADI and MRL:

- A safety factor of 100 - 2000 is used in deriving the ADI from the no-effect level determined in feeding studies with laboratory studies.
- The MRL is set as low as possible, normally accounting for only a small fraction of the ADI.
- Experience shows that residues exceeding the MRL are rare events.
- There is only a very remote possibility that the ADI would be frequently exceeded.
- There is a loss of residues during preparation and cooking.
- The daily intakes of residues under discussion are only a fraction of the quantities required to produce toxic effects.

Before any farm chemical is registered an MRL must be established

### 4.0 The Hazard Analysis Critical Control Points (HACCP) System

The HACCP system, which is science based and systematic, identifies specific hazards and measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing. The successful application of HACCP requires the full commitment and involvement of management and the workforce. It also requires a multidisciplinary approach; this multidisciplined approach should include, when appropriate, expertise in agronomy, production, microbiology, public health, food technology ……..’ (Codex Alimentarius Commission, 1993, p. 2).

The HACCP system consists of the following seven principles:

- Principle 1 - Conduct a hazard analysis (the process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan).
- Principle 2 - Determine the Critical Control Points (CCPs - a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level).
- Principle 3 - Establish critical limits (a criterion that separates acceptability from unacceptability).
• Principle 4 - Establish a system to monitor control of the CCP.
• Principle 5 - Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
• Principle 6 - Establish procedures for verification (methods, procedures, tests and other evaluations, to determine compliance) to confirm that the HACCP system is working effectively.
• Principle 7 - Establish documentation concerning all procedures and records appropriate to these principles and their applications.

The application of HACCP principles follows twelve steps:

• Step 1 - Assemble HACCP team.
• Step 2 - Describe product.
• Step 3 - Identify intended use.
• Step 4 - Construct flow diagram.
• Step 5 - On-site confirmation of flow diagram.
• Step 6 - List all potential hazards associated with each step, conduct a hazard analysis, and consider any measures to control identified hazards (Principle 1).
• Step 7 - Determine Critical Control Points (Principle 2).
• Step 8 - Establish Critical Limits for each CCP (Principle 3).
• Step 9 - Establish a Monitoring system for each CCP (Principle 4).
• Step 10 - Establish Corrective Actions (Principle 5).
• Step 11 - Establish Verification Procedures (Principle 6).
• Step 12 - Establish Documentation and Record Keeping (Principle 7).

A key element in each step is common sense coupled with a sound knowledge of the produce, the processes involved and an understanding of the principles and application of the HACCP system. The HACCP system is also dynamic encouraging food producers to look at new and better ways of processing.

5.0 Discussion on the Application of HACCP Principles and Steps

The strength or success of the HACCP method depends on its application in enterprises. Generally speaking, SHE have had limited exposure to HACCP and it has been the influence of the market, notably major supermarket chains, that have forced implementation. Obviously SHE will not have the same resources as larger businesses - all too often it is one or two people that manage and work the food business on a day-to-day basis and relying on casuals during the harvest period. This fact contributes heavily to potential weaknesses in the application of HACCP.

5.1 Assemble HACCP team

The HACCP system requires a multidisciplinary approach and team members should have a good knowledge of the produce, processes and the potential hazards. However, in the case of small horticultural enterprises, the HACCP team often consists of one - the grower themselves. During the harvest period casual pickers and harvesters may be employed. Such employees often have limited produce knowledge and low level English language skills. Even if they were willing to proactively participate in the food safety and quality process, their contribution would be limited.

The grower therefore needs to be self reliant and keep abreast of good farming practices to minimise risk. Many enlist the support of grower associations (in this case the Victorian Strawberry Growers Association) and industry groups (Agriculture Victoria - Institute of Horticultural Development, National Registration Authority etc.) who can, in most cases, assist them through the maze of potential problems.

At times, even with the assistance of these organisations, the pesticide problem cannot be resolved. How does a strawberry grower deal with the Western Flower Thrip when no suitable chemical is registered for use on strawberries? Off-label use has been suggested but the withholding time (WHT) of that chemical presents a dilemma in itself - pick inside the WHT and risk residues that exceed the MRL or pick outside the WHT and have over ripe produce. Do not use chemicals and the crop is destroyed.

5.2 Describe Product

A HACCP Plan should be specific to a line of produce or product group. Product descriptions include:

• Description of the produce and how it is presented.
• Method of preservation (to ensure produce meets shelf life).
• Chemical/physical characteristics.
• Primary packaging (size, grade of material).
• Secondary/shipping packaging.
• Storage conditions (conditions under which produce is held prior to dispatch and held by customer).
• Distribution method (conditions under which produce is to be transported to customer e.g. chilled 1-5 °C).
• Shelf life (minimum time period before produce exhibits noticeable quality changes or microbial levels become unsafe when stored under specified storage conditions).
• Sensitive population (does the produce contain ingredients that may be hazardous to certain members of the community).

Many SHE have to rely on their customers for assistance in describing their produce. In some cases, notably the major supermarket chains, a produce specification will be offered and growers will be required to meet those terms. Such specifications will include the above information as well as food safety and quality criteria, for example chemical residue limits for farm chemicals derived from the Food Standards Code. Specifications will assist growers to determine appropriate timing for harvest (degree of maturity of produce), the development of a suitable farm chemical spray program (pest and disease management following label instructions and WHT) and delivery schedules.

5.3 Construct Flow Diagram

The flow diagram should provide a picture of the process flow. In the case of SHE this will often include soil preparation and plant selection through planting, nurturing, harvest, grading, packing and distribution to their customer. The flow diagram should also identify all process steps including inputs, transfers, inspections and delays.

The process flow diagram plays an important role in hazard prevention. It details how the produce is produced and indicates all critical steps in the process. It can be used to check that none of the critical steps have been changed or other potentially hazardous steps introduced. With no one else in the business to assist with this step, SHE often miss potentially hazardous inputs when constructing their flow diagrams. This is due to oversight rather than not having an in depth knowledge of their processes. The next step will ensure that all inputs are taken into account.

Farm chemical application will occur throughout the process. Although some applications can be scheduled (e.g. weedicide prior to bed preparation), others will depend on weather conditions (e.g. powdery mildew) and the arrival of particular pests (e.g. western flower thrip, mites). It is these unscheduled applications that present potential problems for growers. Growers must follow label instructions and WHT to ensure residue limits are not exceeded.

5.4 On-site Confirmation of Flow Diagram

This step requires enterprises to confirm that the process operation is reflected in the process flow diagram. The accuracy and the completeness of the flow diagram is verified by visually walking-through the entire process. This is somewhat difficult for horticulturalists because the process is cyclic in nature and takes, in the case of strawberry growers, twelve moths for the full process to be realised. This makes verification somewhat more difficult. Enterprises need to continually check their operations against the flow diagram throughout the produce cycle if they are to be sure that they have shown due regard to all inputs. Once the total process flow diagram has been verified it is relatively easy to compare actual operations against the planned process.

It is worthwhile looking at a worst case scenario for unscheduled farm chemical application ensuring that all contingencies have been taken into account.

5.5 List All Potential Hazards Associated With Each Step

For each step in the process horticulturalists must identify the hazards, assess the significance of the hazards and determine what control measures need to be applied to control the significant hazards.

All inputs to a process including raw materials like fertilisers, farm chemicals, water source and packaging materials, equipment, storage conditions, processing methods, produce, premises and people that have a potential to introduce a hazard into the produce need to be considered.

It is also essential to distinguish between the hazard and the cause of the hazard. For example, the potential hazard of excess chemical residues on produce. The cause of the hazard is more often than not inappropriate
chemical application (not following label instructions or WHT, poorly maintained spray equipment or spray techniques) rather than spray drift from other properties. Control measures can include farm chemical user training for the operator, calibration and preventive maintenance of spray equipment as well as following label instructions including WHT.

Unfortunately the assessment of the significance of a potential hazard is subjective and relies heavily on the knowledge and experience of the HACCP team - the grower. When a hazard has been identified the horticulturalist needs to ask and answer two questions:

- What is the severity of the hazard (the seriousness of the hazard to consumer safety or produce quality)?
- What is the risk of the hazard (the likelihood of the hazard occurring)?

In normal circumstances, farm chemical usage is seen to be both severe in terms of seriousness to consumer safety and has a high likelihood occurring. A control measure must be put in place to prevent, eliminate or reduce the hazard to an acceptable level. In this case a number of control measures are normally put in place:

- Farm chemical user training for the operative.
- The use of registered chemicals for their intended purpose, following label instructions and WHT.
- Preventive maintenance and calibration of spray equipment.
- Good farming practices (common sense and industry best practice).
- Monitoring pest and disease levels in the crop.

The responsibility for controlling agricultural chemical hazards must lie with the grower.

### 5.6 Determine Critical Control Points (CCP)

Once the significant hazards and the control measures have been identified for each step in the process, it is necessary to determine whether that step in the process is a critical control point (CCP). A CCP is one where loss of control will result in a hazard to the safety of the consumer or the loss of produce quality. The question is really ‘if nothing is done at this step in the process, will the hazard become uncontrollable’? If the answer is yes, one or more control measures need to be applied.

Each and every farm chemical application becomes a critical control point for growers.

### 5.7 Establish Critical Limits For Each CCP

Critical limits need to be established for each CCP. A critical limit is a ‘prescribed tolerance’ from which there can be no deviation if the produce is to meet food safety and specified quality criteria. Critical limits must be easily measurable and where possible, monitored continuously. Prescribed MRL’s for particular crops are the critical limits for farm chemical application. These however, cannot be measured on-farm and require specific laboratory processes and so become impractical for growers. As a practical substitute, horticulturalists tend to follow chemical label instructions taking note of application and dilution rates as well as WHT. This is supported by chemical residue testing to validate that their actions are not compromising food safety or produce quality. Other critical limits may include:

- Operatives must have completed a Farm Chemical Users course.
- Spray equipment must be in a serviceable condition and regularly calibrated.
- Crops will be monitored for pests and diseases.

The use of non registered chemicals needs to be addressed. In the ideal world non registered chemicals would not be used however, because of economic necessity, they are used, and used more widely than generally accepted. Many horticulturalists use non registered chemicals and take the risk of MRL being caught out. Following label instructions and WHT for like produce may not be enough. Any level found above the limit of detection (well below MRLs) constitutes a breach of food safety. Simply applying such chemicals and not recording their use in Farm Chemical Spray Diaries constitutes an additional weakness in the system of controlled chemical use. Growers urgently need an industry best practice that will protect their livelihoods and support their food safety and quality practices.

### 5.8 Establish a Monitoring System For Each CCP

The HACCP plan will determine what monitoring procedures are necessary to ensure that the process remains in control and that the critical limits are not exceeded. In the case of farm chemical usage, monitoring procedures will need to specify:
- What is to be monitored - farm chemical application.
- When or how often it is to be monitored - monthly.
- How it is to be monitored - visual check of spray diary. (This can be supplemented by random inspection of application techniques, checking prescribed application rates against actual area covered and produce chemical residue testing).
- Where it is to be monitored - chemical shed.
- Whom is to monitor it - Packhouse Manager (it is always better to have someone other than the farm chemical operator check the diary entries however this is not always possible in SHE).

All too often SHE have to monitor their own actions. Unless specific monitoring procedures are put in place requiring checklists or diary entries to be completed, this task is often overlooked resulting in potential food safety breaches that could have been dealt with early.

5.9 Establish Corrective Actions

When monitoring indicates that a critical limit has been exceeded, corrective action must take place and will include:

- The deviation being brought to the attention of the responsible person.
- The produce affected is identified by tagging and segregated if there is the potential for such produce to contaminate other produce.
- The status of the produce is reviewed and a decision made on what is to be done with it - dump, accept on concession or accept as is.
- The deviation, corrective action and disposition of produce should be recorded.

Corrective action is focused on:

- Identifying the nonconforming produce to prevent it being inadvertently used.
- Deciding what is to happen to the nonconforming product.
- Adjusting the process to maintain control.
- Recording the corrective action taken.

In the case of inappropriate farm chemical usage e.g. harvesting produce inside the WHT or applying the chemical at a rate that exceeds label instructions, the corrective action is straightforward:

- Identifying which produce has been affected by excess chemical or has been harvested inside the WHT.
- Dumping / destroying the product.
- Reviewing the farm chemical spray program and ensuring that when sprays are utilised, the WHT and label instructions have been followed.
- Record the corrective action.

A key question is whether the SHE is in a better position to be able to recognise the potential chemical residue problem and control the process than larger enterprises? There is much to support the argument that if one person is responsible for all tasks, they will have a better understanding of how the process is operating however this needs to be tempered with workload. The majority of SHE suggest that they can exercise control over their processes but many agree that there is a potential to make mistakes because of the multiplicity of activities that need to be done.

5.10 Establish Verification Procedures

There are three main elements to verification:

- Continuous internal review of the monitoring and corrective action records to ensure that the overall process and each CCP is in control.
- Internal and external auditing to ensure that the principles of HACCP are being followed and that the process and inputs have not changed.
- Internal or external justification or validation that all relevant hazards have been identified, that the analysis of significance is valid and justified, the critical limits are appropriate and the monitoring and corrective action procedures are effective.

SHE must utilise external sources to verify that they are managing the potential chemical residue problem. SHE need to introduce a regular schedule of produce chemical residue testing to verify that their farm chemical
application practices are sound. Underpinning this activity are the good farm chemical application practices (following label instructions, WHT etc.) and good farm practices that keep the system under control.

5.11 Establish Documentation and Record Keeping

This is often the most difficult step for SHE. Record keeping must provide objective evidence (for external audit purposes) that:

- Each control measure and monitoring procedure have been correctly applied.
- The critical limits have not been exceeded.
- The monitoring procedures have been followed.
- Verification procedures have been implemented and adhered to.
- Where there has been a deviation, corrective action has been implemented.

For SHE this will mean the maintenance of a Farm Chemical Spray Diary (and in some cases a Fertiliser Diary). Any other documentation, even with good intentions, appears to fall by the wayside. It is essential that SHE record all the information required by legislation, for effective produce identification and traceability, and for the control of their processes.

6.0 Conclusion

Even with good chemical application practices and good farm practices, horticultural enterprises are faced with the possibility of breaching food safety requirements by exceeding produce chemical residue limits. Complacency by individuals will increase the potential risk as will the use of non registered chemicals. Although the perceived risk is deemed to be low (validated by ongoing testing and monitoring by independent authorities) much needs to be done to ensure that growers keep up-to-date with industry best practice in dealing with pests and diseases. Industry groups and relevant authorities also need to be encouraged to address the minor crops and chemical registration problem.

7.0 References


Codex Alimentarius Commission, 1993, *Report of the Twenty-Sixth Session of the Codex Committee on Food Hygiene*, FAO/WHO, Washington DC, 1-5 March,


National Registration Authority, 'Pesticides for 'Minor' Crops' in *Advancing Food Safety*, vol. 2, iss. 7, August, p.35.