PLANNING AND CONTROL OF IPM FOR GREENHOUSE TOMATO GROWERS: PROCESSES USED BY EXPERT CONSULTANTS

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Applied Science
at
Massey University,
Palmerston North,
New Zealand

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March, 1999

ABSTRACT

Given the clean, green image used to promote New Zealand produce, greenhouse tomato growers are under pressure to shift from conventional pest control to more environmentally-friendly methods such as IPM. However, growers often lack the specific knowledge required to tailor IPM strategies to their properties. Greenhouse consultants with expertise in IPM may provide a valuable source of assistance in terms of IPM adoption. However, little is known about how expert greenhouse consultants conduct this task. This study investigated the processes used by expert greenhouse consultants to assist greenhouse tomato growers with the planning and control of IPM strategies.

A multiple case study research method was selected as the most appropriate method for meeting the study objectives. Following the review of the literature, two expert greenhouse consultants were selected, and the data were collected using semi-structured interviews, field observations, and relevant documentation. Qualitative data analysis techniques were used to analyse the data.

The two consultants were found to use similar IPM consultancy processes which, for the purpose of this study, have been separated into the physical activities, and planning and control processes. Both consultants perform similar physical activities (telephone calls and visits) to those used by farm management consultants. However, the two consultants studied distinguish between planning and control purpose telephone calls and visits, which the farm management consultants do not. In addition, both consultants use additional communication tools during the control stage.

Throughout the consultancy processes, rapport is considered important to enable a trusting relationship to be built between the client and the consultant. The study highlights the presence of three phases during the consultancy processes, which were not mentioned in other farm management consultancy literature. The "screening" phase is used to ensure the development of the client's favourable attitudes toward IPM in the planning process. The "provision of information" phase, which occurs throughout the processes, is critical due to the complex nature of IPM. The "validation" phase is used to confirm the existence of the problems in the control process.

During the planning and control processes, the client and the consultant share several roles and responsibilities. As the clients own the problem, they are responsible for making the decisions, implementing the plans, and undertaking monitoring. In order to do this, the clients act as the information providers and receivers for the consultant. The consultant is responsible for understanding the clients' system, providing the information required by the clients and designing the preventative IPM strategies during the planning stage. At this stage, the consultant also provides a monitoring strategy and contingency plans to be used by the clients. During control, the consultant is responsible for validating and diagnosing the existence of the problems, providing information about the causal effect of the problems and designing the curative IPM strategies to solve the problems. During the design phase, the consultant uses decision rules to modify his IPM template, according to the need of each client.

Factors such as type of crop, greenhouse age, crop age, whitefly population levels, the ability to heat, season, stud height, and persistence period are mentally structured to come up with various *Encarsia* introduction rates. In contrast, the IPM manual suggests a single *Encarsia* rate is used for all situations. The *Encarsia* introduction rates comprise the initial and maintenance rates. Case Study One starts with low rates of *Encarsia* for 2-4 weeks, followed by increasing the rates. Case Study Two starts with high rates of *Encarsia* for 6-10 weeks, followed by reducing the rates. Introduction is discontinued when the sustainable level of whitefly parasitism has been achieved. A more detailed IPM manual which allows for the specific circumstances in greenhouse tomato growers' properties is required to assist growers in the adoption of IPM strategies

Key words: consultancy, planning, control, IPM, greenhouse tomatoes, *Encarsia formosa*, multiple case studies.

ACKNOWLEDGEMENT

All glory and honour to the Lord, my God and my Saviour, who has given me unbelievable strength and joy whilst undertaking my two years' study at Massey. What can I do without You?

I would also like to use this opportunity to express my gratitude to the people who have been a great help throughout my study:

- Ewen Cameron and David Gray: Thank you for not only being my great (and I really mean it!!) supervisors for the past two years, but also for encouraging and challenging my thoughts. My apologies for all the last minute writings I submitted, which might have deprived you of your sleep.
- Keith Fisher and Terry Steward: Thank you for giving all your thoughts, which have contributed to enriching my thesis.
- Bryan Hart from Substratus New Zealand Ltd and Andrew Austin from R. A. J. White Horticultural Consultants. Thank you for being open and helpful throughout the interview and field visit process. Also for providing me with all the information I needed. This study would not have been as it is without your cooperation.
- Ministry of Foreign Affairs and Trade: Thank you for providing me with the NZODA scholarship throughout the period of my study at Massey University.
- Denise: Thank you for transcribing most of my transcripts and finishing each of them within days. Also for all the many little things which you've sorted out for me throughout the years.
- All staffs of Agricultural and Horticultural Systems Management: Thank you for all the support, concern, and attention shown to me during the past two years.
- My fellow postgraduate friends, Amelita Rodriguez and Oni Bibin Bintoro: Thank you for sharing all the laughter and tears with me. I will certainly miss watching movies, eating out, and singing in karaoke with you guys!!
- My family: Thank you for all the support you have given me while I was far from you here. For Papa, thank you for asking me the same old question every week ("Now you can get a fixed answer, I'm finished!"). For Mama, thank you for all your delicious recipes which satisfied my craving for your cooking while you were not here. For Uwie, thank you for keeping me up to date with all the interesting stories which you had.

I love you all,

Palmerston North, 31 March 1999

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CHAPTER ONE
INTRODUCTION

1.1 PROBLEM STATEMENT

For the past few years, the New Zealand fresh tomato industry has been flooded with imported field grown tomatoes from Australia. In order to win a larger market share in such a competitive market, domestic greenhouse tomato growers need to show the advantages of their produce against those of their competitors. New Zealand growers have stressed their "clean green" top quality image, promoting New Zealand grown tomatoes as being tastier and containing fewer chemical residues than those of their Australian counterparts (Beck, Martin, Workman, 1992). One means of producing these high quality tomatoes is through the use of Integrated Pest Management (IPM) strategies in the growing process. IPM strategies attempt to integrate various control measures, with emphasis on the use of ecologically-based measures, to maintain pest populations below economic injury levels.

However, since IPM strategies may become complicated for growers, the uptake of IPM strategies by greenhouse tomato growers is related to two major issues. First, growers need to know how to design IPM strategies suitable for their specific circumstances, and second, they need to know how to manage the crop system once IPM is implemented.

The solutions to those two issues may require expert knowledge to combine and integrate various factors such as greenhouse structure, pests, natural enemy biology, life cycles, and cropping system into the grower's circumstances. Consultants have been quoted in the literature (Wearing, 1988; Martin, Workman, Marais, 1996) as being one of the main sources of providing these solutions for growers. These consultants, who have expertise in IPM, may provide assistance to the growers in the planning of IPM strategies to meet their specific circumstances, and in the management of the system once the strategies are up and running.

However, currently, there is a limited number of horticultural consultants with expertise in IPM for greenhouse tomatoes in New Zealand. Moreover, there is also very limited literature available for consultants or growers in the planning of IPM strategies at farm level (Dent, 1995). Most IPM literature focuses only on the principles, approaches, and implementation of IPM, without considering how to move the ideas into practice in the field (Dent, 1995).

Therefore, it is considered important to investigate how these few expert consultants in New Zealand assist their greenhouse tomato grower clients both in the planning and in the control stages of IPM management. The findings from this study will benefit not only the expert consultants taking part in the study, in terms of evaluating and improving their approaches, but also other horticultural consultants who will gain insights into how the experts have operated. This will aid the development of the fresh tomato industry and IPM in New Zealand in general. Moreover, such findings can be used also as teaching material for horticultural management students.

1.2 OBJECTIVES OF THE STUDY

The overall aim of the study was to investigate the processes which consultants use to assist greenhouse tomato growers in IPM planning and control stages.
Specific objectives of the study were:

- to review the literature on the planning and control, consultancy, and IPM strategies for greenhouse tomatoes;
- to develop an IPM consultancy process model, comprised of the planning and control stages used by the consultants in assisting their greenhouse tomato grower clients;
- to identify factors considered important by consultants when developing IPM strategies for their greenhouse tomato grower clients;
- to compare the IPM strategies designed by the consultants with those published in the IPM manual.

1.3 REVIEW OF IPM DEVELOPMENT IN THE NEW ZEALAND FRESH TOMATO INDUSTRY

Tomatoes are the second most commonly purchased fresh vegetable, after potatoes, in New Zealand (Statistics New Zealand, 1997), and have been in this position for at least three years. In 1996/97, New Zealand households have been estimated to spend $55.5 million on tomatoes.

In New Zealand, tomatoes are grown both as a field crop and under cover in greenhouses. The majority of fresh tomatoes, however, are produced in greenhouses, either glasshouses or plastic greenhouses, which are distributed from Keri-Keri in the North Island, to Timaru in the South Island. However, the majority of greenhouse tomato growers are located in the Auckland region, as it is close to the major markets and is an area which has high winter light and warm winter temperatures, thus reducing the need for heating. The size of the average tomato greenhouse is 2,000 m^2 (Austin, *pers.comm.*, June 1998). In 1998, the price of tomatoes on the domestic market varied between $3.80 - $4.50/kg in winter and $1.00 - $1.50/kg in summer. Analysis of the profitability of greenhouse tomato production suggested that, at these prices, a 2,000 m^2 was not financially sustainable (Hart, *pers.comm.*, June 1998). The minimum property size which is financially sustainable (will support a family, mortgage, and reinvestment for expansion) is between 3,000 m^2 to 4,000 m^2 (Austin, *pers.comm.*, June 1998; Hart, *pers.comm.*, June 1998).

Currently, the average production of the greenhouse tomato system in New Zealand is 28 kg/m^2. This is almost half the average level of production achieved by Dutch and UK growers (Austin, *pers.comm.*, June 1998). However, some New Zealand growers currently produce over 50 kg tomatoes/m^2, while others struggle to produce above the national average (Hart, *pers.comm.*, June 1998). A high level of production is normally possible in modern greenhouses, which have a high stud height (3 - 4 m) and a good ventilation system. About 40% of greenhouse tomato growers have installed this type of greenhouse in recent years (Hart, *pers.comm.*, June 1998).

Despite the importance of the tomato in New Zealanders' diet, the number of greenhouse tomato growers in New Zealand has declined from about 1,000 in 1987 to 700 growers in 1997 (Gargiulo, 1997). In the early years of the 1980s, these growers were subject to domestic competition only because insignificant quantities of tomatoes were imported. However, the fresh tomato industry changed when, in 1982, the New Zealand Government allowed tomatoes to be imported from Australia, particularly from Queensland, through the Closer Economic Relations Trade Agreement (Gargiulo, 1997). These are cheaper than the New Zealand produced tomatoes because they are produced outdoors in Australia's more tropical regions, and then imported during New Zealand's winter, when New Zealand growers have high heating costs.

In this competitive market, New Zealand growers must demonstrate that their produce is superior to that of their Australian competitors. The main advantage promoted by New Zealand growers is the "clean green" image of New Zealand tomatoes. The "clean green" image of the New Zealand tomato is enhanced by the shift from a pesticide-dependent production system to more environmentally-friendly methods such as IPM. IPM is favoured by New Zealand growers for several reasons. First, the greenhouse industry suffers from pesticide resistance problems (van Lenteren & Woets, 1988), and therefore an alternative method of controlling pests is urgently needed. In New Zealand greenhouse tomatoes, the most common pests are whitefly and botrytis (Martin, 1990a).

Second, the changing reassessment systems of pesticide legislation in many countries have resulted in the rapid withdrawal of chemicals which have traditionally been used on tomatoes, while at the same time, the registration process of new, less toxic, and narrower spectrum pesticides, which are often compatible with IPM programmes, has been relatively slow (Wearing, 1990; Whalon & Penman, 1991). These factors have limited the number of pesticides available to growers and increased the risk of pest resistance occurring with the remaining pesticides. Non-chemical pest control methods would provide opportunities for growers to deal with these situations.

The third reason for favouring IPM strategies is that there has been increasing consumer concern about pesticide use on food crops, particularly in Europe (East & Holland, 1990; Wearing, 1992; Wells, 1994). Consumer perceptions of food safety are mainly driven by media exposure of dietary hazards, which focus on pesticide residues found in food, and environmental contamination by agricultural chemicals (East & Holland, 1990). Such attitudes have prompted increased pesticide residue monitoring in food supplies, particularly those which are eaten fresh. Minimal pesticide residues are becoming an integral part of food standards demanded by consumers, at no extra cost on their part (Wearing, 1992). Unfortunately, this kind of attitude is not typical of New Zealand consumers, and has therefore not been recognized by the New Zealand tomato packhouses, which pack and market about 20% of greenhouse tomatoes in New Zealand (Austin, *pers.comm.*, June 1998; Hart, *pers.comm.*, June 1998). Currently, there is no premium paid for IPM-grown tomatoes over conventionally grown tomatoes. However, it is acknowledged that growers who are able to produce good quality tomatoes, are usually growers who incorporate IPM strategies into their production systems (Tregidga, *pers.comm.*, May 1998). Hart (*pers.comm.*, June 1998) believes that if there was a premium for IPM produce, growers would be more likely to adopt IPM and invest in new greenhouses to support IPM strategies.

Research on IPM in New Zealand greenhouses was initiated by the DSIR (Department of Scientific & Industrial Research) in 1981 (Beck *et al.*, 1992). The tomato was chosen because it represents such a large proportion of the greenhouse industry in New Zealand. Preliminary key areas for research were identified as (Martin, 1987):

1. control of whitefly prior to release of *Encarsia formosa* (whitefly predator) and the use of selective pesticides harmless to the *Encarsia*;
2. control of fruit and leaf feeding caterpillars;
3. control of tomato stemborer.

The active promotion of IPM programmes for some major greenhouse crops, such as tomatoes, cucumbers, capsicums, and beans, however, had to be delayed until 1991, while waiting for the registration of a selective pesticide, buprofezin, for whitefly control (Martin, 1990a; Beck *et al.*, 1992).

When the research started, it was assumed that the Ministry of Agriculture and Fisheries (MAF), through its horticultural advisory officers, would provide free advisory services (Martin, 1990a) critical to the successful adoption of IPM by growers. However, as a result of Government reforms in 1985, which included the removal of all subsidies in the agricultural sector, growers have had to pay for the advice which they receive (Journeaux & Stephens, 1997). Because greenhouse properties in New Zealand are small and geographically dispersed, consultancy costs are relatively expensive for growers. The cost of IPM advice may be regarded by growers as being not worth the savings obtained from implementing IPM (Martin, 1990a).

According to a pest and disease control survey made of greenhouse tomato growers in New Zealand in 1989, the traditional sources of information (in descending order of importance) for these growers were: other growers, grower journals, overseas trips, and consultants (Martin, 1989). Based on this information, IPM programmes were then further promoted through industry magazines, grower meetings, demonstration plots, and manuals (Beck *et al.*, 1992). Key growers from each greenhouse tomato region were supervised regularly by a full-time advisor appointed to provide free assistance for growers on IPM, and paid by the IPM project funding. Group meetings were held to discuss the programmes in detail, and feedback was obtained from growers to improve the programmes. The key growers were expected to pass on their knowledge to other growers in the area. In the meantime, an IPM manual covering all aspects of pest control for each crop was produced.

From the early stage of IPM promotion and implementation until early December 1992, Crop and Food Research (formerly DSIR Plant Protection) was responsible for the supply of beneficial organisms to growers (Beck *et al.*, 1992). However, the supply of these predators, particularly *E. formosa*, sometimes arrived late, by which time the growers had sprayed their crops. These growers often then decided not to use IPM in the following season (Austin, *pers.comm.*, June 1998). To minimize this problem, responsibility for supplying the beneficial organisms has been passed over to several commercial companies.

Unfortunately, short-term and uncertain funding, particularly for the provision of free consultancy services for growers, have resulted in the lack of permanence of the IPM project. After the completion of the three-year IPM project, growers had to rely on private consultants or retailers of beneficial organisms for advice on IPM, which was often inadequate. In 1992, funding for a two-year IPM project for greenhouse crops was obtained from three sources: the Technology for Business Growth (TBG) scheme, the Fresh Tomato Sector of the Vegetable and Potato Growers' Federation (VegFed), and Crop and Food Research (Martin *et. al.*, 1996). A specialist IPM advisor was again appointed to assist greenhouse growers. In addition to the approaches for IPM promotion used in the first project, this IPM project provided training for consultants and representatives of beneficial organism retailers (Robertson, 1995). It also undertook the distribution of leaflets on the biology of pests and natural enemies, and the establishment of Hortnet, an internet-based source of information on horticulture (Martin, 1996). At the end of this two-year project, growers were again left without a free advisory service. The provision of information for growers has since become a major issue in IPM. This information is now the competitive edge for private consultants and companies which supply beneficial organisms (Hart, *pers.comm.*, June 1998).

Despite the work of the previous IPM projects, few of New Zealand's horticultural consultants specialising in vegetable crops have developed expertise in IPM. Limited literature is available to guide horticultural consultants in developing expertise in tailoring IPM strategies to meet the specific circumstances of growers. Therefore, investigating how such processes are conducted by expert horticultural consultants will assist the development of IPM in greenhouse tomatoes in New Zealand.

1.4. THESIS STRUCTURE

This thesis reports on the findings of a study of the processes used by expert horticultural consultants to help greenhouse tomato clients in the planning and control of IPM strategies. In Chapter One, the fresh tomato industry in New Zealand is described, along with the development of IPM programmes for greenhouse tomatoes in New Zealand. Chapter Two contains a literature review of IPM, IPM programmes for greenhouse tomatoes, the planning and control process, the farm management consultancy processes, and the role of consultants in IPM crop business is presented. The selection and description of the research method used in the study is provided in Chapter Three. Chapter Four contains a detailed description of the findings from the case studies. In Chapter Five, the cross-case analysis is discussed. Generalization from the case studies are then compared and contrasted with the literature. Finally, the main findings from the literature and the case studies are reported in Chapter Six, followed by a critical assessment of the method used for the study, and indications as to possible areas for future research on the subject.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Integrated Pest Management (IPM) is a control philosophy which has been adopted in many areas of agriculture worldwide. Indeed, it has been claimed as the only pest management approach which is able to meet the needs of all parties in the agricultural industry (Tait, 1987; Wearing, 1992). The strategy has been adopted in the glasshouse industry (van Lenteren & Woets, 1988; Beck, 1992), field vegetable industry (Trumble & Rodriguez, 1993; Herman, 1994), and also in orchards (Furness, 1982; Wearing, 1987; Stewart, Norton, Mumford, & Fenemore, 1993; Steven, Tomkins, Blank, & Charles, 1994). The increasing adoption of IPM by growers is facilitated by the strong assistance provided by extension services such as private consultants (Martin, 1991; Whalon & Penman, 1991; Beck *et al.*, 1992; Weddle, 1990, *cited in* Wearing, 1992).

In this literature review, the definitions of IPM, its origin, and concepts associated with IPM are discussed. This is followed by an examination of IPM approaches to greenhouse pests and pollinators, and an IPM programme for greenhouse tomatoes in New Zealand. Finally, the review examines the planning and control processes used by consultants to assist greenhouse growers with IPM.

2.2 INTEGRATED PEST MANAGEMENT (IPM)

2.2.1 DEFINITIONS

Since the term "Integrated Pest Management" (IPM) was first introduced in 1959, there have been numerous definitions written to explain it. Bajwa and Kogan (1998) were able to collect 67 IPM definitions used in various literature worldwide from 1959 to 1998. The number of definitions would have been higher if all IPM literature could have been included. Interestingly, the number of definitions increased from decade to decade, proving that IPM is becoming a more popular subject in agriculture.

The precursor to IPM was first introduced as "integrated control" by Stern, Smith, van den Bosch, and Hagen (1959) and was defined as "applied pest control which combines and integrates biological and chemical control" (pp. 86). Their landmark research paper showed that reduced doses of organophosphate insecticide were able to control organophosphate resistant aphids, simply because the reduced dosage reduced also the damage to natural biological control systems. Geier and Clark (1961, *cited in* van Emden & Peakall, 1996) proposed the term "pest management", which they defined as "the reduction of pest problems by actions selected after the life systems of the pests are understood and the ecological as well as the economic consequences of these actions have been predicted, as accurately as possible, to be in the best interest of mankind" (pp. 39). The term "integrated pest control" was then suggested by Smith and Reynolds (1965, *cited in* Apple & Smith, 1976) to incorporate all control methods, instead of just biological and chemical control. Later, the term "integrated pest management" itself gained popularity in the 1970s, and was intended to broaden such insect pest control definitions to include all classes of pests (insects, pathogens, nematodes, weeds, and even mammals). Such a broad definition of IPM was then recognised worldwide (i.e. Whitby, Rowlinson, Topham, & Younger, 1988; Arntzen, & Ritter, 1994), and is used in this study also.

The many definitions of IPM, although differing in wording, contain three basic similarities.

1. The integration of several methods of pest control. IPM still recognises the importance of pesticides use, but requires that they are used more effectively, and in combination with other methods. Broad spectrum pesticides, in particular, are to be avoided. The focus of IPM strategies is to use biological control, combined with other methods such as cultural control and plant diversity, to achieve acceptable pest control levels.
2. The use of monitoring as the basis for pest control decision making. IPM does not aim to eradicate all pests in the growing environment, but aims instead, by monitoring the pest density for economically damaging levels, to enable growers to decide the appropriate control measure(s).
3. The goal of IPM strategies is to ensure favourable economic and ecological consequences. In fact, the ability of IPM to balance these two factors has been its strength, particularly in comparison to conventional pest control methods which focus on the use of chemicals on the basis of calendar or scheduled spraying, despite the actual damage potential of the pest population. Conventional pest control methods have been blamed for being one source of environmental pollution.

Environmental concerns seemed to influence scientists more after the 1970's. This is evident from the explicitly mentioned need to have environmentally sound control measures in managing pests. None of the definitions from the 50's and 60's which were collected by Bajwa and Kogan (1998) mentioned minimising environmental risks, while almost all definitions from the 90's clearly stated that goal. IPM strategies currently aim not only to maintain pest population below the economic injury levels, but also to do this in a way which minimises impacts on human health, society, and the environment.

2.2.2 ORIGIN AND DEVELOPMENT OF IPM

The tactics employed in IPM are not new in agriculture. Most of these control techniques were developed during the late nineteenth and early twentieth century (Smith, Apple, & Bottrell, 1976; Kogan, 1998). Through trial and error, growers of those times learned that methods such as sanitation (i.e. destruction of infected plants and surrounding weeds, cleaning of tools), crop rotation to prevent buildup of soil-borne pathogens, eradication of alternate hosts of insects or pathogens, and timing of planting dates, could be used to reduce pest damage. However, as agriculture became more intensive and new pests were accidentally introduced into new areas, an urgent need arose for more effective pest control measures to be developed (Smith *et al.*, 1976). These developments led to increased research into chemical compounds. The discovery of synthetic organic insecticides in the 1920s led to optimistic predictions that all pests could be controlled by chemical pesticides (Casida & Quistad, 1998). Many advances in the development of synthetic organic insecticides took place during the 1940s to the mid-1960s (Smith *et al.*, 1976; van Emden & Peakall, 1996; Kogan, 1998), a period which was termed, by some, "the dark ages of pest control" (Kogan, 1998). The use of synthetic pesticides replaced growers' dependence on non-chemical pest control actions (van Emden & Peakall, 1996).

Although pesticides are able to eliminate quickly many pest problems, they have also a negative side (Smith *et al.*, 1976; Wearing, 1992; National Research Council, 1996; van Emden & Peakall, 1996). This includes problems such as:

- pesticide over-use, which can lead to pest resistance;
- loss of natural pest predators, which can lead to severe pest outbreaks, including secondary pest outbreaks;
- and the abandonment of cultural control methods such as crop rotation, which has been a sustainable way of farming over the ages.

Warnings about the risks of high dependence on pesticides started to emerge in the late 1950s (Casida & Quistad, 1998; Kogan, 1998) from the work of Stern *et al.* (1959), and erupted in Rachel Carson's book entitled "Silent Spring" in 1962. Carson's concern about the damaging impact of pesticides to the environment and public health has increased public awareness about pesticide safety issues (Smith *et al.*, 1976; van Emden & Peakall, 1996; Casida & Quistad, 1998). Moreover, her arguments, which were particularly addressed against DDT, had a great impact on agricultural policy-makers and the agrichemical industry in the USA, and initiated a new era of pest control methodology in agriculture worldwide. It was in this kind of political climate that the reintroduction of traditional pest control methods, in the form of IPM, regained their popularity.

For almost four decades, there has been much research put into the development of IPM. Since its initial introduction, IPM faced doubt and scepticism from various parties in the industry, before eventually receiving growing acceptance (Wearing, 1992). The concept has currently been embraced not just by entomologists and environmental groups, but also by the food industry and politicians (Pedigo & Higley, 1996). Developments in the chemical industry, such as the introduction of selective pesticides, and the genetic engineering of crops, have made IPM a more feasible approach to pest management in agriculture.

2.2.3 PRINCIPLES AND METHODS

There are three basic principles which characterise the IPM approach. The first two principles, the concept of economic threshold, and the use of monitoring activities, are the basic components of crop protection decision making in IPM. The third principle relates to the nature of the IPM itself as a knowledge-based system. Each of these principles will be discussed in more detail, followed by a review about control action measures used in IPM strategy.

2.2.3.1 ECONOMIC THRESHOLD

Conventional pest control is based on a regular calendar spray system, where growers spray their crops according to a spraying schedule, despite the pest populations in their fields. One of the major differences between this conventional system and IPM is that IPM does not seek to eradicate the whole pest population in the growing environment. Instead, a certain level of pests is tolerated. This level, termed the economic threshold, is used as a guide to spraying decisions (Luna & House, 1990; van Emden & Peakall, 1996). The economic threshold concept was first introduced by Stern *et al.* (1959) and defined as the "density at which control measures should be determined to prevent an increasing pest population from reaching the economic injury level" (pp. 86). The term "economic injury level" itself is used by Stern *et al.* to define "the lowest population density that will cause economic damage" (pp. 86). As a consequence, the economic threshold will always be lower than the economic injury level, to allow the control actions to take effect before the pest population reaches the economic injury level (Stern *et al.*, 1959).

Economic thresholds can be determined in several ways (van Emden & Peakall, 1996). They are derived specifically for each crop and crop pest. A certain degree of knowledge about agricultural ecosystems, naturally-occurring biological controls, and the effects of various control actions on other organisms in the environment is required to determine the thresholds (Lin, Vandeman, Cornejo, & Jans, 1994). Although many IPM manuals developed by scientists for growers have normally included these thresholds, in practice, the levels actually may vary depending on growers' risk perception and their knowledge (Mumford, 1980, *cited in* Cammell & Way, 1987).

Pests are maintained below the economic thresholds through the use of the various IPM control methods discussed later. In this way, IPM attempts to delay and reduce pesticide use without affecting the economic value of the crops. This, in turn, should reduce ecological problems within the growing environment and its surroundings (Pedigo & Higley, 1996).

2.2.3.2 MONITORING

The second principle, monitoring, is closely tied to the economic threshold concept. In order to be able to find out the pest population status in a given growing environment, growers need to monitor closely the number of insects, weeds, or diseased plants in the crop in question. The results are then compared with given economic thresholds (Lin *et al.*, 1994). Growers usually monitor the pest population in several sampling areas of their properties (Binns & Nyrop, 1992) and may include visual assessment of the crop and pest populations, or the use of traps to estimate pest population. These activities need to be conducted at appropriate times to get the best pest population estimation (Finch, 1987). In terms of preventing diseases, growers are also required to carry out environmental monitoring, particularly in greenhouses (Nederhoff, 1997a). This may include monitoring of factors such as humidity and temperature.

The monitoring system replaces, or partly replaces, the calendar-based spraying used by conventional growers. With monitoring in place, day-by-day decision making on the part of the grower is required, and therefore IPM is termed 'management intensive technology' by Ridgley and Brush (1992). However, these activities, although very crucial in IPM, have always been associated with extra labour and cost (Grieshop, Zalom, & Miyao, 1988). Therefore, Finch (1987) suggests that the time and effort for such techniques to be feasible have to compare favourably with the cost of applying pesticides. Moreover, growers need to gather and up-date their information regarding pest, crop, and even, weather conditions continually before making any crop protection decision.

2.2.3.3 KNOWLEDGE-BASED SYSTEM

Many authors have mentioned the complexity of IPM strategies in their reviews (e.g. Grieshop *et al.*, 1988; Wearing, 1988; McNamara, Wetzstein, & Douce, 1991; Hale, 1993; Zalom, 1993; McDonald & Glynn, 1994; Herbert, 1995). The strategies combine several disciplines from molecular biology to bioassay (Hale, 1993). This complexity has arisen because in practice, growers are required to pay attention to the compatibility of the strategies they choose, so that they will be integrated well when applied. The use of a given method must not interfere with the effectiveness of other methods. For example, the application of chemicals must not kill beneficial organisms introduced into the greenhouse.

Moreover, unlike the conventional calendar-based spray system where growers apply pesticides without knowing the pest situation in their crops, the control actions in IPM are based on current information about the crop-pest relationships in the crop through monitoring (National Research Council, 1989). Therefore, growers who want to adopt IPM need to posses at least a certain degree of knowledge about these crop-pest relationships, pests and their natural enemies, and the damage caused by pests. Without being able to obtain all of this information, it is difficult for growers to react appropriately to each specific situation they face (Ravensberg, 1994).

2.2.3.4 IPM METHODS

As mentioned earlier, IPM combines and integrates several methods of pest control. Among these are biological, cultural, semiochemical, chemical, and genetic controls (Cornejo & Kackmeister, 1996; van Emden & Peakall, 1996). Although IPM stresses the use of biologically-based methods, strong integration of the methods is still the key aspect of IPM, which leads to more than the additive results of every single method. Each of these methods will be discussed in more detail in the following sections.

A. BIOLOGICAL CONTROL

The term "biological control" is mentioned in almost all literature on IPM. In fact, it has become very recognisable that only a few authors (e.g. Huffaker, 1985; Schroth & Hancock, 1985; Martin, 1994a; Price, 1996) felt that it was necessary to include its definition. These authors agreed that biological control is a method of pest suppression through the use of natural enemies, so that the pest population can be maintained at a lower level than would occur in the absence of the enemies. Luna and House (1990), Chapman, Penman, & Hicks (1992), van Emden and Peakall (1996), although they did not suggest their own definitions of biological control, implicitly agreed with this concept. However, other authors (Lindow, 1985; Lin *et al.*, 1994) include crop rotation and the use of semiochemicals, such as pheromones, as part of biological control. For the purpose of this review, crop rotation and the use of semiochemicals, although they are biologically-based, will not be included as part of biological control.

Biological control requires an in-depth understanding of the interactions among various organisms in the field with the environment. Moreover, the effectiveness of biological control is influenced by various factors, e.g. micro-climate in the given growing environment (particularly, temperature), type of pest damage, crop diversity, and the use of pesticides (Chapman *et al.*, 1992). A serious disadvantage of biological control is that it is often slow to impact on the pests (van Emden & Peakall, 1996), unless beneficial organisms are used like insecticides (inundative). It can take some time for beneficial organisms to multiply and reach a balance level with the pests as they do in undisturbed wildlife.

Beneficial organisms can be divided into three types according to the way they kill the pests (Chapman *et al.*, 1992; Martin, 1994a; van Emden & Peakall, 1996). Predators kill their prey (the pest) by eating them, and are normally larger than their prey. These insects may act as predators during their larval and/or adult stages (Chapman *et al.*, 1992; van Emden & Peakall, 1996). Parasitoids, on the other hand, eradicate pests by completing their development on or within the pest's body and hence, destroy the host in the process. In most cases, it is the larval stage which feeds on the host, although adults of some species also act as predators (Chapman *et al.*, 1992; van Emden & Peakall, 1996). The last type, pathogens, cause disease in pests. Unlike the previous types, pathogens are normally introduced into a system the same way insecticides are applied, e.g. the application of *Bacillus thuringiensis* (Chapman *et al.*, 1992; van Emden & Peakall, 1996). However, their effectiveness often depends on the environment. With the exception of pathogens, effective beneficial organisms generally have characteristics such as good searching ability, high reproductive ability, adaptability to the environment, and the ability to survive pest-free periods (Rosen & Huffaker, 1983; Chapman, *et al.*, 1992).

Biological control can be implemented in four ways, classical (inoculative), conservation, inundative (Chapman *et al.*, 1992; Martin, 1994a; van Emden & Peakall, 1996), and seasonal inoculative release (van Emden & Peakall, 1996). Classical biological control is used to refer to the technique of introducing beneficial organisms into a country to establish and provide long-term control of pests. The beneficial organisms may be annually released at several sites for up to 5 years. Once they are established in the new environment control, hopefully, becomes self-perpetuating. Conservation occurs when the crop is managed to conserve beneficial organisms which are already established. In the inundative or augmentation technique, beneficial organisms are used like insecticides, which means that they are released as a single introduction in large quantities to the crops to obtain immediate control. Most of the agents are pathogens, whose shelf-life is limited, and hence, they will normally die soon after application and killing the pests. Therefore, inundative release is often used in annual crops to control pests which have only one generation a year (van Emden & Peakall, 1996). Seasonal inoculative release, is mostly used to target fast-breeding pests of short-lived crops in greenhouses (van Emden & Peakall, 1996). The biological control agents are released to obtain a stable pest-natural enemy balance for as long as possible. This method is currently used in combination with chemical application to control many greenhouse pests such as greenhouse whitefly and two-spotted mites (van Emden & Peakall, 1996).

B. CULTURAL CONTROL

Cultural control methods attempt to control unwanted organisms by manipulating agricultural practices to favour crops and beneficial organisms, and discourage pests. The methods are often targeted to prevent and reduce pest outbreaks rather than to control an existing pest infestation (Luna & House, 1990). The results are, therefore, sometimes hard to see and difficult to quantify. However, they still have important roles in crop protection. Even a slight modification in crop practices, such as changing the crop density, may create a significant effect on the plant-pest-natural enemy dynamic (Herzog & Funderburk, 1985).

Like biological control, the use of cultural control requires thorough knowledge of pests' biology and habits, the crops, plant-pest-natural enemy relationships, ecology, and phenology (Coaker, 1987). In the planning of cultural control methods, particular attention must be given to the weak links of the pest cycle. The methods include such diverse practices as; cultivation, mixed cultivation/intercropping, planting and harvesting timing, sanitation, crop rotation, and planting density (Luna & House, 1990; van Emden & Peakall, 1996).

Cultivation is used particularly to manage soil-dwelling insects or those who spend part of their life-cycle in the soil (Chapman *et al.*, 1992). Some cultivation practices, such as soil tillaging and avoiding compaction, are more applicable to field crops since these practices are not conducted in greenhouses. Other cultivation actions such as irrigation, mulching, manuring and fertilisation, are conducted to promote rapid growth and healthy crops, so that they are less susceptible to pests (Coaker, 1987). The choice of irrigation and mulch types may affect not only the plant, but also the micro environment surrounding the plant and its relationships with pests. The type and dosage of fertiliser used does not affect the pest directly, but is more related to plant conditions.

Intercropping is the practice of growing two or more kinds of crops in the same area. It can result in higher yields because of reduced weed competition and better use of sunlight, water and nutrients (Coaker, 1987). This method is easier to conduct in fields than in greenhouses, because field crops have more crop options. Other methods, such as planting and harvesting time manipulation, aim to avoid the oviposition or invasion of pests. By managing the planting and harvesting times, growers try to reduce the crop availability during the period it is susceptible to attack (Coaker, 1987). The method may include practices such as sowing the seeds earlier than normal so that young seedlings have time to grow stronger before the period of pest attack comes, or adjusting the planting dates to correspond with the weather conditions to synchronise the pest attack with its natural enemies (Coaker, 1987).

Sanitation has a major role in managing pests, particularly in greenhouses (Collins, 1990; van Emden & Peakall, 1996). The destruction of crop residues and weeds aims to prevent carry over of pests from one generation to another, and eliminating alternative hosts of pests. General cleanliness needs to be maintained not only in the greenhouses, but also in the area surrounding the structure.

The next method, crop rotation, is particularly applicable to soil-borne diseases. It is often not so effective on insects because of their higher mobility and ability to find alternative hosts at the same time, compared to pathogens. For soil-borne diseases, it may take a few years, or decades, depending on the characteristics of the pathogens, to disrupt their life-cycle. The principle is not to grow crops which have the same pests in sequence. The application of crop rotation for greenhouse crops is limited due to the small number of crop types grown in greenhouses.

Crop plants are usually planted at spacings which maximise the yields without reducing the quality. Plant density may affect pest numbers and the microenvironment surrounding the plant (Coaker, 1987). Crops grown at high densities may attract more pests than those less densely planted. Appropriate crop spacing reduces competition for light, nutrient, and air among plants, thereby, providing a better growing environment. This leads to strong plants, which are more tolerant to pest attacks.

C. SEMIOCHEMICAL CONTROL

Semiochemicals provide chemical signals with information content and hence are able to modify the behaviour of organisms (Lewis & Nordlund, 1985; Chapman *et al.*, 1992; Loke, Tan, & Vijaysegaran, 1992; Jones, 1994; van Emden & Peakall, 1996). In nature, they are secreted by certain glands in the pests, and used to transmit messages to other organisms from the same, or other, species. However, due to developments in the chemical industry, scientists are now able to produce semiochemicals synthetically. The categorisation of semiochemicals is based on the type of behaviour induced by each of them. A chart illustrating this is presented in Figure 2.1.

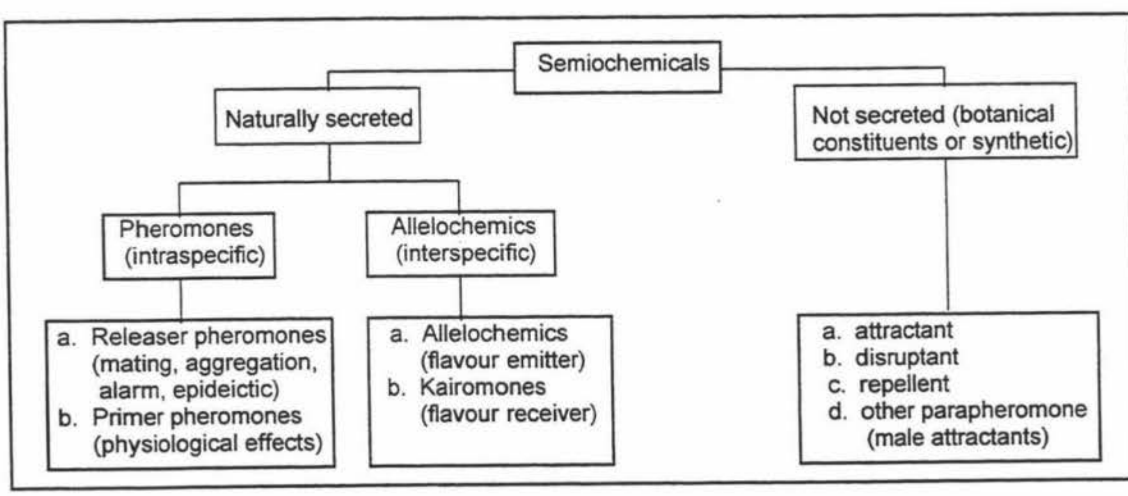

Figure 2.1 Classification of semiochemicals.
Source: Loke *et al.*, 1992.

Most developments in semiochemical control are to do with the use of sex pheromones to attract male insects (Lewis & Nordlund, 1985). Pheromones have specific desirable characteristics such as a high level of species specificity, non-toxicity to other living organisms, and activity at low concentration (Hodosh, Keough, & Luthra, 1985, *cited in* Jones, 1994). Sex pheromones are used for two major purposes, monitoring and controlling pest populations (Jones, 1994).

Monitoring pest populations, a basic component of IPM strategies, may be conducted with the assistance of semiochemical attractants (Chapman *et al.*, 1992; Jones, 1994; van Emden & Peakall, 1996; Herman & Clearwater, 1998). Most of these attractants are able to attract only male insects (e.g. sex pheromones). There are two key issues regarding the use of attractants to monitor pest populations. Firstly, the traps have to be able to catch samples of pests in a consistent proportion with the pest population as it fluctuates (Jones, 1994; Herman & Clearwater, 1998). Secondly, the traps must be easy to use, in the sense that the results must be easily interpreted to estimate the actual pest populations in the growing environment (Jones, 1994). Also they must be easy to service (Herman & Clearwater, 1998).

For the purpose of controlling pest populations, semiochemicals are used in three ways, i.e. mass trapping, lure and kill, and mating disruption (Jones, 1994). In mass trapping, a high density of sticky pheromone traps are used to annihilate insects (Jones, 1994; van Emden & Peakall, 1996). In most cases, sex pheromones are used to attract as many male insects as possible, and then remove them from the population to reduce female fertility (van Emden & Peakall, 1996). This method often works effectively only when insect population is low. Greater success may be achieved with the use of pheromones which attract both sexes. The lure and kill method is similar to mass trapping, but instead of being trapped, the responding insects actually come in contact with insecticides, which then kill them (Jones, 1994). Mating disruption involves a small, but sufficient, quantity of sex pheromones being released into the air surrounding the crops to confuse the male insects and prevent them from locating the female ones (Chapman *et al.*, 1992; Jones, 1994; van Emden & Peakall, 1996). The pheromone is normally distributed either by spraying "encapsulated droplets (which tend to release pheromone for a few days only) or broadcasting hollow polymer fibers sealed at one end and a few centimeters in length" (van Emden & Peakall, 1996, pp. 125).

D. CHEMICAL CONTROL

The term "chemical control" used here refers to the use of pesticides to control pest populations. It incorporates a wide array of agricultural chemicals such as insecticides, herbicides, fungicides, miticides, bactericides, etc. Some pesticides are derived from naturally-occurring chemicals in plants, or organisms, while most pesticides are synthetically manufactured in agrichemical industries.

Graham-Bryce (1987) proposes that the use of chemicals has at least five advantages, in that they are: highly effective in the absence of resistance, rapid acting, economical, flexible and readily available, and easy to use by growers. However, he also acknowledges that there are some disadvantages of the use of pesticides as a curative measure compared to other approaches, such as; resistance, insufficient selectivity, inappropriate persistence, induction of secondary pests, transient effectiveness, and weather-dependency.

Experience has proven that when chemical control is used without considering the presence of natural pest enemies, pest problems can increase rapidly. However, the use of pesticides is still needed in IPM, although they are no longer the first priority, given that they are selectively used. The selectivity here refers to physiological and ecological selectivity (Hull & Beers, 1985; Graham-Bryce, 1987). Physiological selectivity is the selection of pesticide based on its characteristic as a chemical compound in terms of mortality rate of the target pests (Hull & Beers, 1985), while ecological selectivity is the concept of maximising dosage transfer to target pests while minimising impacts on unintended targets (Graham-Bryce, 1987).

Despite large efforts by agrichemical companies to produce less toxic and more selective chemicals which are compatible with IPM (van Emden & Peakall, 1996; Kelly, 1998), many chemicals used currently are still broad-spectrum in nature because of difficulties in developing target-specific chemicals (Hull & Beers, 1985). In many cases this situation leaves growers only one option, that is to use broad-spectrum pesticides in ecologically selective ways. This includes correct selection of pesticides, proper timing, reduced dosage, and improved application techniques and placement (Hull & Beers, 1985; Graham-Bryce, 1987; van Emden & Peakall, 1996).

Pesticides are not equal in their toxicity to pests and natural enemies, therefore, preference should be given to pesticides which offer more selectivity to a beneficial organism, while still maintaining adequate toxicity to the target pests (Hull & Beers, 1985; van Emden & Peakall, 1996). Timing of application is considered by Newson *et al.* (1976, *cited in* Hull & Beers, 1985) as "the most effective and economical method" of achieving high selectivity of pesticide use. However, determining the proper time to apply pesticides requires knowledge of the biology and behaviour of the target pests and their natural enemies, and information about the economic thresholds (Hull & Beers, 1985). For example, pesticides can be applied before the arrival or introduction of beneficial organisms, or while they are protected in some way (for instance while they are in the pupal stage).

Attempts to reduce pesticide dosage in an IPM system should take into account the optimal dosage required to prevent an economic loss (Metcalf, 1980) and the potential for natural enemies of the pests to survive similar dosage (Hull & Beers, 1985). With their computer simulation, Tabashnik and Croft (1982, *cited in* Hull & Beers, 1985) demonstrate that lower pesticide use is likely to reduce pest resistance whilst maximising biological control. They also demonstrate that the use of low dosage chemical or pesticide mixtures has the potential to achieve effective pest control, preserve natural enemies, and is easier to combine with other IPM control measures.

Application techniques and placement in an ecologically selective approach relates to the method of application, topography, and the microclimate environment (Hull & Beers, 1985). Application techniques can be broken down into two areas. The methods of application (e.g. concentrate spraying, seed treatments, etc.) and technology of application (e.g. ultra-low volume technique, electrostatic sprayers, etc) which aim to achieve more efficient pesticide use. Moreover, the use of these techniques may be accompanied with selective placement of the pesticides in local areas or parts of the plant where pest attacks are more severe than they are in other areas or parts. This kind of selectivity also aims to minimise impacts on non-target organisms.

Considering the slow development of new pesticides which are compatible with IPM programmes, and the potential of increased pest resistance to the currently used pesticides, van Emden and Peakall (1996) suggest some strategies to prolong their useful life. Among the strategies are rotational use of pesticides and increasing the contribution of other control methods in IPM.

E. HOST-PLANT RESISTANCE

Host-plant resistance is defined by Chapman *et al.* (1992) as "the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect". Although he defines it in relation to insects only, the definition can be applied to other pests as well (excluding weeds). Host-plant resistance can be categorised into three groups based on the way the plant reacts against pests (Chapman *et al.*, 1992; van Emden & Peakall, 1996). These groups are: antixenosis, antibiosis, and tolerance.

Antixenosis refers to the characteristics of the plant which make it unattractive to pests for feeding or oviposition, hence reducing their colonisation of the plant (van Emden & Peakall, 1996). The term antixenosis is introduced to replace the term "non-preference", which is considered as referring more to pests' behaviour in a choice situation, whereas antixenosis refers more to the plant's attributes (e.g. hairiness, tissue hardness) and 'non-acceptance' in a no-choice situation (van Emden & Peakall, 1996).

Antibiosis is the condition where the plant negatively affects the performance of the pests feeding on it (Herzog & Funderburk, 1987; Chapman *et al.*, 1992). Performance here refers to pest characteristics such as growth, survival, generation time, fecundity, longevity, etc. While tolerance is the ability of the plant to endure or compensate for damage (usually measured as yields) caused by pests, compared with that of other non-tolerant plants, given the same pest numbers and conditions (Herzog & Funderburk, 1987; Chapman *et al.*, 1992; van Emden & Peakall, 1996). Host-plant resistance may result from either one of these types, or a combination of them.

The mechanisms of such resistance are not completely known, however, van Emden (1987) suggests that the resistance mechanisms may relate to factors such as foliar colour, palatability, hairiness, waxiness, tissue hardness, etc. Moreover, although resistance genes are passed on to subsequent generations, their expressions are also affected by variations in the environment (Chapman *et al.*, 1992). Changes in the temperature, light intensity, soil fertility and moisture can increases or decrease a plant's resistance to pests. The effects influenced by these factors are complex and many conflicting observations have been reported (Chapman *et al.*, 1992).

Variation in a host-plant's genetic may come from such diverse sources as germplasm banks[1], geographic location, random and induced mutation, or in some cases, from wild races of a given plant (van Emden, 1987). New resistant varieties may be developed from repeated selections and breeding processes of these variations. Such breeding processes can be further differentiated into classical approach, induced mutation, and molecular approaches (National Research Council, 1996). The classical approach, or hybridisation, is used to transfer genes from one plant to other compatible plants, usually from the same species or genus. This may include techniques such as grafting, pedigree breeding (van Emden, 1987), and random outcrossing (van Emden & Peakall, 1996). Induced mutation is conducted by exposing seeds to X-rays or chemical treatment of the seeds (van Emden & Peakall, 1996). The molecular approach involves transgenic

[1] Banks with collections of either regional or world wide variation, kept as small stocks of seeds, budwood, etc., stored or regenerated as necessary to maintain viability on a continuing and permanent basis (van Emden & Peakall, 1996).

techniques using molecular technology such as gene splicing (National Research Council, 1996).

Strong plant resistance however, although appearing to offer less severe damage from pest attack, may carry risks such as the production of secondary plant compounds which can be toxic to natural enemies (Herzog & Funderburk, 1985), the survival of adapted biotypes of the pests, reduced yields because of energy diversion for defence, increased level of toxins for human consumption, and the possibility of increased susceptibility to other pests (van Emden & Peakall, 1996). Therefore, the primary objective of plant breeding programmes nowadays is not necessarily to develop strong plant resistance. Instead, van Emden and Peakall (1996) suggest that the main goal of plant breeding programmes is to generate partial plant resistance "on which pests are more easily killed with insecticides, on which we can make insecticide applications more selective in relation to natural enemies, and on which biological control would be enhanced" (pp. 152-153).

2.3 IPM FOR GREENHOUSE CROPS

2.3.1 INTRODUCTION

Growing crops in greenhouses differs from producing them in the fields (van Lenteren & Woets, 1988). As an isolated unit, a greenhouse may provide the crops with an environment which is different from that outside. Growers can have greater control over the growing environment in the greenhouses than they have in the fields. This may include control of pest immigration, sanitation, temperature (van Lenteren & Woets, 1988), and can include adjustments to air humidity to avoid unwanted extremes (Nederhoff, 1997a), adjustments to light to control day length (Jones, Chase, Garber, Hudson, Norcini & Bondari, 1996), and manipulation of CO_2 levels (Martin, 1993a; Nederhoff, 1996). As a result, many greenhouses (in temperate areas) can be utilized for crop production throughout the year (Jarvis, 1992).

However, while healthy crops which are able to produce high quality and quantity yields are the ideal, such plants are usually affected by a combination of many factors, as shown in Figure 2.2. These factors affect crops in hierarchical order (Clarke, Shipp, Jarvis, Papadopoulos, & Jewett, 1994). First-order factors affect the greenhouse crops directly; second-order factors affect the first-order factors directly and indirectly affect the greenhouse crops, and so on. For example, pests can affect the crop performance directly, but pests are also affected directly by the greenhouse environment, chemical pesticides, and the management system applied in the greenhouse. In this framework, it is clear that the same factors may affect the crops both directly and indirectly (Clarke *et al.*, 1994). For instance, pesticides may directly reduce the pest population and indirectly improve the quality and quantity of the crop. Examples such as this illustrate why managing greenhouse crops is complicated and requires good integration of all factors in order to ensure production of crops in an efficient and profitable manner.

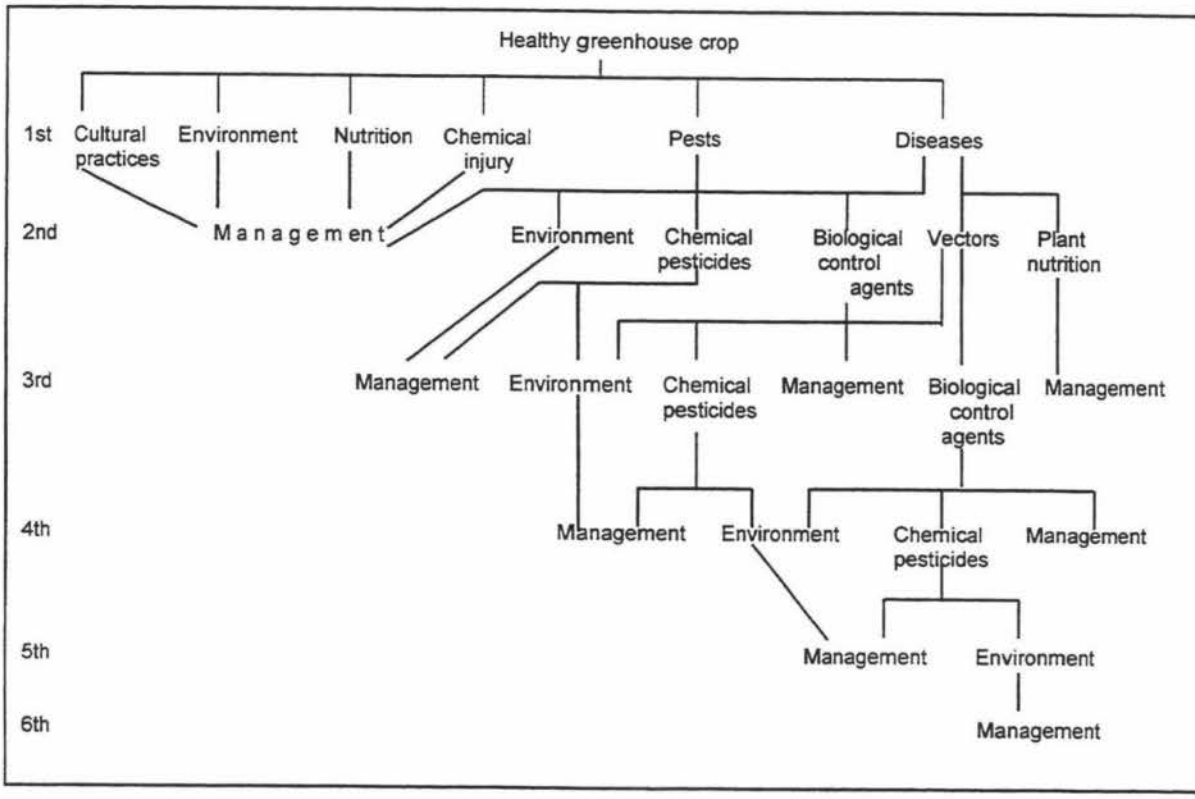

Figure 2.2 Factors affecting greenhouse crops within an integrated crop production framework.
Source: Clarke *et al.*, 1994.

Because the management system is so complex, and as the costs involved in both setting up and maintaining the greenhouse are high (Gould, 1987), only high value crops, such as tomatoes, capsicums, and ornamentals, are grown in greenhouses in New Zealand. Any damage to the crops, particularly from pests, is not tolerated. However, the environment inside greenhouses can be very favourable for the development of insects and diseases, due to the continuous growing of crops in a warm environment (van Lenteren & Woets, 1988). Moreover, many of the greenhouse pests have developed resistance to many pesticides (Gould, 1987; van Lenteren & Woets, 1988; Hoddle, van Driesche, & Sanderson, 1998). Therefore, managing pests in such a way that integrates all possible control methods such as with IPM strategies, is very important in order to produce high quality and quantity yields.

Currently, in many parts of the world, intensive research is being conducted to support the development of IPM. Much of this research is on the development of biological control of common greenhouse pests. In the implementation of this research, the use of beneficial organisms still needs to be matched to the crop features, greenhouse environment, and other control methods. Since many greenhouse crops have common pests, the review below will discuss first some IPM methods based on these common pests, which are also pests of greenhouse tomatoes, the focus crop of this thesis. The current advances of the IPM programme for greenhouse tomatoes in New Zealand will then be summarised.

2.3.2 COMMON PESTS OF GREENHOUSE CROPS

Most insects and diseases are able to infest more than one crop. Diseases may create fewer problems for greenhouse crops generally because of the availability of disease resistant varieties for most important vegetable crops (van Lenteren & Woets, 1988). Moreover, many diseases can be greatly reduced by maintaining adequate ventilation, low humidity, and keeping the leaves dry (Martin, 1995). Meanwhile, insects still create problems for growers, as well as for researchers, because of the existence of new, more damaging strains, and their possibility of being accidentally imported into New Zealand.

GREENHOUSE WHITEFLY

Greenhouse whitefly (*Trialeurodes vaporariorum*) is a pest of many plant species, including greenhouse crops such as tomatoes, cucumbers, and ornamentals. The damage caused by this pest has been investigated and reported by many authors (e.g. Gould, 1987; Muggleston, 1991; Spriegel, 1992; Marais, 1998). Greenhouse whitefly feed particularly on the young shoots of the plant. They also secrete honeydew, which provides a favourable environment for the development of black sooty mould. Eventually this will reduce the effectiveness of photosynthesis of the plant, spoil the fruit, and increase the cost of post-harvest handling because of the need to wash the produce before selling it.

As early as 1926, biological control for greenhouse whitefly had been developed by English entomologists, and, in the 1930's the parasite, *Encarsia formosa* (popularly known among growers as *Encarsia*), was shipped to some European countries, Canada, Australia, and even New Zealand (van Lanteren & Woets, 1988; Hoddle *et al.*, 1998). However, after 1945 the use of *Encarsia* was reduced sharply as growers switched to using pesticides for more convenient and efficient control of greenhouse whitefly. The parasites became popular again after enormous outbreaks of whitefly in the 1970s in the

Netherlands due to the development of resistance to the pesticides used to control them. This also marked the revival of the use of biological control in greenhouses in many countries (van Lenteren & Woets, 1988).

Encarsia kills the host in two ways. First, by wounding the whitefly for adult nutritional purposes (host-feeding) and then subsequently killing them. Second, by laying eggs in whitefly nymphs, which will eventually hatch out and kill the hosts from within. The key to success in introducing *Encarsia* into greenhouses is making sure that whitefly numbers are very low at the time the parasites are released, and then conducting multiple introductions of *Encarsia* to stabilise the population dynamics (Spriegel, 1992; Hoddle *et al.*, 1998; Martin & Marais, 1998). *Encarsia* works best in greenhouse tomatoes and cucumbers (Hoddle *et al.*, 1998). In greenhouses, *Encarsia* is introduced as parasitised whitefly scales (black scales), glued to a piece of card, which should be attached to the plant (Figure 2.3). Each card may contain between 50 to 75 black scales.

Figure 2.3 *Encarsia* card.

However, the effectiveness of *Encarsia* must be backed up by providing an optimal greenhouse environment (Hoddle *et al.*, 1998; Martin & Marais, 1998). This means maintaining a warm temperature at about 23 °C. For this reason, *Encarsia* are particularly effective during summer. Low temperatures prevent the parasites from walking and flying to locate the hosts.

An optimal greenhouse environment also means that growers need to control the weeds surrounding the structure, maintain the greenhouses properly to prevent new infestations, and prevent *Encarsia* from exposure to toxic pesticides (Martin & Marais, 1998). Moreover, growers need to monitor their crops regularly to spot check for local whitefly outbreaks (Martin & Marais, 1998). The use of *Encarsia* without any of these activities will significantly reduce the effectiveness of the parasites.

TWO-SPOTTED MITE

Two-spotted mite (also known informally in greenhouse production as red spider mite or two-spotted red spider mite) (*Tetranychus urticae*) has a wide array of hosts, which includes almost all important greenhouse crops such as tomatoes, cucumbers, capsicums, beans, ornamentals, and strawberries (Spriegel, 1992). It has become a major pest of protected crops throughout the world (Gould, 1987). The mites are active during winter in greenhouses, and are able to withstand soil sterilisation in greenhouses (van Lenteren & Woets, 1988). Although the pests do not often attack the fruits or flowers of the crops, they can cause substantial damage to the leaves by sucking out the cell contents, which eventually causes significant yield reduction (Gould, 1987; Muggleston, 1992). In heavy infestations, the plant may be covered with web and die prematurely (Muggleston, 1992). In New Zealand, they are rarely a problem on greenhouse tomatoes (Martin, 1995), but do cause damage on other crops mentioned above.

The biological control agent developed for two-spotted mites is *Phytoseiulus persimilis*. This predator of two-spotted mites is actually a mite itself. These predators were initially applied to greenhouses in 1968 in Great Britain (van Lenteren & Woets, 1988). Within twenty years, their use in greenhouse areas for controlling two-spotted mites had increased more than 25 fold. As predators, *P. persimilis* mites are particularly effective. They do not harm the crops at all, and their life-cycle is twice as rapid as that of two-spotted mites (Gould, 1987; Martin, 1995).

Like other biological control agents, *P. persimilis* needs growers' assistance to maintain a favourable greenhouse environment for maximum effectiveness. The optimum temperature for the predator mites is about 20°C. At a very warm greenhouse environment (27 °C), the females stop breeding, whereas the two-spotted mites can multiply rapidly at this temperature (Gould, 1987). It is important to introduce the predator evenly throughout the crop at the beginning of the programme, and while the number of two-spotted mites is low. The predator needs to be re-introduced in the next growing season (Gould, 1987).

THRIP

The two most common thrips in New Zealand greenhouses are onion thrips (*Thrips tabaci*) and western flower thrips (*Frankliniella occidentalis*) (Marais, 1998). Both can be pests of cucumbers, capsicums, eggplants, tomatoes, and ornamentals (Spriegel, 1992). Western flower thrips are particularly difficult to handle because of their resistance to many pesticides and their ability to survive outdoors (Martin, 1996). The thrips suck out cell contents of flowers, fruits, and leaves, causing silver or white-grey spots on parts of the plant (Nederhoff, 1997b; Marais, 1998). High infestations of thrips may prevent flower setting and consequently, reduce yields (Nederhoff, 1997b). Apart from feeding damage, thrips are also vectors of harmful greenhouse crop viruses such as the tomato spotted wilt virus (TSWV) (Workman, Dymock, Martin, & Ennis, 1994; Martin, 1995; Marais, 1998). The virus, which affects tomatoes and capsicums, can be transmitted by the pest feeding on infected plants (Marais, 1998).

Both types of thrips can be controlled, although not completely, by *Amblyseius cucumeris*, a predatory mite which feeds mainly on the first instar of thrips and also the pollen of the crops. *A. cucumeris* can also prey on two-spotted mites (Marais, 1998). They favour a relative humidity above 70% and temperature between 12° and 30 °C. A major limitation of *A. cucumeris* as a biological control agent is its natural reproductive diapause during winter. At this time its prey keeps breeding (Martin, 1990b; van Houten, van Rijn, Tanigoshi, van Stratum, & Bruin, 1995). The persistence of *A. cucumeris* in greenhouses, even in the absence of thrips, is determined by the availability of pollen as an alternative food source (Workman *et al.*, 1994; van Houten *et al.*, 1995). That is why this biological control agent performs better in capsicums, compared to cucumbers.

The effectiveness of *A. cucumeris* should be supported by the maintenance of good sanitation in the greenhouse (Martin, 1996; Marais, 1998). Infested plants should be disposed of as soon as possible. Growers need to make sure also that new plants brought to the greenhouse have not been infested by the TSWV (Martin, 1996). These activities can still be accomplished with the use of thripstick[2], which should be placed below the crops to catch the thrips as their larvae drop from the leaves to pupate on the ground (Gould, 1987).

APHID

Aphids can attack a wide range of greenhouse crops such as tomatoes, capsicums, cucumbers, beans, and ornamentals (Spriegel, 1992), and may cause damage to host plants in several ways (Herman, 1995). They suck out and drain plant juice, release toxins which may alter plant growth, and produce honey dew, which allows the growth of black sooty mould (Herman, 1995, Nederhoff, 1997b). In this way they cause direct damage to the host. Indirectly, they may transmit viruses from plant to plant (Herman, 1995; Martin & Workman, 1997).

Two types of aphids often found in greenhouses are green peach aphid (*Myzus persicae*) and melon aphid (*Aphis gossypii*). The former has long been known as being resistant to many pesticides, but a case of melon aphid resistance in New Zealand was first reported two years ago (Martin & Workman, 1997). Currently, there is no biological control agent commercially available for New Zealand greenhouse growers to control aphids (Martin, 1997). The recommended control is to apply selective pesticides, and wait for natural immigration of aphid predators and parasites (Martin, 1995). Cultural practices such as clearing the weeds surrounding greenhouses, and the use of sticky cards, may help reduce aphid populations further (Herman, 1995). Greenhouse growers are expected to adopt an aphid pesticide resistance prevention and management strategy to prevent severe damage caused by melon aphids (Herman, 1995; Martin & Cameron, 1997). This strategy recommends that growers utilise non-chemical methods of aphid control, reduce pesticide use, and alternate the pesticides used when applications are required.

CATERPILLAR

Like aphids, caterpillars of moths and some species of butterflies also have a wide range of hosts and have spread widely in New Zealand (Valentine, 1998). The two most common caterpillars in New Zealand are green looper and tomato fruitworm. Both cause holes in the leaves (Nederhoff, 1997b), which are unacceptable for ornamental plants. In fruit-bearing crops, such as tomatoes and capsicums, they may also bore into the fruit (Valentine, 1998). Currently, they are controlled by a spray containing the biological

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[2] A board containing sticky polybutane and deltamethrin to serve as a combined mechanical and chemical control of thrips.

agent *Bacillus thuringiensis* (Gould, 1987; Martin, 1995; Nederhoff, 1997b). This environmentally-friendly spray is no threat to other biological control agents (Gould, 1987).

DISEASES

Without any adjustment, the greenhouse environment tends to be generally warm, humid, and wind-free, which is ideal for the development of many diseases, particularly those caused by fungi and bacteria (Jarvis, 1992; Nederhoff, 1997a). The list of common diseases in New Zealand greenhouses and their hosts is shown in Table 2.1. The list was compiled from IPM Manual series for greenhouse crops published by the New Zealand Institute for Crop and Food Research Limited.

Table 2.1 Common diseases in New Zealand greenhouse crops.

Cause	Diseases	Hosts
Fungi	*Botrytis cinerea*	Tomatoes, capsicums, cucumbers, beans, roses
	Sclerotinia spp.	Capsicums, cucumbers, beans
	Bremia lactucae, Peronospora sparsa (downy mildew)	Capsicums, cucumbers, roses
	Erysiphe cichoracearum, Sphaerotheca pannosa (powdery mildew)	Cucumbers, roses
	Didymella lycopersici (stem canker), *Alternaria solani* (early blight), *Phytophthora infestans* (late blight)	Tomatoes
	Puccinia spp., *Phragmidium* spp. (rust)	Beans, roses
	Fulvia fulva (leaf mould)	Tomatoes
	Colletotrichum coccodes (anthracnose)	Cucumbers, beans
	Rhizoctonia spp.	Capsicums, beans
Bacteria	*Pseudomonas syringae* (bacterial speck), *Xanthomonas campestris* (bacterial spot), internal stem root, stem bacteriosis, tomato canker, *Pseudomonas corrugata* (tomato pith necrosis)	Tomatoes
Virus	Tomato mosaic virus	Tomatoes, capsicums
	Tomato spotted wilt virus	Tomatoes, capsicums, beans
	Cucumber mosaic virus	Tomatoes, cucumbers

As mentioned earlier, many of these diseases are encouraged by poor environmental management in the greenhouse. Poor ventilation increases the humidity inside the greenhouse, which worsens *Botrytis*, *Sclerotinia*, and leaf mould infestations (Martin, 1995). Long periods of high humidity provide a suitable environment for fungal spores such as *Botrytis*, to establish, germinate and multiply, particularly on injured plants or old leaves on the ground (Nederhoff, 1997a). Fungal and bacterial infection is more likely to occur in a film or drop of water on the plant surface (Jarvis, 1992), when all other factors are favourable. Therefore, one of the main IPM techniques to control diseases is to keep plants dry at night (Martin, 1995). This can be achieved by warming the air, circulating it through the crops, and opening the vents for short intervals (5-15 minutes) during the night to eliminate warm and wet air (Martin, 1995). Moreover, greenhouse maintenance is important: greenhouses should be cleaned by removing old leaves and infected plants from the ground, and weeds which could act as hosts for diseases should be taken out from around the greenhouses (Collins, 1990; Jarvis, 1992; Nederhoff, 1997b).

Among the diseases, *Botrytis* is regarded by greenhouse tomato growers in New Zealand as being the most troublesome (Martin, 1995). Not only are its spores easily spread, but also the pathogen has a wide host range. Besides the preventative approaches discussed above, researchers are now trying to develop beneficial organisms to control this disease. The organisms are *Trichoderma* and *Cladosporium* species, which work as antagonists to *Botrytis*. By applying the beneficial organisms to the infected wounds, they may prevent *Botrytis* from infecting fresh wounds (Eden & Hill, 1996; Nederhoff, 1997a).

One disease against which the environmental standard disease control measures are ineffective is powdery mildew, which can germinate at low humidity (Nederhoff, 1997a). Currently, this mildew is controlled by chemicals, which are applied under strict guidelines to prevent the development of fungicide resistance (Martin, 1993a). Moreover, before applying chemicals in greenhouses, growers should consider the compatibility of the products and their effect on other beneficial organisms in the crop. Growers are required to check the pesticide label instructions carefully prior to use, and to consult their advisors regarding pesticides not listed in the IPM manual.

To control virus-transmitted diseases, different approaches are required. These diseases are mainly transmitted by insects (mites and aphids) or by mechanical damage. Tomato mosaic virus can now be prevented in capsicums by growing a resistant variety (Martin, 1994b), or in tomatoes by inoculating susceptible cultivars with a mild strain of the virus (Martin, 1995). Tomato spotted wilt virus (TSWV) is transmitted by onion thrips and western flower thrips, and can cause bronze top of tomato plants. The virus is acquired by larval thrips through feeding on infected plants, and is then transmitted to healthy plants by the adult thrips. The wide range of hosts of this virus, including weeds, make sanitation (removing weeds and infected plants) one of the more effective control measures (Martin, 1995).

Cucumber mosaic virus is transmitted by aphids and also mechanically (Martin, 1993b). The spread of mechanically-transmitted diseases can be prevented, or at least, reduced, by isolating all tools used for treating infected plants. Both TSWV and cucumber mosaic virus can also be managed by controlling their vectors.

WEEDS

Weeds often become alternative hosts for insects and pathogens, so, must be controlled. With the increasing number of growers in New Zealand using soiless media, weeds have become a lesser problem. Most soiless media are sterile and therefore they carry no weed seeds. However, particular attention must be given to weed control in the area surrounding the greenhouses, as weeds there may act as sources of reinfestation. It is important that these weeds are controlled 3-4 weeks prior to pulling out old crops from the greenhouses, to prevent insects such as whitefly moving from the dying weeds to newly-planted crops and infecting them (Martin, 1995). Important weeds to be controlled are broadleaf weeds such as mallow, sowthistle, and nightshade (Marais, 1996a). Insects such as *Aphis gossypii* are known for their ability to feed on over 20 weed species, even those which are not crop-related weeds (van Emden & Peakall, 1996). Therefore, it is important always to apply cultural control to the whole environment, not just where the crops are situated.

2.3.3 THE USE OF BUMBLEBEES FOR POLLINATION

The importance of bees as good pollinators has long been known in agriculture. Two genera of bees, *Apis* (honey bees) and *Bombus* (bumblebees), are currently produced commercially as pollinators (van Heemert, de Ruijter, van Eijnde, & van der Steen, 1990; de Ruijter, 1997; Corbet, 1996). There are four species of bumblebees established in New Zealand. These were imported between 1885 and 1906 from England to help pollination of red clover (Anonymous, 1992; Matheson, 1997). Bumblebees are more popular than honey bees in temperate regions because of their greater ability to adapt in cooler weather with low light intensity (van Heemert *et al.*, 1990; Corbet, 1996).

Bumblebee colonies are sold in cardboard hives (Figure 2.4) with special devices such as a "bee lock system" to keep the bees temporarily in the hives, and so safe, while pesticides are sprayed, or to manage flower pollination (Griffiths & Robberts, 1996). Since bumblebees are very sensitive to many pesticides, the adoption of bumblebees has increased the adoption of other biological control agents for greenhouse crops (Anonymous, 1992; Martin, 1994a).

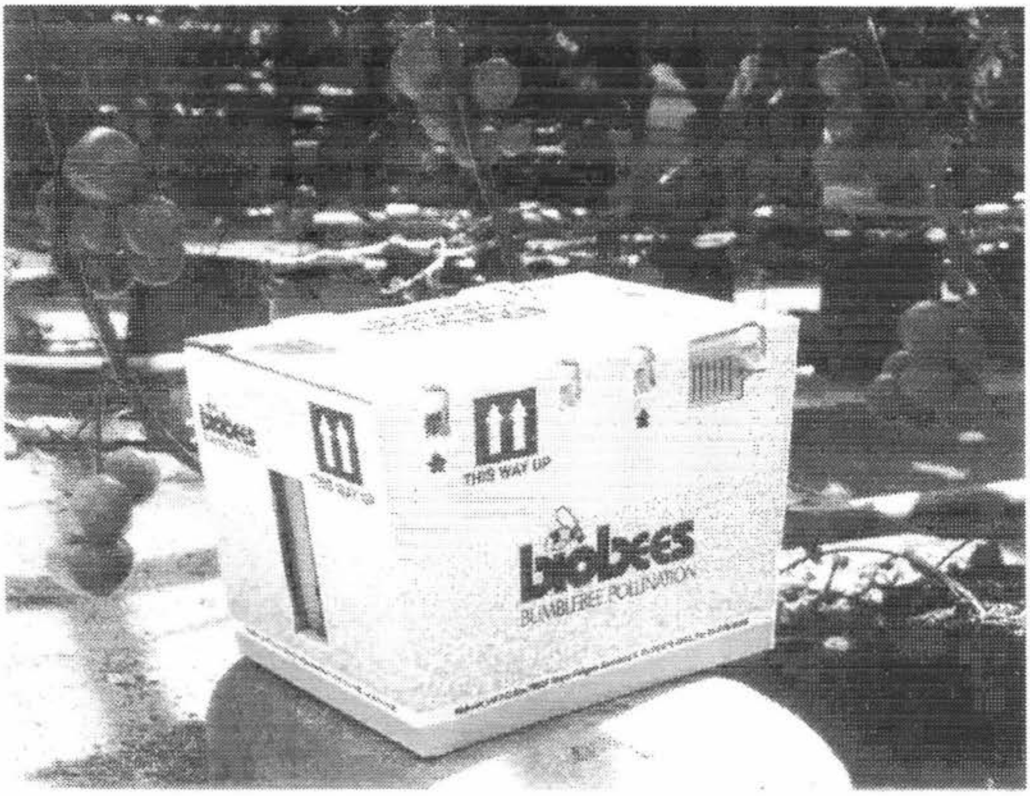

Figure 2.4 Bumblebee cardboard hive.

Bumblebees have several characteristics which may increase their effectiveness as pollinators, particularly in greenhouses. As individualists, bumblebees do not convey information about alternative food sources they find to their nestmates, and therefore seem to spread their attention relatively evenly among food sources (van Heemert *et al.*, 1990; Corbet, 1996; Griffiths & Robberts, 1996). This characteristic is particularly important during spring, where flowers inside greenhouses have to compete with other flowers outside the greenhouses. Moreover, while honey bees concentrate on collecting either nectar or pollen during an individual foraging trip, bumblebees normally collect both at the same time, and therefore assist pollination on each of their visits to the flowers. By seeking out flowers at their optimal ripeness (Anonymous, 1992) and clinging to the flowers and vibrating them at a high frequency, bumblebees bring out of the anthers the pollen, which will then fall to the stigma (Corbet, 1996). In greenhouse tomatoes, this results in increased yield (van Ravestijn & van der Sande, 1991) and greater uniformity of fruit size (Anonymous, 1992).

In addition, the brown mark left by bumblebees following their visit to the stigma enables growers to be reassured that pollination has occurred (Griffiths & Robberts, 1996). The significance of this pollination effectiveness indicator may differ from season to season.

The indicator is most prominent during winter, because flowers open for a longer time during this period, providing more time for bumblebees to visit them, and hence leave a clearer mark. During summer, when flowers open for a relatively shorter time, the visiting time also is shorter, and therefore the marking is more difficult to see. Some flowers may even show no mark at all (Griffiths & Robberts, 1996). Pollen production is influenced by factors such as temperature, relative humidity, irrigation (related to water stress), or chemical applications (Griffiths & Robberts, 1996). Consequently, if growers find that their bees are refusing to visit the flowers, something may be wrong with the crop's growing environment.

2.4 IPM FOR GREENHOUSE TOMATOES IN NEW ZEALAND

Probably, one of the most advanced IPM programmes for greenhouse crops in New Zealand is that designed for tomatoes. The importance of tomatoes in the domestic fresh vegetable industry, as well as for the export market, may have encouraged its development. A recent two-year project by the Fresh Tomato Sector of the New Zealand Vegetable and Potato Growers' Association[3] and Crop and Food Research aimed to ensure the successful and widespread adoption of IPM through intensive research and the provision of technical assistance for growers (Robertson, 1995).

Research, particularly in the biological control area, makes up an important part of the programme since there is always the possibility of having to deal with accidentally imported new pests or increased resistance of pests to the currently used pesticides (Martin, 1996). Researchers, therefore, need to plan well in advance before any new pest establishes in New Zealand. Moreover, as suggested by Metcalf (1980) research programmes should also assess the selectivity of diverse pesticides on pests and natural enemies. Besides, there is an urgent need to train more consultants, both independent ones and the ones employed by the retailers of IPM products, to assist growers in the implementation of IPM programmes (Martin, Cameron, Falloon, Fletcher, & Herman, 1993; Robertson, 1995; Anonymous, 1998). Assistance from consultants is particularly critical at the beginning of an IPM programme (Martin, 1995; Anonymous, 1998). This service was provided free for New Zealand vegetable growers for a few years at the beginning of the introduction of IPM programmes (Martin, 1993c). Consultancy advice, together with the provision of IPM programme manuals, and grower discussion groups, provide growers with access to the information they need. The IPM specialist advisors

[3] A grower organization aims to represent the interest of New Zealand's commercial growers.

focused their work on a group of 'exemplar growers' in both the North and South islands (Robertson, 1995). This work involves providing advice on IPM methods and field supervision in the first two growing seasons. These growers are then expected to share the knowledge with other growers.

To date, the greenhouse tomato IPM manual has been revised once based on the research results and growers' experiences. The manual, edited by Nicholas Martin from the New Zealand Institute for Crop and Food Research Ltd., provides information and recommendations on the integration of biological control method (use of *Encarsia* and bumblebees) with other pest control measures in an IPM programme, such as plant management (e.g. deleaving, layering, irrigation, nutrition, choosing plant density), environmental control, and pesticide applications. In the IPM manual for greenhouse tomatoes, only one level of *Encarsia* introduction is used throughout the season. The time period *Encarsia* is required depends on the ability to heat, season, crop duration, and cropping system (e.g. layering), while the commencement of *Encarsia* introduction is influenced by season, the presence of pests, and the persistence period. The IPM manual also stresses the importance of having low whitefly and other pest (e.g. thrip and tomato stemborer) populations prior to *Encarsia* introduction. A monitoring chart for whitefly monitoring is provided, along with the monitoring methods for other pests. In addition, the IPM manual provides information on the use of pesticides to control other pests (including diseases) and some environmental controls to deal with diseases. Recommendations for pesticide applications are always followed by information about their effects on *Encarsia* and bumblebees, if known. Threshold levels for some pests are also mentioned in the manual. The summary of the IPM programme for greenhouse tomatoes is shown in Table 2.2, while the details of each of the recommendations are provided in Appendix 1. Both the summary and the details are taken from the IPM manual for greenhouse tomatoes (Martin, 1995).

Table 2.2 Summary of IPM programme for greenhouse tomatoes.

Problems	Solutions	Notes
Whitefly	*Encarsia formosa* Buprofezin and Methomyl	 Some population of whitefly are resistant to buprofezin.
Aphid	Pirimicarb Natural immigration of parasites	
Caterpillar	B. thuringiensis,	The spray must cover both side of the leaf.
Fungus gnat	Diazinon,	
Spider	Pesticides for spider control	- Apply to the greenhouse structure as a high volume spray. - Try to make spray into direct contact wit the spider.
Onion thrip	Deltamethrin Endosulfan Methomyl	Deltamethrin is harmful to *Encarsia* for at least 3 weeks. Endosulfan is harmful to *Encarsia*, use before 2[nd] truss flowering. Methomyl is harmful to *Encarsia* for 7-14 days.
Western flower thrip	Maldison Methamidophos	Maldison pesticides are harmful to *Encarsia* for 10 days. Methamidophos pesticides are probably harmful to *Encarsia* for more than 4 weeks.
Tomato stemborer	Insecticides	
Tomato rust mite	Dicofol, Sulphur	Consult your advisor if you are not sure if the mites are present.
Two-spotted mite	*P. persimilis*	Consult your advisor about mite resistance and biological control assistance.
Botrytis	Environment control. Protectant fungicides Dicarboximides Benzimidazoles	 For routine control. Captan cannot be used for crops exported to Australia. Benzimidazoles are very harmful to *P. persimilis*.
***Didymella* stem canker**	Propineb Dichlofluanid	 Dichlofluanid high volume spray is safe to *Encarsia*, but concentrate spray is harmfül.
Early and late blight	Metalaxyl + Mancozeb Copper oxychloride Cupric hydroxide	Metalaxyl + Mancozeb is harmful to *P. persimilis*.
Leaf mould	Environment control. Benomyl Mancozeb, Maneb, Thiram.	 Benomyl is harmful to *P. persimilis* for up to 14 days.
Bacterial speck	Cultural control. Copper oxyxhloride, Cupric hydroxide,	Pull out and burn infected plants.
Bacterial spot	Cultural control. Streptomycin, Agrimy-cin, Key Streptomycin.	Remove infected plants including ripe fruit on the ground. Every 7-10 days on seedling tomatoes only.
Internal stem rot	Cultural control.	Prevented by growing strong plants.
Stem bacteriosis	Copper oxychloride, Cupric hydroxide,	
Tomato canker	Cultural control.	Remove and destroy infected plants.
Tomato pith necrosis	Copper oxychloride, Cupric hydroxide,	
Tomato mosaic virus		Inoculate susceptible cultivars with a mild strain of the virus, Tomovax.
Tomato spotted wilt virus	Cultural control. Thrip control.	Remove infected plants.
Cucumber mosaic virus	Aphid control.	
Pollination	Bumblebees	

2.5 THE CHARACTERISTICS OF IPM AS AN INNOVATION

Innovation is defined by Rogers (1983) as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (pp. 11). Therefore, although IPM was proclaimed in the 1950s as the only rational approach for achieving a long-term solution to pest problems (Metcalf & Luckman, 1982), it can still be considered an innovation by growers, as long as they perceive IPM as something new to them.

Rogers, E. M. (1995) identifies five characteristics of innovations which may affect the adoption decisions for a particular innovation. Different individuals may perceive a particular innovation differently in terms of its characteristics, and therefore they may make different adoption decisions. These five characteristics can be applied also to IPM when it is introduced to growers as an innovation. They are:

1. relative advantage: the degree to which an innovation is perceived as better than the idea it supersedes (Rogers, E. M.,1995, pp. 15). The relative advantage of IPM, in terms of economic and health benefits, is hard to measure in the short run (Wearing, 1988; Cornejo, Beach, & Huang, 1992; Zalom, 1993; Steffey, 1995). The high cost of labour associated with IPM or the expense of beneficial organisms, and the perceived risk of not spraying lessen the calculated short term profit (Wearing, 1988), while the long-term advantage, in terms of maintaining future productivity, is not observable at the time the decision to adopt or not to adopt is made.
2. compatibility: the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters (Rogers, E. M.,1995, pp. 15). Growers tend to prefer an innovation which is compatible with their beliefs and perceptions of crop production and pest control methods. Certain principles of IPM, such as the need to tolerate carefully maintained low levels of pests in the growing environment are sometimes unacceptable to growers. This is because they are not compatible with the common belief that all pests must be eliminated (Goodell, 1984).
3. complexity: the degree to which an innovation is perceived as difficult to understand and use (Rogers, E. M., 1995, pp. 16). The need to monitor continually the information about pests, crops, and weather conditions to make correct decisions, makes IPM more complicated and labour intensive, when compared to the calendar-based spraying system.
4. trialability: the degree to which an innovation may be experimented with on a limited basis (Rogers, E. M., 1995, pp. 16). In terms of trialability, the use of IPM in greenhouses has advantages compared to IPM in the field, because it can be trialed on a small scale on the property, such as in only one greenhouse. This is possible

because each greenhouse can be run separately and is thus unlikely to affect the production of other greenhouses (van Lenteren, 1995; McNally, *pers.comm.*, June 1998).

5. observability: the degree to which the results of an innovation are visible to others (Rogers, E. M., 1995, pp. 16). The benefits of using IPM may not be clearly evident and observable by other growers. In contrast, the immediate effect of reducing the use of pesticides, which reduce the cosmetic appearance of the crops, is easily observed, and hence makes IPM less attractive for other growers (Herbert, 1995).

The other characteristic of IPM strategies relates to their requirement for well integrated strategies to support each other (Section 2.2.3.4). This makes IPM a technology cluster. A technology cluster is defined by Rogers (1983) as an innovation which "consists of one or more distinguishable elements of technology that are perceived as being closely interrelated" (pp. 14). This means that growers can actually be interested in one or some of the strategies only, and not in IPM as a whole. Therefore, it is possible for growers to select only those pest control methods from the cluster which best suit their needs, goals, and specific conditions (Ridgley & Brush, 1992; Glynn, McDonald, & Tette, 1995). In some cases, the decision to adopt a certain method will enhance the decision to adopt other methods. For example, once growers have decided to adopt the use of bumblebees for pollination, they will need to adopt biological control methods as well, to reduce the use of chemicals (Steiner, 1996).

IPM is crop and site specific (Cornejo & Kackmeister, 1996), which means that modifications to the procedures specified in IPM manuals will be required to any specific growing system (Wearing, 1988; Ridgley & Brush, 1992; Glynn *et al.*, 1995). Growers, however, lack knowledge of how to modify the components of IPM strategies to better suit their circumstances (Martin, Workman, Burgess, & Wearing, 1984; Grieshop *et al.*, 1988; Zalom, 1993). Therefore, adoption of IPM strategies will require growers to undertake careful management from the planning stage, implementation, until the control stage.

2.6 FARM MANAGEMENT FUNCTIONS: PLANNING, IMPLEMENTATION, AND CONTROL

Management principles and knowledge are similar for any business (Downey & Erickson, 1987). Since there is a lack of literature in the management of the business of producing crops under IPM, insights from other management literature are needed. The general functions of farm management have been discussed in the farm management literature, for example Barnard & Nix, 1979; Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987). However, this topic is not covered as deeply or explicitly as it is in the business management literature. Therefore, in the following discussion of farm management functions, literature from business management will be included where appropriate.

Management involves three basic inter-related functions: planning, implementation, and control (Barnard & Nix, 1979; Boehlje & Eidman, 1984). Planning involves selecting certain strategies which best meet the goals of the firm from alternative courses of action that and establishing the standards of performance for control (Boehlje & Eidman, 1984). Implementation is the process where the planned strategies are put into action (Boehlje & Eidman, 1984). Downey and Erickson (1987) also considered that implementation comprised the functions organising, coordinating, and directing. The control function is the process whereby the actual performance of the farm is monitored and compared against the predetermined standards set in the planning phase (Boehlje & Eidman, 1984). Corrective action is taken when actual performance differs significantly from the predetermined standards (Barnard & Nix, 1979; Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987). Wright (1985) also offered a broader definition of control to include continuous modifications of plan based on the results of plan implementation monitoring to achieve the desired performances. For the purpose of this thesis, the more traditional definition of control as given by Boehlje and Eidman (1984) will be used.

Planning and control are interdependent functions because a plan provides the standards for control, and control helps to indicate the progress of the plan toward its goals over time (Koontz & Weihrich, 1990). Once a plan is implemented, control activities are conducted through time to monitor progress, identify deviations from the plan and initiate corrective action if required (Figure 2.5). If corrective action is not required, implementation of the current plan continues. However, if changes are required, a decision must be made as to whether the current plan should be modified or a new plan created, to correct the deviation. The management process is actually a cyclical process involving the three functions.

Planning can be undertaken at three levels: strategic, tactical, and operational (Boehlje & Eidman, 1984; Downey & Erickson, 1987; Parker, Shadbolt, & Gray, 1997). Strategic planning involves the whole business in the long term (several years). Tactical plans are within-year strategies which are used to achieve the longer-term farm business goals. Operational planning occurs on a day-to-day basis.

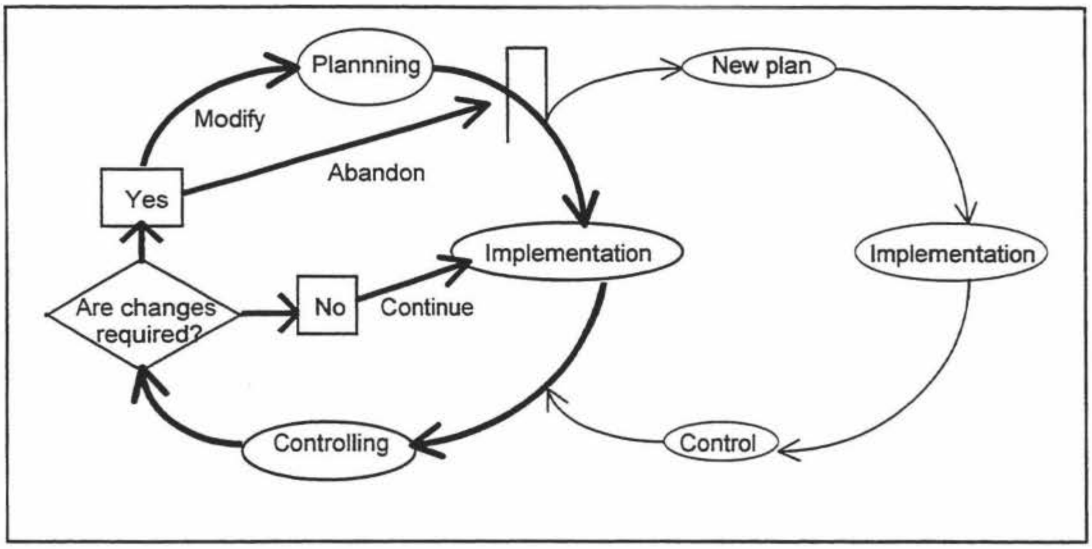

Figure 2.5 The management cycle.
Source: Parker *et al.*, 1997.

In the business management literature (e.g. Baird, Post, & Mahon, 1990; Koontz & Weihrich, 1990), the process which a planner goes through in making a plan is covered in detail. However, in the farm management literature this is not the case (Wright, 1985). The lack of conceptual development in the farm management planning literature is demonstrated by the lack of consistency in relation to descriptions of the process and the definitions of concepts. Analysis of the literature (Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987) suggests that planning comprises five steps; goal formulation, data collection, identification of possible strategies, analysis of possible strategies, and selection of strategies (Figure 2.6).

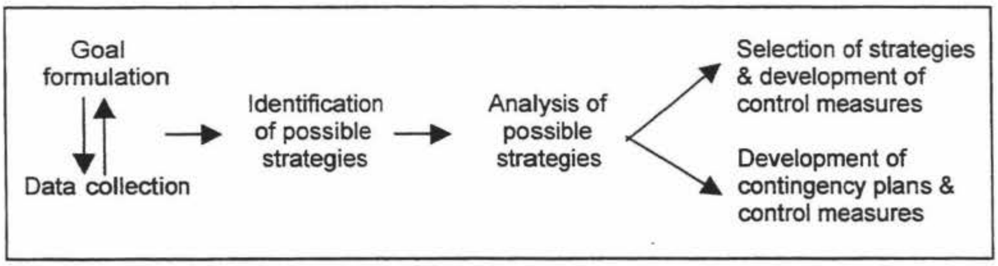

Figure 2.6 The planning process used by farm managers.
Source: After Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987.

The first two stages of farm planning, goal formulation and data collection, are interdependent (Downey & Erickson, 1987) and may occur simultaneously rather than in sequence (Baird *et al.*, 1990). The goals determined during the planning process set the direction for the farm business for a certain planning horizon. This may be short-, medium-, or long-term. The goals also provide the criteria by which the feasibility of alternative plans is judged (Boehlje & Eidman, 1984; Wright, 1985). The information collected during the initial planning phase serves two purposes. First, the information may be used to analyse the current situation and predict possible future situations and the likelihood of such situations (Boehlje & Eidman, 1984; Wright, 1985). This analysis is useful to determine whether the existing plan needs to be modified, or a new plan needs to be drawn up (Wright, 1985). Second, the information can also be used as a basis for developing alternative plans (Barnard & Nix, 1979). All alternative plans are analysed and evaluated in the light of the farm business goals and resources, before a choice of plan is made (Barnard & Nix, 1979; Wright, 1985; Downey & Erickson, 1987). The plan which best achieves the goals within the farm constraints is then selected.

After the plan is selected, the planner should also establish standards of performance (Boehlje & Eidman, 1984; Downey & Erickson, 1987). Standards are "the criteria against which actual performance can be measured and are derived from the goals that have been specified" (Boehlje & Eidman, 1984, pp.19). In addition to this, the plan should also specify the time interval at which various performance measures should be monitored for control purposes.

An important aspect of planning is the element of uncertainty (Boehlje & Eidman, 1984). Therefore, the plan should contain provision for contingency plans, based on different scenarios (Boehlje & Eidman, 1984; Wright, 1985). Contingency plans provide a degree of preparation for farm managers if factors in the environment differ from those predicted in the plan, and enable them to react before undesirable consequences have been incurred.

Once planning is complete, the selected plan can be implemented. Implementation requires farm managers to acquire, organize, and direct resources to ensure tasks specified in the plan are completed (Boehlje & Eidman, 1984). While the plan is being implemented, farm managers should also regularly monitor progress by measuring farm performance and comparing it against the standards determined previously in the plan. The monitoring results should "show trends, or direction in which the business is going .. [and therefore, can] sound a warning when plans or program are heading off purpose" (Downey & Erickson, 1987, pp. 182) and give farm managers enough time to take any action, should the need to do so arise. Corrective actions may involve modifying or changing the plan, changing the farm business goals, improving the implementation of the current plan, or, more typically, involve the implementation of contingency plans (Boehlje & Eidman, 1984).

Because planning is conducted at three levels of management, the control function should be used to monitor and evaluate the effectiveness of plans at the operational, tactical and strategic levels. Routine appraisals for operational plans are normally conducted within days or weeks after implementation of tasks specified in the plan (Wright, 1985). Control and monitoring of tactical plans occurs when the period of the tactical plans expires. With the strategic plans, control is likely to be urged by "the emergence of stimuli which suggest to the planner that plan revision may be appropriate" (Wright, 1985, pp. 13).

However, planning, implementation, and control of relatively complex innovations such as IPM, may not be able to be fully conducted by growers, who are often considered to lack knowledge of IPM. A survey among New Zealand greenhouse tomato growers in 1989 found that growers used a range of information sources to improve their knowledge of IPM (Martin, 1989). These sources, in decreasing order of importance, are: other growers, grower journals, visits to overseas growers who use IPM, and consultants (Martin, 1989). The survey was conducted at the peak of the time when there were concerns about the cost of private consultants. Therefore, in more recent articles, several authors (Whalon & Penman, 1991; Beck *et al.*, 1992; Herman & Beck, 1993; Martin, 1993c; Clarke *et al.,* 1994) have stressed the important role played by consultants in growers' adoption of IPM and its ongoing use.

2.7 THE CONSULTANCY PROCESSES IN FARM/HORTICULTURAL MANAGEMENT

A considerable amount of horticultural management literature (e.g. Etwell, 1982; Errington, 1984; Palti & Ausher, 1986; Lambur, Kazmierczak, & Rajotte, 1989; Wardlow, 1992; Koppert, 1997; Wright, DeVries, & Kamble, 1997) has observed the involvement of outsiders, such as consultants, in various aspects of management in agricultural and horticultural business. Surprisingly, very limited literature, particularly in the area of greenhouse horticulture, provides any definition of the consultants or their roles. To overcome the limitations in the literature, the author has drawn on work in the area of farm management and general business consultancy. For the purpose of the thesis, "horticultural consultancy" is defined similarly to that proposed by Gardner and Parker (1993) and van den Ban and Hawkins (1996) for farm management consultancy, that is, as "a service that provides information or advice to a client or grower on a fee paying basis."

In New Zealand, most of the research in consultancy has been conducted in farm, and not horticultural, management (e.g. McCosh, 1995; Rogers, N.,1995; Rogers, McCosh, Gray, Kemp, Gardner, 1996; Spies & Frengley, 1996; Williams,1997; Gray, Kemp, Gardner, Rogers, and McCosh, 1999). Therefore, insights for the horticultural consultancy need to be drawn from overseas literature (e.g. Lambur *et al.*, 1989; Mellinger, 1996). The range of services which a consultant offers depends on his/her area of specialisation. Generalist consultants offer an holistic service by providing clients with advice on technical, financial, and/or management issues tailored to the client's specific needs (Spies & Frengley, 1996). While specialist consultants provide expertise in certain areas such as finance, dairy, sheep and beef (McCosh, 1995), certain crops (Mellinger, 1996), or IPM (Robertson, 1995; Mellinger, 1996). In the case of IPM in New Zealand, such services are provided not only by independent consultants, but also by representatives of the retailers of beneficial organisms (Robertson, 1995).

Gray *et al.* (1999), who summarised the studies conducted by McCosh (1995) and Rogers, N. (1995), found that the farm management consultancy processes consists of both the physical process and the problem solving framework (Figure 2.7).

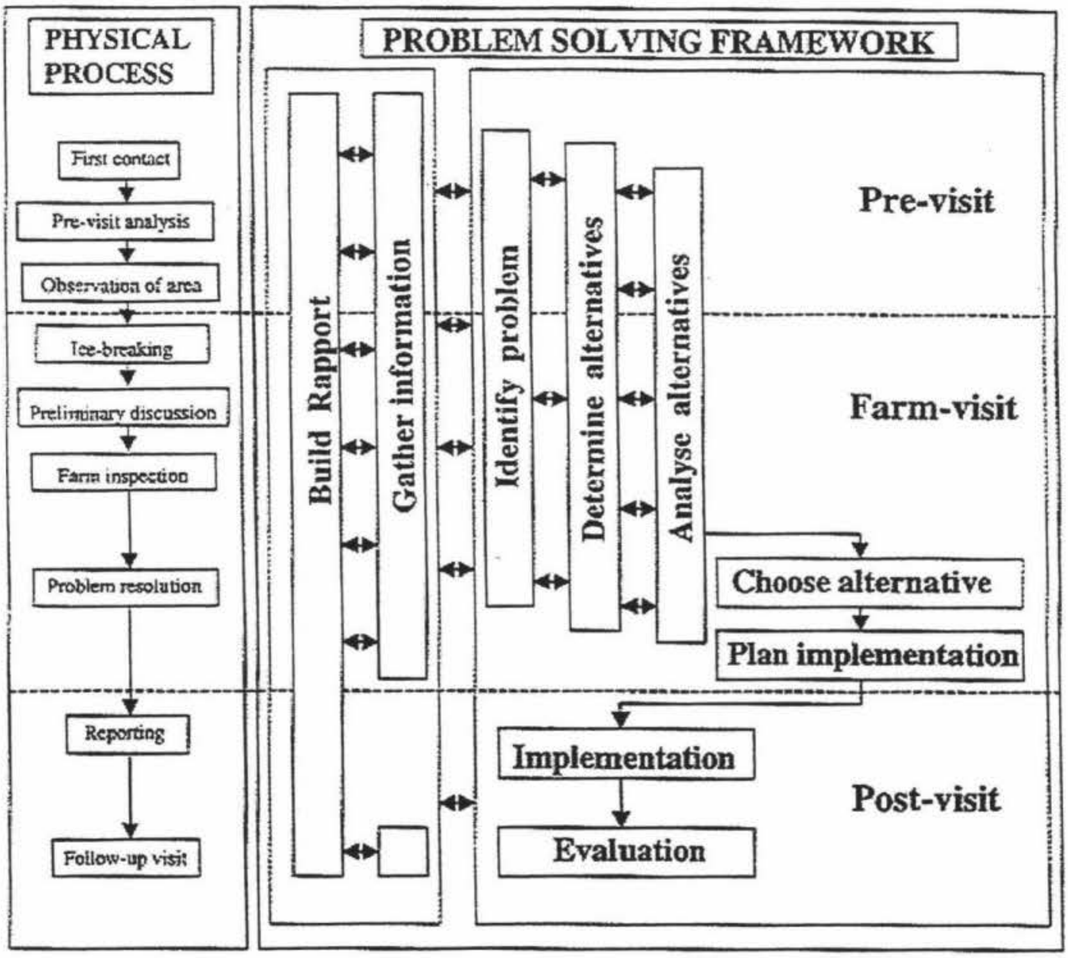

Figure 2.7 Farm management consultancy processes.
Source: Gray *et al.* (1999).

The physical activities undertaken by a farm management consultant can be separated into three stages, pre-, farm, and post-visit. First contact normally occurs through the telephone, where a client informs the consultant about his/her problems and makes an appointment for a field visit. General information about the client, the properties, and the client's concerns is collected. Prior to the visit, the farm management consultant may undertake some form of pre-visit analysis, such as accounts analysis or an evaluation of soil test results. The levels of information collected and amount of pre-visit analysis conducted vary among farm management consultants. On the way to the property, the consultants observe the area surrounding the farm "to assess the farm's physical potential" (Rogers *et al.*, 1996; Gray *et al.*, 1999).

Upon arrival, the consultant initiates ice-breaking conversation about family or sport, with the farmers. Rapport is built from this early stage, and maintained throughout the consultancy processes (Rogers *et al.*, 1996; Williams, Kemp, Gray, Kuiper, Gardner, 1997; Gray *et al.*, 1999). Following this, the farm management consultant then starts conducting preliminary discussions about the farmer's goals and resources. The farmer is also asked to restate his/her reasons for requiring the consultant's assistance. After this preliminary discussion, the farm management consultant conducts a farm inspection with the farmer (McCosh, 1995, Rogers *et al.*, 1996; Gray *et al.*, 1999). During this activity, information collected previously is confirmed and investigated further. The farm management consultant also discusses potential problems observed in the field.

After the farm inspection, the consultant normally returns to the farmer's house, and a problem resolution phase takes place. Based on the information collected and observed, the consultant highlights the problems (s)he has identified and the opportunities (s)he has found during the discussions and farm inspection (McCosh, 1995; Rogers, N. 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). These problems or opportunities are confirmed with the farmer, then possible solutions are identified and discussed with him/her. Decisions regarding which option is selected are made by the farmer. The consultant then focuses the discussion on planning for the implementation of the option on the farm. A written summary of the problems and their solutions made on the day's visit is provided by the consultant at the end of the visit (Williams, 1997). If it is not provided on the day, then a written report containing a visit summary and plan for implementation, is sent to the farmer by the consultant after the visit (Rogers *et al.*, 1996; Gray *et al.*, 1999).

In addition, McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999) also identified two important interdependent aspects of farm management consultancy, rapport and problem solving (Figure 2.7). Rapport building serves an essential role throughout the problem solving framework in order to develop a trusting relationship between the consultant and the client. The problem solving framework consists of 9 steps which occur iterative in nature. Rapport building and information gathering occur in tandem throughout the consultancy processes. The farm management consultant seeks information on the client's family, farm's resources, management, and productivity (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). Problems are identified using trend and comparative analysis. The consultant develops a hypothesis of the cause of the problems, tests it by asking more questions, and finally the existence of the problems is confirmed with the farmer (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999).

Once the problems have been identified, the consultant identifies possible alternatives from his/her 'mental' database of potential solutions for each problem area, in addition to the possible alternatives provided by the client (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). These alternatives are then analysed in the light of the available resources, and result in a reduction in the number of potential solutions to the feasible solutions. The farmer is responsible for choosing the alternative (s)he considers best for solving his/her situations. Following this decision making process, the consultant assists the farmer in planning the implementation of the solution. The farmer however, is responsible for the implementation of the plan, which will occur after the visit ends. A follow-up visit to "evaluate the client's implementation and the suitability of their advice" (McCosh, 1995; Rogers et al., 1996; Gray *et al.*, 1999) is normally conducted by the consultant.

An important consideration derived from these studies is whether or not greenhouse consultants undertake similar consultancy processes to that of farm management consultants. Dent (1995) stresses the importance of planning in developing IPM strategies. Therefore, a planning and control framework, and not a problem solving framework, is used to study the consultancy processes used by greenhouse consultants in assisting greenhouse tomato growers in IPM issues.

2.8 THE ROLE OF HORTICULTURAL CONSULTANTS IN IPM-GROWN CROP BUSINESS

In regard to the management functions as shown in Figure 2.5, horticultural consultants tend to be involved mainly in the planning and controlling stages of the horticulture business, since these are the stages where knowledge and expertise are often needed to make appropriate decisions. Their involvement in the implementation of farm plans has received less attention in the literature. McCosh (1995) states that implementation is the responsibility of farm managers.

Little is reported in the literature about the roles which horticultural consultants play in assisting growers in the matter of IPM (e.g. Lambur *et al.*, 1989; Grieshop *et al.*, 1988; Martin, 1990b; McNamara *et al.*,1991; Beck *et al.*, 1992). In general, roles played by consultants can be summarised into three areas:

1. Information providers

The consultants, particularly those with expertise in IPM, may provide information to assist growers in their decision to adopt or reject the use of IPM strategies. According to Rogers, E. M. (1995), individuals follow certain stages, which he called the "innovation-decision process" (Figure 2.8), before they can make up their minds about an innovation. At the knowledge stage, the information provided by consultants gives the growers some understanding about what IPM strategies are, and how they work. Further information may also be used by the growers when they reach the persuasion stage. At this stage, when the growers have formed a favourable or unfavourable attitude toward IPM, the consultants may provide them with information about the advantages and disadvantages of IPM over conventional pest control methods. Such information can also reduce the growers' uncertainty about the ability of IPM strategies to meet their goals. Up until this stage, the consultants' role is to assist growers in making more informed decisions.

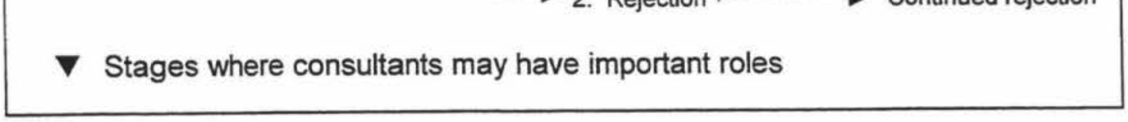

Figure 2.8 Rogers' model of the innovation-decision process.
Source: Rogers, E. M. 1995.

2. Design of IPM strategies

Should growers decide to adopt IPM, the general strategies provided in IPM manuals need to be tailored to meet their specific circumstances. The second role which consultants undertake is in assisting growers to plan IPM strategies specifically for their situations (Wearing, 1988; Wardlow, 1992; Marais, 1996b; Koppert, 1997). Growers often ask questions such as: "how can I switch from chemical to integrated control?" (Koppert, 1997). Benbrook, Groth III, Halloran, Hansen, & Marquardt (1996) point out that dealing with pests during the transition from a calendar-based spray programme to IPM, is both a technical and an economic challenge. Modifications to general IPM programmes should be designed carefully to avoid the occurrence of problems later in the season. In some cases, the growing environment may need to be modified to accommodate the requirements of an IPM system. For example, growers may need to renovate their greenhouses to improve the ventilation system. Such modifications can often become complicated for growers who lack understanding and access to expert knowledge, or who face time constraints, and therefore may require the consultants' assistance (Martin *et al.*, 1984; Herman & Beck, 1993).

3. Control

The third role of consultants in IPM occurs once the design is implemented. During this implementation period, growers learn about IPM strategies by doing. The control is provided by consultants, who help growers solve problems as they unfold while growers monitor the implementation process. Such guidance also improves growers' knowledge of the suitability of different IPM strategies for their situations. At this stage, the consultants may also help to facilitate the transfer of information between the growers and research providers (Herman & Beck, 1993). The guidance provided by consultants during this period, particularly for growers who have just begun to use IPM, helps them "to obtain a balanced decision making policy in crop protection measures" (Koppert, 1997) and determines the success of the strategies (van Lenteren, 1995).

Of the three roles undertaken by consultants, the first role, which relates to the adoption of IPM strategies, has received greater emphasis in the literature (e.g. Lambur, Whalon, Fear, 1985; Grieshop *et al.*, 1988; Martin, 1990b; McNamara *et al.*, 1991). In contrast, the assistance provided by consultants in the planning and control of IPM strategies has received little attention in the literature, despite its importance in determining the success of IPM. In fact, the tasks of planning and control in relation to IPM require expertise, which most growers lack (Koppert, 1997). Although these three roles will be covered in the thesis, the focus of the study will be the consultants' role in the planning and control of IPM strategies.

2.8.1 MANAGEMENT CONSULTANCY OF IPM STRATEGIES FOR GREENHOUSE TOMATOES

Once growers have decided to adopt IPM, they are confronted by the problem of how best to design IPM strategies which fit in with their particular situations. However, since these tasks require specialised technical knowledge, the assistance of consultants is often required. The consultants' involvement seems to be prominent during the planning stage, where the consultants design the specific IPM strategies for the growers (Koppert, 1997). In this case, the consultants are actually designing ways to manage pests using various pest control strategies which are compatible with each other.

Although IPM strategies have been implemented in greenhouses in New Zealand for a number of years, little has been written about the processes used to design IPM strategies for a particular grower, and the role which consultants play in these processes. The literature tends to focus on IPM adoption and development (e.g. Martin, 1989; Beck *et al.*, 1992; Martin *et al.*, 1996) or its practice in outdoor and greenhouse vegetable production (e.g. Martin, 1993b, 1994b, 1995; Marais, 1998). However, a few authors have discussed the design of general IPM programmes at the country, or regional, level (e.g. Dent, 1995; Ausher, 1996). The general principles discussed in this literature can be used to tailor the design of an IPM programme for a specific grower.

2.8.1.1 PLANNING

Planning is essential in the design of a pest management strategy (Dent, 1995). In the case of IPM, such plans may include within-year pest management strategies which are tailored to the current crops, pest problems, and environmental circumstances. This study focuses on the planning of IPM strategies at the tactical and operational levels. The conceptual framework of farm management planning discussed in Section 2.5 is used as the framework to explain the planning process of IPM strategies.

Since consultants are dealing with other people's properties, it is important for them to find out the resources available to the growers, since IPM strategies can be developed only within the available resources (Dent, 1995). For the development of general IPM strategies at the national or regional level, Dent (1995) suggested four important resources; human, institutional, financial, and time (of the consultants). At the grower level, information related to the clients' human resources, institutional (facility), and financial situations needs to be sought. In addition to these resources, consultants need also to find out about the clients' crop production practices because this information can affect the IPM strategies developed for them (Clarke *et al.*, 1994). Therefore, the four categories of information needed from clients are:

1. Human resource

Before designing any IPM strategies to meet the clients' specific circumstances, consultants need to understand about the clients':

- goals (Norgaard, 1976; Dent, 1995; Koppert, 1997). Growers' production goals, such as to produce pest and damage-free plants using broad band pesticides or the maintenance of healthy plants using only low-toxic pesticides, will determine their tolerance of pest damage. These goals are related to their expectations of using IPM strategies. The consultants need to know whether the clients have realistic or unrealistic expectations of IPM.
- attitudes toward IPM (Ausher, 1996). Clients' attitudes toward IPM strategies and chemicals are related to their risk perception (Norton, 1982). Risk averse clients are more likely to prefer the apparent security of the calendar based spray programme than to rely on IPM strategies. It is important for consultants to understand clients' perceptions of pest damage so that appropriate threshold levels can be predetermined.
- knowledge (Koppert, 1997). Knowledge about pest and natural enemy life cycles, and pest symptoms greatly aid a client's ability to anticipate and deal with pest problems throughout the production cycle. Moreover, clients' degrees of knowledge affect their acceptance of IPM (van Lenteren, 1995).
- marketing philosophy (Cameron, *pers.comm.*, March 1998; Tregidga, *pers.comm.*, June 1998). Some packhouses in New Zealand are encouraging their growers to incorporate IPM strategies in their production systems.
- labour. Since IPM-trained staff contribute quite significantly to the success of IPM implementation (Wardlow, 1992), consultants need to find out the capability of the clients' work forces.

2. Facility

This includes all the greenhouse facilities used by clients to grow their crops. Important attributes of the greenhouse include; the number and volume of greenhouses, the cladding material (glass or plastic), structure and height, the level of technology used to produce and maintain temperature and humidity within the greenhouses, the quality of the greenhouses (e.g. the age of the plastic greenhouses, accumulation of chemical residues on the cladding material of plastic greenhouses), location in relation to climate of district and neighbours, and the occurrence of problems which may occur in the greenhouse crop such as the incidence of certain pests during a particular season (Martin, 1993a; Taylor, 1994).

3. <u>Financial resource</u>

The financial resource includes the budget allocated by the clients to deal with pests. The use of beneficial organisms or selective pesticides can sometimes become more expensive than conventional pest management strategies. Clients' ability to carry out such plans will be restricted by their financial situations. Therefore, consultants need to know whether the IPM strategies are within, or beyond, the pest management budget allocations of their clients.

4. <u>Crop production practices</u>

Together with the greenhouse facilities available, crop production practices determine the specific circumstances and suitability of the properties for IPM strategies. Information related to crop production practices include:

- crop production. This refers to clients' methods of producing crops such as the type of media they use, the irrigation and nutrition system, and the level of technology for their climate control management (Clarke *et al.*, 1994).
- pest control. Information about clients' pest control strategies may include information about their spray programmes, type and dosage of pesticides, and the way in which they are applied (Bot, 1992; Spriegel, 1992; Clouaire, Schotman, & Tchamitchian, 1996).

The amount of information gathered early in the planning stage may vary among clients, depending on whether or not the consultants have ever had contact with the clients before, and the level of rapport established between the clients and the consultants. Such information can be gathered with a telephone call or while visiting the clients (McCosh, 1995). Using their knowledge and experience, the consultants can analyse the information to get a general understanding about the clients and their crop businesses, and from this, predict the possible scenarios which might occur in the coming growing season.

Clients' specific goals for using IPM strategies may be formulated after, or in conjunction with, the data collection process. It is important for the consultants and the clients to arrive at feasible goals. In other cases, the clients may already have specific goals which they wanted to achieve prior to the involvement of the consultants in the planning of their IPM strategies. Once the clients' situations and their expectations of IPM are clear, the consultant can then start identifying the possible IPM strategies for the clients. All of these possible measures are analysed and weighed thoroughly in the light of the goals and by considering all important factors related to IPM (Dent, 1995).

IPM strategies are based on prevention and intervention measures (Pedigo, 1995). Well planned and designed prevention measures attempt to avoid unnecessary weaknesses which might lead to the occurrence of pest problems. Whenever possible, preventative strategies are always preferred to those requiring interventions. There are at least four factors, as compiled from the literature, which need to be considered by consultants when planning the preventative IPM strategies for clients. Each of these factors will also make up the components of the plans developed for clients. The factors are:

- greenhouse environment and characteristics. The ability to manage the greenhouse environment will benefit not only the crops being grown, but also the pest-natural enemy competitions. Optimal growing conditions for the crops can be obtained by controlling the heating (temperature), ventilation, humidity, solar radiation, and CO2 level (Clarke *et al.*, 1994). At the same time, such parameters can be used to suppress the development of pests, particularly diseases (Jarvis, 1992), and encourage the growth of their natural enemies. The set points for each of these parameters should be determined early in the planning process. Greenhouse characteristics, such as stud height, can also influence the design of IPM strategies, particularly because low stud height greenhouses require frequent deleafing, and thus increase the likelihood of taking the *Encarsia* away before they hatch out (McNally, *pers.comm.*, June 1998). It is also of particular importance to develop standards of hygiene within the greenhouses as part of the plan components, and to start with a clean production area (Ausher, 1996; Koppert, 1997).
- crop production strategies. Cultural practices aim to generate healthy and strong plants which are able to withstand injury from pests (Ausher, 1996; Koppert, 1997). Good cultural practices can lessen pest problems, and hence reduce the need to intervene with pesticides (Ausher, 1996). In order to produce healthy plants, the crop production plan strategies must be planned to include media selection, varieties, crop duration (long, semi, or short crop), planting date, plant density, nutrition and irrigation programmes, training system, and pollination strategies. The planting date should be planned taking into consideration the ability of the greenhouses to provide an optimum growing environment during a particular season, the likely incidence of pest attack, and the market price situation during the harvesting period. Crop production should start with the selection of pest-free seeds (Koppert, 1997).

- pests and beneficial organisms. Understanding the interactions of the common pests (which often cause problems in the greenhouse), with their natural enemies plays a crucial factor in the design of preventative strategies (Mellinger, 1996). Besides identifying the pests, the consultants need also to determine the pest population levels before the beneficial organisms are introduced, the threshold levels for these pests based on their understanding of the clients' risk perceptions and attitudes toward IPM, levels and period of the beneficial organisms introduction. The consultants will need to determine also the suitability of the greenhouses for beneficial organisms. If the environment within the greenhouses can support the development of beneficial organisms, then they need to plan when, and how, to introduce the beneficial organisms, at what rate, and how often they may need to be introduced (Clarke *et al.*, 1994). These factors relating to the introduction of beneficial organisms should be planned while considering their compatibility with other preventative strategies, such as the use of chemicals to clean up the area before planting to prevent the carry-over of pests from the previous season to the current season.
- external environment. Although the crops are grown under cover in a controllable environment, it is still necessary to consider the external environment surrounding the greenhouses. This may include strategies to maintain the hygiene of the area surrounding the greenhouses, and to ascertain whether or not any activities of the neighbours may affect the crop. Whenever possible, the consultants should use also weather forecast data to predict the likelihood of weather patterns (e.g. solar radiation) which may affect crop production.

While determining the components of a plan, consultants are actually faced with many alternatives (Koppert, 1997), from which a selection should be made. For example, in terms of crop production strategies; which varieties and crop duration should be used, when to plant, or which training system the clients should use. In terms of pests and their beneficial organisms, there are alternatives about when to introduce the *Encarsia*, whether pesticides should be applied or not before introducing *Encarsia* (Martin, 1995), or whether they should be introduced in bulk or in cards. The strategies which best meet the clients' goals, while remaining feasible in view of their resources, are then selected to be implemented by the clients. Since the properties belong to the clients, it is their responsibility to make many of these selections, while the consultants can only suggest those which they consider the best. However, there has been research in England (Errington, 1984) which shows that external advisers often acted as the decision makers, particularly in relation to decisions concerning sprays.

Monitoring and pest-record keeping are the basis of any IPM programme (IPM Staff, 1996). Consultants should select also control parameters which are able to reflect the actual conditions of the crop-pest-natural enemy dynamics (Mellinger, 1996). These parameters should be measured at the right times and regularly. Pest population levels in the greenhouses should be monitored through scouting of representative samples of crops, and the results of the monitoring should be compared to the threshold level. Consultants have to determine the number of samples to be taken, methods used, and the frequency of sampling for each client situation. To observe any fluctuations within the greenhouse environment, the monitoring plan should include also monitoring of environmental parameters such as temperature and humidity. In addition, the monitoring plan needs to include ways of evaluating the effectiveness of any intervention strategies used to solve pest problems (Peacock & Smart, 1995).

Besides the selected IPM strategies, consultants need also to prepare contingency plans to accommodate possible scenarios which may develop. The scenarios are built by asking the "if/then" type of questions such as "If the grower next door suddenly pulled out his onions, then...?"; "If there was not enough sunlight during winter, then...?". By providing the clients with some contingency plans, the consultants enable them to adapt their decisions as the situation changes from the prediction.

Since this literature review is particularly interested in the involvement of consultants in the management cycle of the IPM-grown crop business, and consultants are not normally involved in the implementation of the plans (McCosh, 1995; Kubr, 1996), therefore, the implementation stage of the management cycle is omitted from this literature review.

2.8.1.2 CONTROL

After the plan has been put into action, clients should start monitoring the progress of their IPM implementation regularly. Observation or monitoring activities are conducted as the basis for decision making about which control measures should be taken (Newton, Neale, Arslan-Bir, Brandl, Fidgett, & Greatrex, 1996). Should they find any discrepancy between the plan and the actual situation, the consultants may be called in again to assist them in solving the problems. In such situations, where unexpected problems relating to pests occur, intervention or curative strategies to deal with the pests may need to be considered. However, the curative strategies selected to deal with the pests must not, whenever possible, upset the previous preventative strategies. Klassen (1979) suggests that intervention strategies should be applied in stages, starting from temporary alleviation to management of localised populations. The former approach is used on an emergency basis in certain spots of the greenhouses, while the latter attempts to control pest population at the greenhouse level. The intervention strategies may include the use of chemicals, increased rate of beneficial organisms, and physical (e.g. elimination of infected plants) methods. Peacock and Smart (1995) suggest that the choice of these strategies should be based on their effectiveness, environmental impact (including to the beneficial organisms), safety, economics, and the site characteristics.

The effectiveness of solutions offered by consultants to solve pest related problems depends on their ability to identify the problems, that is, their ability to recognise pests and their symptoms (Peacock & Smart, 1995; Mellinger, 1996; Newton *et al.*, 1996). In addition to this, the ability to analyse and interpret the monitoring results is essential in making the correct decisions about pest problems. Based on the analysis and interpretation of the monitoring results, the consultants may then conclude whether such deviations from the standards need to be corrected or not. If deviations are not significant, the implementation process can proceed normally. However, if changes are necessary, then the consultants may need to modify their earlier plan, or abandon it and create a totally new plan, or use the contingency plan to be implemented by the clients. Throughout this whole process, the consultants need to involve the clients as the decision makers and implementers of the suggestions provided by the consultants.

At the end of the season, the success or failure of the IPM strategies can be measured in terms of how the crop performance has been improved, both quantitatively and qualitatively; the clients' increased knowledge; and the improvements which can be made in the next growing season.

CHAPTER THREE

SELECTION AND DESIGN OF RESEARCH METHOD AND CASE STUDIES

3.1 INTRODUCTION

Social science research can be conducted using various research designs. Each research design has its own advantages and disadvantages. Although each strategy can be used to serve exploratory, explanatory or descriptive research, the strategy selected for a research topic depends on: the type of research questions to be answered; the investigator's control over the events; and the type of phenomena which becomes the focus of the research (Yin, 1994). The main research question for this study was 'How do consultants assist greenhouse tomato growers in the management of IPM strategies?' Factors considered in the selection of the research method for this study are discussed in Section 3.2, and the design of the research method is discussed in Section 3.3.

3.2 ALTERNATIVE RESEARCH METHODS

There are five major research methods: experiments, surveys, archival analysis, histories, and case studies (Yin, 1994). Although each strategy has its own characteristics, the boundaries between these strategies may not always be clear, and sometimes overlap (Sieber, 1973). The strategies are characterised by three main criteria, as summarised in Table 3.1 (Yin, 1994).

Table 3.1 Relevant situations for different research strategies.

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Survey	who, what, where, how many, how much	no	yes
Archival analysis	who, what, where, how many, how much	no	yes/no
Experiment	how, why, what	yes	yes
History	how, why, what	no	no
Case study	how, why, what	no	yes

Source: Yin, 1994.

The first factor to be considered when selecting a research method is the type of research question which is to be answered by the study (Yin, 1994). Research questions can be classified into five common types: 'what', 'who', 'where', 'how', and 'why'. Exploratory type or 'what' questions, such as 'What strategies are included in IPM?', can be answered by all research strategies. 'How many', 'how much', 'who' and 'where' type of questions are best answered by survey and archival analysis strategies. While 'how' and 'why' research questions, which are more explanatory in nature, are best answered using case study, history, and experimental research strategies.

The second factor researchers need to consider is the degree of control required over the behaviour of the subjects in the study (Yin, 1994). The degree of control required in a study depends on the research objectives. Certain studies, such as this research topic, do not seek to control the behaviour of the research subjects because the focus of the research is how these subjects (in this case, the consultants) behave in their natural setting.

The third factor researchers need to consider is the degree of focus on contemporary, as opposed to historical, phenomena (Yin, 1994). History is definitely a preferred strategy when access to relevant subjects is not possible because they are no longer alive. Data collection in such situations must rely on documents and artifacts. In contrast, the case study method allows the subjects to be interviewed and observed (Yin, 1994).

3.2.1 SELECTION OF RESEARCH METHOD

In order to answer the research question: 'How do consultants assist greenhouse tomato growers in the management of IPM strategies?', an in-depth investigation of the topic was required. A research strategy employing surveys, a traditional farm management approach, although useful for obtaining background information about the consultants ('who', 'what', 'where' questions), was discounted because it was not suitable for obtaining detailed information regarding the IPM management consultancy processes (i.e. 'how' and 'why' questions). Experiment, history, and case study research strategies could be used to answer how and why research questions. However, because the consultants needed to be studied in their natural setting, the use of an experimental design was ruled out. The history strategy was also ruled out, because it is designed to investigate the past rather than contemporary events. In summary, the case study method was considered appropriate to meet the research objectives because it: is useful to answer 'how' and 'why' questions, provides the opportunity to investigate the consultants in their natural setting, and allows contemporary events to be investigated.

3.3 DESIGN OF CASE STUDY METHOD

The case study is defined by Eisenhart (1989, pp. 534) as "a research strategy which focuses on understanding the dynamics present within single settings". A case study can be either a single or a multiple case study (Yin, 1994). The decision about which type of case study research design to adopt needs to be made prior to the commencement of data collection.

The use of a single case study design is justifiable under certain conditions such as where the case represents: a critical test of existing theory, a rare or unique event, or a revelatory phenomenon previously inaccessible to scientific research (Yin, 1994). Multiple case studies can be used to compare the similarities and differences between cases, using cross-case analysis (Yin, 1994). The findings of multiple case studies therefore, are often regarded as more robust than a single case study (Herriott & Firestone, 1983, *cited in* Yin, 1994; Eisenhart, 1989; Miles & Huberman, 1994). However, Patton (1990) argued that depth is sacrificed at the expense of breadth when one moves from a single to a multiple case study. Moreover, a multiple case study can demand extensive resources, including time and funding. Ideally, the number of cases used in a study is dictated by saturation, that is, additional cases are added to the study until no additional information is gained from further cases (Maykut & Morehouse, 1994). Accordingly, the number of cases should be carefully considered to ensure that the research question can be answered within the research timeframe.

A multiple case study approach was selected for this study because it was assumed that consultants might use different approaches in the planning and control stages of IPM strategies for their greenhouse tomato grower clients. Given the time and financial constraints imposed on the study, the number of cases was confined to two. Moreover, it was considered that two cases would provide a useful cross-case comparison without sacrificing the depth to any great extent.

3.3.1 MULTIPLE CASE STUDY RESEARCH DESIGN

Yin (1994) provides a detailed overview of the multiple case study method (Figure 3.1). This general approach was used for the study. The first step, theory development, was conducted by reviewing the literature on IPM, planning and control process, farm management consultancy processes and the roles of horticultural consultants in greenhouse crop business (Chapter 2). The cases were then selected (Section 3.3.3) and the data collection protocol was designed (Section 3.4) using the literature as a guide. Data on the case studies was collected, analysed and individual case reports were written (Chapter 4). Cross-case analysis (Section 5.1) was used to: reveal the similarities and particularly, the differences between cases, and develop a general model of the planning and control stages of IPM strategies used by the consultants. This was then compared with the literature review in Chapter Two, to reveal the similarities and differences (Section 5.2), and modify the theory where necessary.

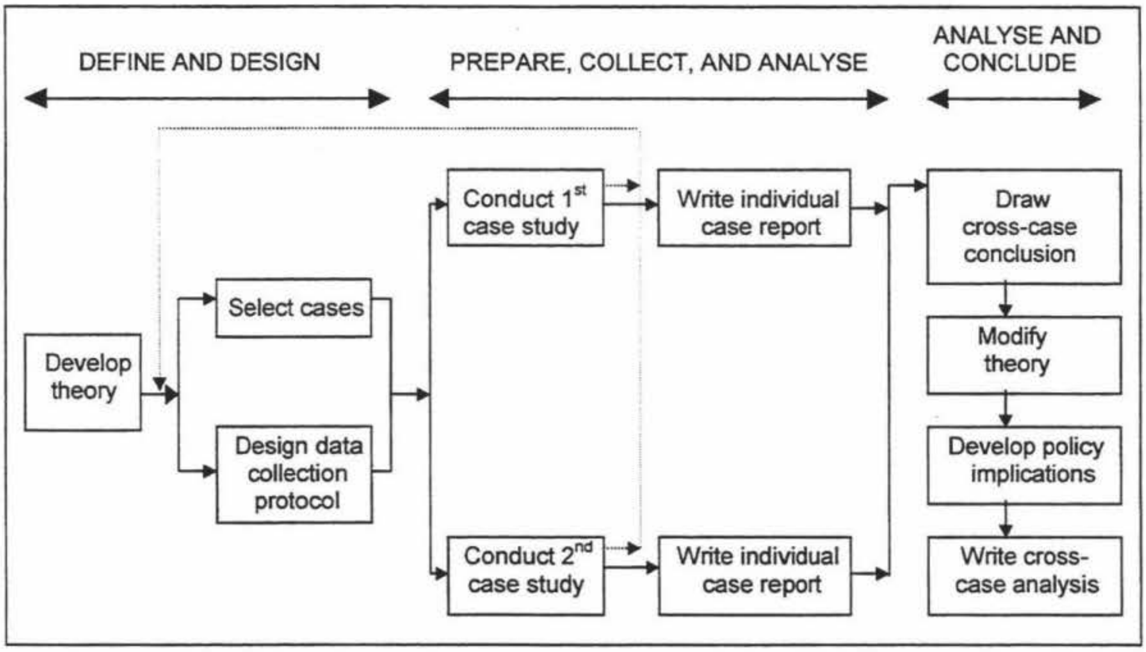

Figure 3.1 Multiple case study method.
Source: Yin, 1994.

3.3.2 THEORY DEVELOPMENT

Theory development forms an essential part of case study research (Yin, 1994). It acts as the blueprint for the study, and provides direction in deciding which data to collect and how best to analyse it. In order to develop the theory, literature on the principles of IPM and the general IPM programme for greenhouse tomatoes in New Zealand were reviewed. In addition, planning and control processes and consultancy processes from the farm management literature were also reviewed. This literature was used as a conceptual framework to design the data collection protocol and guide the analysis.

3.3.3 SELECTION OF CASES

One of the most critical stages in the case study method is the selection of the appropriate cases. These should provide the best possible understanding of the phenomena of the study (Patton, 1990; Miles & Huberman, 1994; Yin, 1994). The objective of the study was to investigate the processes expert consultants use to assist greenhouse tomato growers in the planning and control stages of IPM strategies.

Suitable cases for this study would, therefore, need to posses expertise in IPM strategies for greenhouse crops, and in particular, tomatoes. Choosing expert consultants instead of novices for the study is important because the former possess a higher level of knowledge in their domain, and they are able to carry out domain-related skills with fewer errors than novices might make (Cooke, 1992). More importantly, experts tend to perform strategies which they know will work on the information provided, while novices are more tempted to fill in the gaps when information is incomplete (Winkles, 1992).

Although there are no well defined criteria for classifying people as "expert", experience is commonly used as the main criterion (Cooke, 1992). Other factors which are often quoted to contribute to expertise are: specific characteristics of the individual, such as stability (Ericsson & Smith, 1991), high motivation and capabilities (Cooke, 1992); and social perception of expertise in the domain area (Sternberg & Frensch, 1992).

In this study, the criteria used to select expert consultants are determined also by their accessibility. Stake (1994) suggested that cases should be selected also based on their availability and access. Gummeson (1991) concluded that obtaining access is the researcher's number one challenge. Access here refers to "the ability to get close to the object of study, to really be able to find out what is happening" (Gummeson, 1991, pp. 21). It includes access to the system (that is, the consultancy firm), and access to the individual in the system (e.g. consultant with the highest level of expertise in IPM) (Brown *et al.*, 1976, *cited in* Gummeson, 1991). Access to one expert consultant was denied due to the commercial sensitivity of their knowledge. Moreover, accessibility provided by the consultants who were involved in this study was influenced also by their time constraints and interest in the topic. Interested consultants were more willing to provide access.

Two greenhouse consultants were selected, who were socially rated second and third in New Zealand in terms of greenhouse IPM expertise (Cameron, *pers.comm.*, March 1997). These consultants were contacted by telephone and asked if they would be interested in participating in the study. The research proposal describing the study, their roles in the study, and the time commitment asked of them, was then mailed to the consultants. A second telephone call was made to confirm that each consultant was willing to be involved in the study.

3.4 DESIGN OF DATA COLLECTION PROTOCOL

The data collection protocol contained procedures and general rules which needed to be followed when data were collected and recorded so that the analytical requirements of the study were met. Semi-structured interviews were chosen as the primary data collection method because they allowed the researcher to obtain an in-depth understanding of the

IPM management consultancy processes used by the consultants. During the interviews, documents related to each consultancy firm (e.g. prospectus) were also collected as a source of secondary data. In addition, field observations were used to confirm the information gathered through the interview, and to identify other aspects which were not mentioned in the interviews.

Prior to the interview, the researcher conducted a review of literature to obtain an overview of IPM strategies in general. Specific information was sought about the IPM strategies used in greenhouses, and the way consultancy services in New Zealand assist greenhouse tomato growers in the planning and control stages of such strategies. An understanding of these domains and discussion with the supervisors were then used as a basis to develop the interview objectives and protocol. The protocol for the interviews is shown in Appendix 2.

Two sets of interview guides, one each for the consultant and the researcher, were developed for each interview. The interview guide for the researcher was accompanied by a checklist of points for each issue to ensure that relevant details were covered. These points were obtained from either the literature, issues raised in previous interviews with the consultant, or from the other case study. The checklist points were not printed on the consultant's interview guide to avoid bias. Examples of the two versions of the interview guide are shown in Figure 3.2 and 3.3.

1. Is there any attribute of your client that you think is important for you to know before starting designing specific IPM strategies for him? Could you please list them and tell me why they are important?
2. Is there any attribute of yourself as consultant that was taken into account?
3. How would you determine (what factors do you consider to determine) that IPM strategies are suitable or unsuitable for his particular circumstances or should he use IPM just for half of the season?

Figure 3.2 An example of interview guide sent to the consultants.

The objectives of the first interview were to:

1. build rapport with the consultants,
2. obtain an understanding of the consultants' background, client base, and areas of speciality,
3. obtain their opinions and perceptions of the greenhouse tomato industry and IPM-related consultancy services in New Zealand.

1. Is there any attribute of your client that you think is important for you to know before starting designing specific IPM strategies for him? Could you please list them and tell me why they are important?
    - goals
    - budget
    - risk perception
    - attitudes toward IPM
    - level of knowledge
    - greenhouse and cropping system history (& the current systems)
    - greenhouse characteristics
    - neighbours
    - resources
2. Is there any attribute of yourself as consultant that was taken into account?
    - knowledge
    - experience
3. How would you determine (what factors do you consider to determine) that IPM strategies are suitable or unsuitable for his particular circumstances or should he use IPM just for half of the season?

Figure 3.3 An example of the interview guide used by the interviewer during the interview.

The objective of subsequent interviews was to elicit an in-depth understanding of how the consultants assisted a client with the planning and control of IPM strategies on his/her property. During the second interview, the consultants were asked to describe the process they would use to serve clients who were planning to shift their pest management practices from conventional methods to IPM. The specific objectives for the second interview were to:

1. obtain an understanding of the planning process the consultants went through with their clients,
2. identify information about the attributes of the clients and their properties which was collected by the consultants in the planning of IPM strategies,
3. identify the important factors considered by the consultants when they planned the IPM strategies,
4. investigate the extent and form of the IPM strategies submitted to their clients.

The results from the second interview were summarised in the form of a planning process outline and information gathering hierarchy. This was sent to the consultants for discussion in the third interview. The third interview was used to:

1. confirm and further investigate the planning process outline and information gathering hierarchy,
2. identify the decision rules used by the consultants during the planning process .

These decision rules were redrawn into a decision tree to include more details after the interview, and were sent back to the consultants. The objective of the fourth interview was to confirm the decision tree and obtain more detail about the decision rules of the planning process which the consultants conducted when they tailored their template plan for a particular grower. Formalising the consultants' decision rules into a written decision tree was an important part of the study.

In the fifth and sixth interviews, the role of the consultants in the control stage was investigated. The objectives of the fifth interview were to investigate the consultants' role and the process they went through during the control stage. The objective of the sixth interview was to obtain details of the curative strategies the consultants recommended during the control stage. The final interview was also used to confirm all the information obtained from the interviews.

3.4.1 INTERVIEW PROCESS

Prior to an interview, the consultants were contacted by telephone to discuss the date, time, and venue for the interview. In compliance with the Privacy Act 1993, permission was sought to record the interview and accompany each consultant on field visits. Both consultants agreed to this process. After the telephone conversation, a letter or email confirming the time for the interview, together with its objectives and questions, was sent to the consultants. The interviews were recorded and transcribed to ensure the accuracy of the data. Each transcript was summarised to highlight key findings from the interview and identify areas to be addressed in the next interview. To obtain confirmation of content and to refresh the consultant's memory about the topics which had been covered in the previous interview, a summary of each interview was sent through email to the consultants at least a week prior to the next meeting.

The purpose of in-depth interviewing is to gain an understanding of the experience of the interviewees (Seidman, 1991). In this study, the purpose of such in-depth interviewing is to understand how the consultants conduct the IPM management consultancy processes. The quality of information obtained from such interviews depends largely on the interviewer (Patton, 1990). Therefore, to optimise the data collection process, several tactics were adopted in the interview. Time was taken at the start of the interview to build rapport between the interviewer and the interviewee. This was important particularly in the first interview because the interviewer and interviewee had never met before. By having good rapport with the consultants, sensitive and more in-depth information was more likely to be obtained (Fontana & Frey, 1994). Rapport was developed through firstly, undertaking icebreaking conversation with the interviewee before the interview, and then providing some background about the interviewer and the project. Once the interviewee was more relaxed, the interview was initiated. To further develop rapport, the interviewee was always asked simple non-threatening questions at the start of the interview.

The interview was then followed by a series of broad open-ended questions, prepared in the interview guide. By asking open-ended questions, the interviewer was free to explore and probe with the interviewee (Patton, 1990). Such a structured format is especially critical for exploring phenomena when little is known about the subject area (Maykut & Morehouse, 1994). Moreover, the format "provides a framework within which the interviewer could develop questions, sequence those questions, and make decisions about which information to pursue in greater depth" (Patton, 1990, pp. 284).

Probing questions were used in three ways, by: asking follow-up questions to get more detailed information; encouraging the interviewee to tell more; and confirming issues when the interviewer was not sure about them (Patton, 1990). In all situations, the use of leading questions was avoided as much as possible. During the interview, notes were sometimes made by the interviewer, if interesting issues were brought up by the interviewee which were not reflected in the prepared guideline. These issues were followed-up later in the interview. Each interview took on average about two hours to complete.

3.4.2 DOCUMENTATION

The use of multiple sources of evidence can lead to a more robust data collection (Yin, 1994). Therefore, documentation was used to corroborate and add detail to the interview results. If contradictory, instead of corroboratory, documentary information was obtained, the issue could be investigated further in interviews (Yin, 1994). Permission to obtain copies of the consultants' documents was always asked. Documentary information was normally obtained during interviews and field observations, and could comprise the consultancy firm prospectus, letters to clients, and the consultants' visiting checklist. Due to the confidential nature of the documents, not all documents can be attached to the thesis.

3.4.3 FIELD OBSERVATION

The objectives of the field observations were to: observe how the consultants acted in their natural setting, confirm information obtained in the interviews, and identify aspects of the planning and control processes of IPM strategies which were either not mentioned or overlooked during the interviews. Photographs of the property were taken during the visits to document the field observation. Field observations were dictated by the availability of relevant cases during the period of study. Three field visits were made during the study, two with Case Study One and one with Case Study Two. Several growers were visited during each field visit. The ideal case for the planning process was a visit to a greenhouse tomato client who was considering a shift from conventional pest control methods to IPM strategies. A grower who had recently implemented IPM strategies made an ideal observation case for the control stage. The cases visited with Case Study One met the ideal for planning and control, while the growers visited with Case Study Two met the control stage requirement only. The growers visited during the field observation were on-going clients of the consultants.

Permission to accompany the consultants during field visits was sought at the start of the first interview. The type of visit required for the study was explained to the consultants. The suitability of the cases was confirmed to the researcher through telephone or email prior to the field visit. Later, prior to the field visit, the consultants would inform the client about the presence of the researcher and gain his permission. On the way to the grower's property, the consultants provided a brief description of the client and his property. Upon arrival, the consultants briefly introduced the researcher and explained the purpose of the study to the grower. Permission to take pictures at the property was obtained from the grower. Pictures of important features of the property and the aids used by the consultant to explain IPM, provide visual information about the nature of the consultant's work, particularly for outside observers.

The rest of the visit was used to observe and take note of the process which the consultants went through with the grower, the topics they covered during the visit, the aids used by the consultants to explain about IPM to the grower, and time duration for each stage in the consultancy processes. Prediction of the consultancy stages which might occur was prepared, based on discussion with the supervisors, and was helpful in recognising such stages when they occurred in the field. Based on the interview results, the topics which the consultants said were normally covered during the visit were listed, and checked in the field. However, the consultants failed to follow the linear process as identified during the interview, and this made the recording process difficult. Therefore, after the first visit, the process was recorded as it occurred in hand-written form (Figure 3.4). On the way back to the consultant's office, the day's events were discussed to clarify the reasons behind certain recommendations and the sequence of events. A summary of each field visit (Figure 3.5) was made and sent to the consultants for confirmation.

— 1.22 ints of water & nutrient probs
G. report all his probs (he hasn't been visited for 7 (yr).
thought he got wrong advice & analysis from other people.
1.30 move to gh.
C: gh detail → size, height → make drawns.
vent, at automatic / not
temp diary
policy on to achieve temp.
C: wall between rows, check media, advice on deleafing process & season. Give example.
spray & botrytis
Explain his probs w/ fungus
C: A about the yellow leaves based on his observation. Tell why.
1.50
in office / prep. room.
C: how's your experience w/ Encarsia last yr
Resistance prob?
Make notes on grower's Encarsia introd. rate & when start
Comment on how to reduce fungicide effects on Encarsia.
Tell what to do in the next few months until 1st harvest.
No mention about when to introduce, rate etc, more to how Enc. survive within his env.
check the root
Give notes on things to do for grower. 2.35 finish

Figure 3.4 An example of field observation notes showing the conversation between the consultant (C) and the grower (G).

Outline of the consultancy visit process

1. Arrival on the property
⇓
2. Review and checking
⇓
3. Discussion
⇓
4. Summarise key changes
⇓
5. Leaving the property

Details:

1. Arrival on the property
   Once arrived on the property, Case Study One directly went to the greenhouses or preparation room to find the grower.

Figure 3.5 An example of summary of field observation notes.

3.5 ANALYSIS OF DATA

The objectives of the analysis of qualitative data is to interpret, explain, provide understanding, and predict 'how' the process works and 'why' it performs such operations (Dey, 1993). The analysis of data is conducted progressively and iteratively through a series of activities such as fact finding, data-bit location, sampling and comparing, contrasting, classifying, and cataloguing (Dey, 1993; Miles & Huberman, 1994). In a multiple-case study such as used in this thesis, both data collection and analysis processes are conducted to: reveal similarities and differences between the two cases, guide the decision making as to whether given ideas should be followed up or abandoned, and to achieve an understanding of the subject being studied (Crawford, 1996). By carrying out these two processes iteratively, the researcher can modify the data collection techniques whenever required during the research period to ensure that accurate and complete data for analysis are obtained (Schatzman & Strauss, 1993; Hedrick, Bickman & Rog, 1993).

Data in the form of verbatim transcripts and field notes were analysed separately for each case study. Dey (1993) suggests that qualitative data analysis, which consists of describing, classifying, and connecting activities, is iterative in nature and may be represented by a spiral (Figure 3.6). In the first step of data analysis, a thorough description of the phenomena under study is developed within its context from interview transcripts and field notes (Dey, 1993).

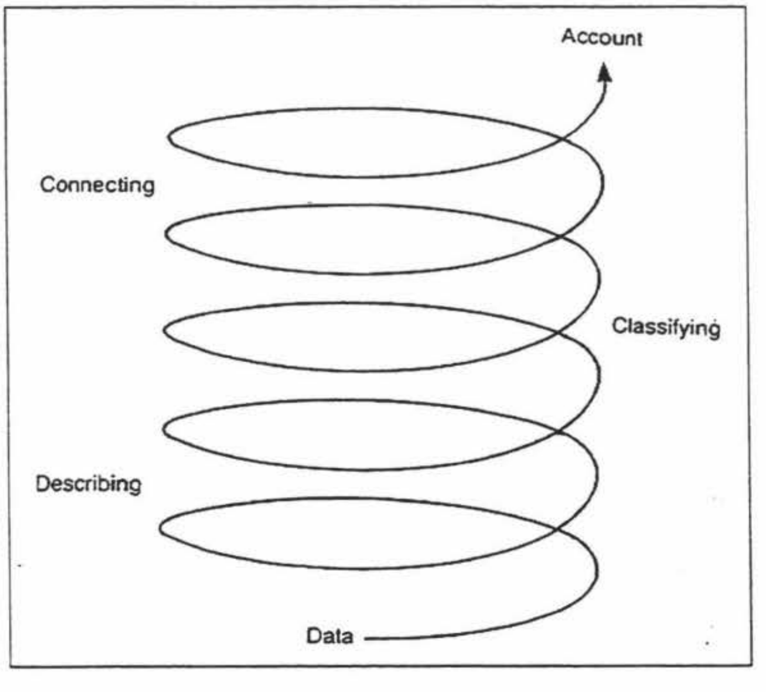

Figure 3.6 Qualitative analysis as an iterative spiral.
Source: Dey (1993).

The second step, classification, is used to organise bits of data into groups based on relevant characteristics, so that useful comparisons between these data bits can be made for interpretation and explanation of the phenomena in the study (Dey, 1993). Classification, which is termed "coding" by Strauss and Corbin (1994), consists of three major activities. First, categories are developed and a definition for each category is provided as a boundary. Secondly, the data are broken into bits and assigned into the categories, and thirdly, the bits are re-classified. In this last step, the broad categories may be subdivided into sub-categories, while overlapping categories may be combined to form a supra category, and new categories may be developed from the data (Dey, 1993; Maykut & Morehouse, 1994). In order to conduct these three steps of classification, decision rules need to be developed, so that similar data-bits from the verbatim transcripts can be consistently allocated, while still allowing the development of new categories whenever necessary (Figure 3.7). The use of decision rules results in a structured hierarchy of categories and sub-categories, which may assist in establishing connections between the data.

The third step of qualitative data analysis is connection, which involves identifying meaningful relationships between categories (Dey, 1993; Maykut & Morehouse, 1994). The links are identified by conjunctions (e.g. therefore, after, because) in the transcript, and are also inferred from the context of the data. The process of finding these connections can be aided by discussing possible links between categories with one's supervisors or interested others (Maykut & Morehouse, 1994).

This whole process of within-case analysis resulted in an understanding of the cases being studied. Following the within-case analysis, a cross-case analysis was undertaken, where descriptions of both cases were compared and contrasted to identify similarities and differences. Cross-case comparisons may assist the researcher to go beyond her initial impressions of the cases, and improve "the likelihood of accurate and reliable theory" (Eisenhart, 1989, pp. 541) being generated from the case studies. Finally, the generalisations were compared to the conceptual framework developed at the start of the study. Deviations from the literature were investigated in terms of why they occurred.

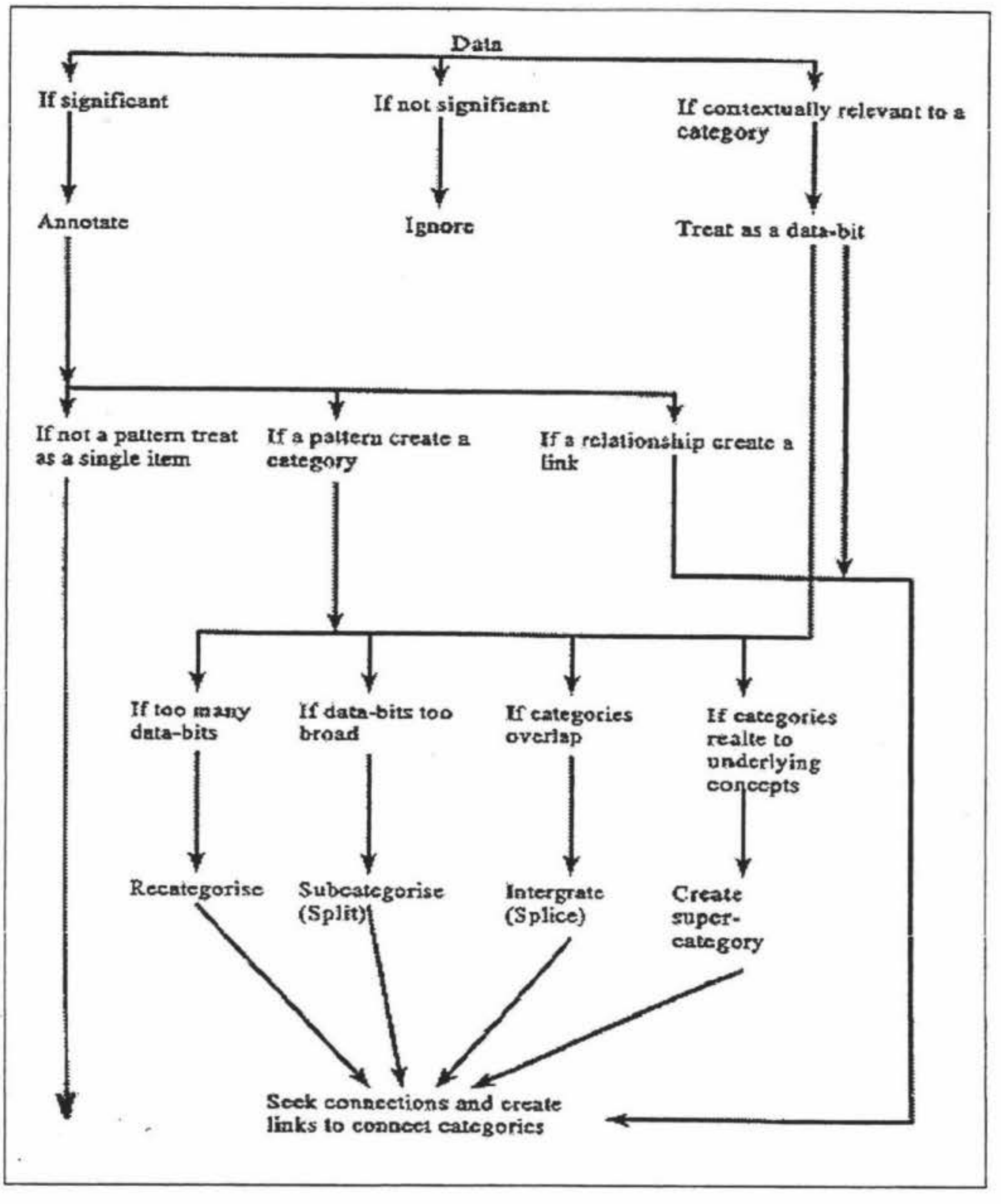

Figure 3.7 Decision rules for allocating data-bits to categories.
Source: Crawford (1996, adapted from Dey, 1993).

3.5.1 WITHIN-CASE ANALYSIS

DESCRIPTION

Raw data from the taped interviews were typed as verbatim transcript, while the hand-written field notes were typed into detailed summaries. The description process started by studying the interview and field visit transcript carefully. A summary of each transcript was then written, highlighting important aspects discussed with the consultants during the interview and the activities conducted by the consultants during the field visit. The summaries were useful for the researcher in two ways. First, the summaries highlighted possible categories for the classification step. Second, the summaries were also useful to highlight linkages between data-bits in the transcript. Through the linkages, an initial model of the planning and control stages of IPM strategies used by the consultantswas able to be developed at this early stage of data analysis.

CLASSIFICATION

Data categorisation in this study was conducted using NUD-IST, which stands for Non-numerical Unstructured Data Indexing, Searching and Theorizing. It is a computer software programme designed to assist users in managing non-numerical and unstructured data in qualitative analysis (QSR, 1997). It allows users to choose words, lines of text, sentences, paragraphs, or even whole speeches as text units. The text units should be decided prior to entering the transcript files into NUD-IST. Ideally, the text unit should generally be related to one topic and still retain the context of the data. For this study, sentence was selected as the text unit. Sentences with multiple ideas were allocated into the different categories which were talked about. Such sentences enabled links between the categories to be clearly established.

The summaries developed from the description process were used to generate broad categories, and the classification process (Section 3.5) was applied to the data. A definition was provided for each category. The definition determined the boundaries for each category, and was critical for assessing whether or not data from the transcript belonged to a specific category. The categories were structured into hierarchies of sub and supra categories. Under the broad category, 'Consultancy', the hierarchy included the sub-categories of 'Subject', 'Type of service', 'Consultant', and 'Grower' (Figure 3.8, Second draft hierarchy). These sub-categories were further sub-divided into lowerlevels categories. For example, sub-categories of 'Type of service' included 'Preferential customer' and 'One-off consultancy'. Subsumed under each of these sub-categories were subsequent divisions relating to attributes of each sub-category. As the transcripts were read in detail, further classifications at the lower levels of the hierarchy were generated to provide a more detailed description of the case being studied (Appendix 3 and 4). The process of data allocation was reviewed several times throughout the classification process to ensure the definitions accurately described the data within the categories, and to assess the logic of the category hierarchy. The process of redefinition and reallocation of categories was conducted iteratively until the final category hierarchy used in this study emerged (Figure 3.8).

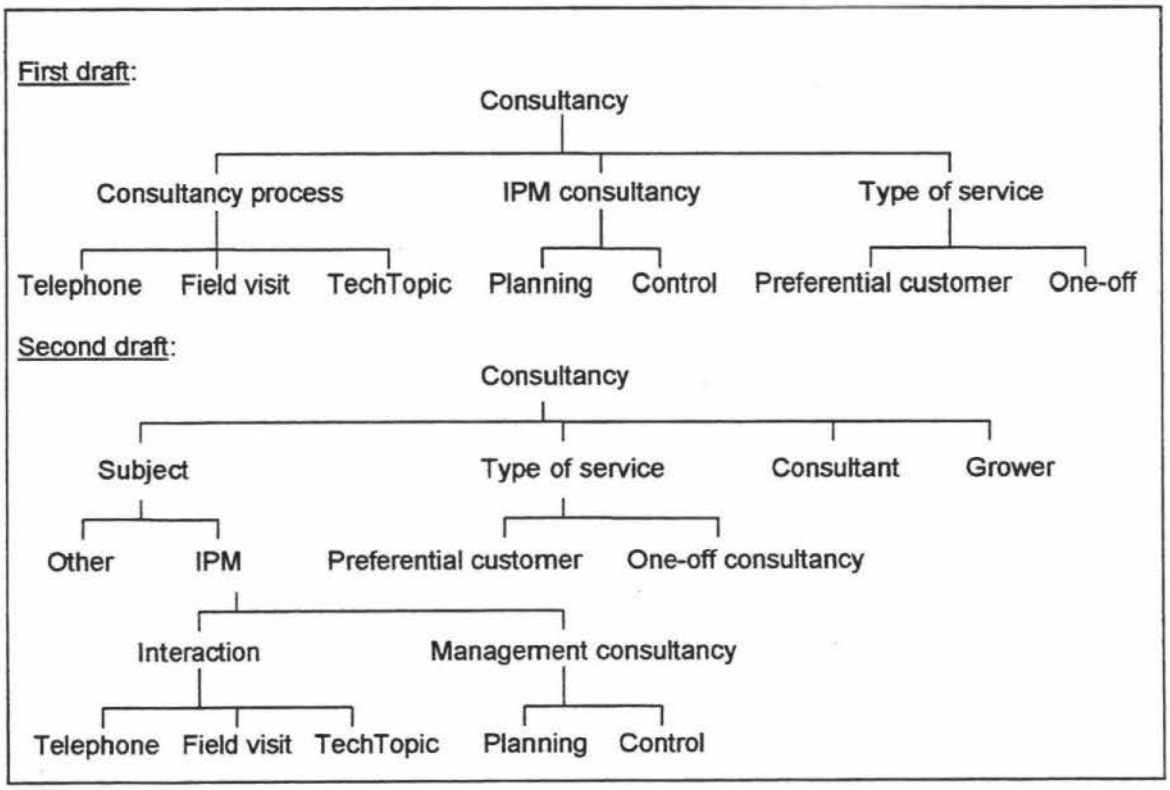

Figure 3.8 An example of changes in the hierarchical categorisation at the high levels.

The data-bits from the transcripts and field note summaries were allocated into the categories using the decision rules based on the definition provided for the category (Figure 3.9 and 3.10). The process of assigning categories may lead to modification of the existing categories or to the development of new categories when a given data-bit could not be assigned to an existing category. The use of NUD-IST allowed the classification steps to be conducted easily because categories could be cut and pasted, definitions changed, and data-bits assigned to categories using simple mouse-driven menus.

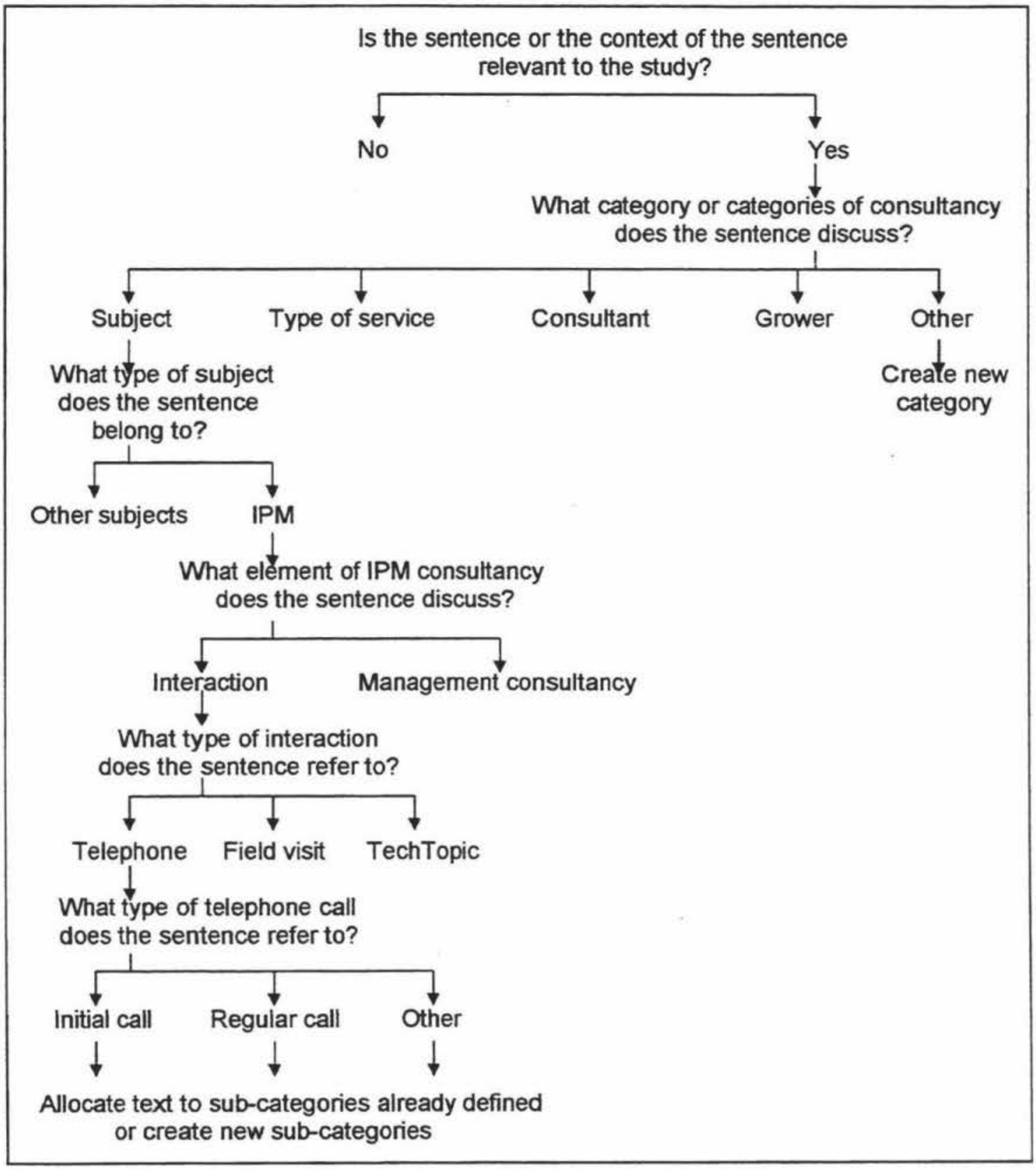

Figure 3.9 The decision rules used in allocating text blocks to the categories.

Conversation: Normally they would be saying we want to talk consultancy services and we're also very interested in IPM. Can we sort of do a programme that would allow to put the IPM in place?

Decision rules:

Is the sentence(s) or context of the sentence relevant to the study?

↓

Yes

↓

What category or categories of consultancy does the sentence discuss?

↓

Subject

↓

What type of subject does the sentence belong to?

↓

IPM

↓

What elements of IPM consultancy does the sentence discuss?

↓

Interaction

↓

What type of interaction does the sentence refer to?

↓

Telephone

↓

What type of telephone call does the sentence refer to?

↓

Initial phone call

Figure 3.10 An example of the allocation of a text block into a category using the decision rules outlined in Figure 3.9.

CONNECTION

In breaking up the data into categories, information about the relationships between different parts of the data may be lost (Dey, 1993). Therefore, in order to apprehend this information, the development of linkages between data-bits is important. The process of developing the linkages may occur prior to, in conjunction with, or after the classification step (Dey, 1993). The linkages provided an empirical basis for connecting the categories to which the data-bits were assigned.

As mentioned earlier, the summaries written at the description stage were useful in identifying the majority of the linkages in the data. These linkages identify the relationships within the initial model of the planning and control processes of IPM strategies used by the consultants. Further linkages, which may have been overlooked in the summaries, were identified during the classification process through the analysis of conjunction and context.

These additional linkages resulted in the modification of the initial model of the planning and control processes of IPM strategies conducted by the consultants. However, time constraints meant formal documentation/coding of the linkages could not be made. Such formal documentation, if conducted, may have resulted in the identification of further categories or refinement of the model.

In summary, throughout the within-case analysis, the three stages of data analysis, description, classification, and connection, were not conducted separately and in linear sequence. Instead, the three stages occurred in an iterative manner, where each stage could be conducted repeatedly after each other to complement the analysis and obtain an in-depth understanding of the case study.

3.5.2 CROSS-CASE ANALYSIS

Cross-case analysis aims at developing an understanding of the phenomena being studied. Having finished with the within-case analysis, individual case reports for each case study were written. The case reports were then compared and contrasted to each other (Section 5.1). Differences between the two case studies were discussed, and explanations for these were proposed. General models of the planning and control stages used by the expert consultants in the development of IPM strategies for greenhouse tomato growers were also drawn as the conclusion from the case studies.

3.5.3 COMPARISON TO THEORY

Finally, the conclusions drawn from the case studies were compared and contrasted against the literature reviewed at the start of the study. The key aspects for comparisons were the consultancy processes, which comprises the physical activities and the planning and control processes, and the components of IPM strategies for greenhouse tomatoes. Reasons for differences between the case studies and theory were identified.

CHAPTER FOUR

CASE STUDY REPORTS

This chapter starts by presenting and discussing the case report for each case (Section 4.1 and 4.2). Within each case report, a description of the case is provided (Section 4.1.1 and 4.2.1), followed by sections on the planning (Section 4.1.2 and 4.2.2) and control processes (Section 4.1.3 and 4.2.3). Physical activities and the phases within each planning and control process are also discussed. To avoid repetition, aspects of Case Study Two's consultancy practice which are similar to those of Case Study One, which have been fully described, are mentioned only briefly in the case report of Case Study Two. Although the consultancy processes are conducted on a one-on-one basis, the terms "clients" or "growers" are used in most of the discussion in this chapter and may be used interchangeably with the terms "client" or "grower".

4.1 CASE STUDY ONE

4.1.1 CASE DESCRIPTION

Case Study One has considerable horticultural industry experience from his upbringing in the kiwifruit industry, through study at Massey University and from eight years' work as a consultant with the Ministry of Agriculture and Fisheries (MAF). Currently, he focuses on greenhouse production of tomatoes, cucumbers, and capsicums, although he is open to work with other horticultural sectors. As a consultant, he thinks that it is his responsibility to assist greenhouse growers to adopt IPM as easily, comfortably, and quickly as possible, as he thinks that this is the way the New Zealand horticultural industry will go in the future.

Currently, Case Study One and his partner serve between 150 and 200 clients per year. The clients are distributed from Christchurch and Canterbury in the South Island to Whangarei in the North Island. Some 80% of his client base are located in the Tauranga, Waikato, and Auckland regions. His clients' properties range from those covering 1,000 m^2 to as large as 3.5 ha. The majority of his clients however, posses between 2,000 to 4,000 m^2 of greenhouse.

Case Study One's clients can be divided into two categories, preferential and one-off clients. Clients in the Preferential Customer Programme are visited on a regular basis (weekly - quarterly), the frequency of which depends on the clients' needs. The contract for this programme is renewed annually. Case Study One provides in-depth advice in terms of planning and the on-going control of the business. In relation to IPM, these include activities such as the use of: bumble bees, *Encarsia* and other beneficial organisms, soft and organic sprays, and making sure that the environmental systems are working well to support the crop and beneficial organisms. As a rule of thumb, Case Study One spends half an hour doing 'behind the scene' work for every hour he spends with a preferential client. Although only about 15% of his clients are currently in this category, Case Study One spends up to 40% of his time with these clients. The second category incorporates growers who want only a one-off consultancy service. These growers usually telephone Case Study One asking for technical "fire fighting" advice, or to ask his opinion on some particular issues.

In his approach to his clients, Case Study One prefers to help them to learn, rather than just to give them instructions. "*We're trying to actually educate them at the same time and give them some information and upskill the growers and* [that] *hopefully helps us too.*"

4.1.2 PLANNING

4.1.2.1 PHYSICAL ACTIVITIES

New clients may express over the telephone their interest in changing to IPM, while existing clients may indicate such interest either on the telephone or, in most cases, during their regular visit. In a few cases, where his existing client seems indifferent to the developments in the greenhouse industry, Case Study One may take the initiative and raise the IPM issue during a visit, provided that he considers that there is a relatively high chance that IPM will be successfully implemented in the client's property.

Once the interest is expressed on the telephone, Case Study One gathers information from the grower, provides IPM-related information and an initial IPM design, screens the client, makes an appointment for a field visit, and formalises the initial IPM strategies. This visit is made within one to four weeks of the initial call. At this stage, new clients are required to choose the type of service they want the consultant to provide. If growers are interested in IPM, Case Study One encourages them to choose the Preferential Customer Programme because it provides the growers with the support they need in the early stages of IPM implementation. For the existing clients, a visit to discuss the issue further may be made during their regular visiting schedule, or an additional visit may be required. This process normally occurs in the same telephone call.

Following the telephone call, Case Study One formalises the initial IPM strategies by modifying his Grower Summary Letter template, and sends it to the client. This letter contains brief information about IPM and how it works, the initial design of IPM strategies based on the background information about the client's property, and the approximate cost for *Encarsia*. It is useful for the clients to read such information before the issues are discussed further during the field visit.

During a visit, Case Study One follows a certain procedure (Figure 4.1). If Case Study One knows that IPM will be one of the topics which a client will want to discuss in a given visit, he will then make sure that he brings all the tools necessary for his explanation of IPM to the grower later. In cases where Case Study One is visiting an existing client, then only a short ice-breaking conversation occurs. The review and checking, crop walk, and discussions are conducted as part of his involvement in the control stage of the client's crop management, and are not related to IPM. However, if Case Study One is visiting a new client, then the early stages of the visits, such as ice-breaking conversation, review and checking, and crop walk are used to familiarise himself with the client, the property, and the client's crop management. More time is allocated at the review phase to gathering as much information as possible about the new client's systems. This phase is normally conducted in places where growers are not easily distracted, such as in the packing shed, office, under the shade, or adjacent to a greenhouse. In such a first visit, a short crop walk is used by Case Study One to get a complete picture of the cropping systems. Case Study One's assessments of the crop performance are quantified and written in the Tomato Recording Sheet, a form he adapted from those developed by Substratus B.V. (Belgium).

When visiting an existing client, the discussion phase is used by Case Study One to discuss technical issues related to the control stage, and to provide the IPM-related information. However, if he is dealing with a new client who is interested in IPM, then this phase is not used to discuss issues relating to control stage. In providing IPM-related information, tools such as a video, pictures or living samples of *Encarsia* life stages can be used to give clients a better understanding of IPM. To ensure that the grower is comfortable with the use of *Encarsia* to control whitefly, the screening phase, if has not been done on the telephone, will also be conducted at this stage. Case Study One will design the IPM strategies on the day and these will be provided either verbally or through hand-written notes. Normally, if he is dealing with a new client, then only minor changes, in terms of pest management, are recommended at the first visit. After he knows the grower's ability to implement the plan, then more major changes can be suggested. Following the discussions, Case Study One summarises all major changes he has recommended and writes these in his Tomato Recording Sheet. Prior to leaving the property, more relaxed conversations about personal and non-professional issues are conducted.

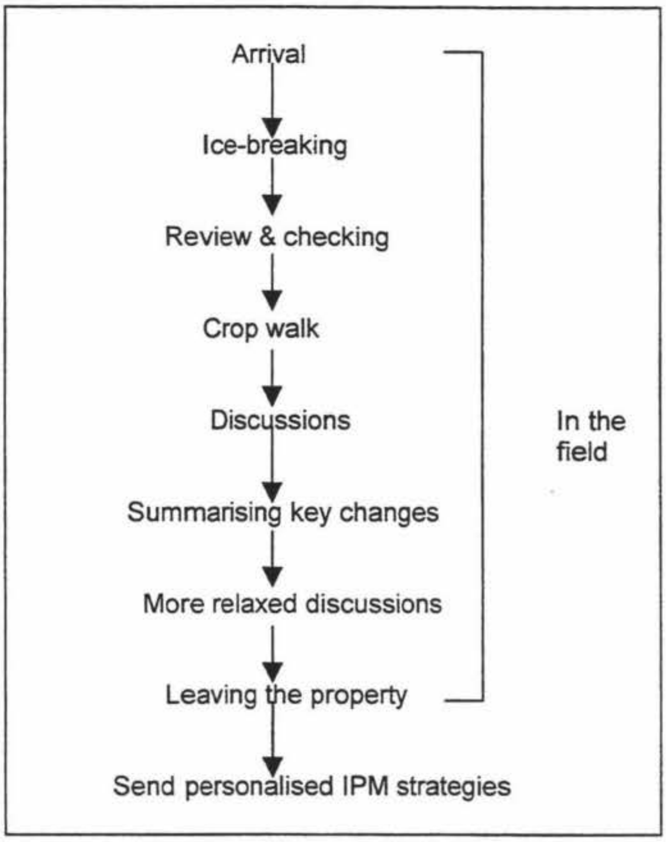

Figure 4.1 Physical activities conducted by Case Study One on the property during the planning stage of IPM strategies.

After finishing a visit where IPM strategies are designed, Case Study One then will formalise, type, and send the strategies to the grower in the form of another Grower Summary Letter (Appendix 5) or Crop Timetable (Appendix 6). This activity is conducted by modifying his template Grower Summary Letter. The Grower Summary Letter provides the key points relating to the establishment of IPM strategies on the clients' properties. The key points include: the environmental set point recommendations for humidity and temperature, the initial rate of *Encarsia* introduction and the rate to use should an outbreak of whitefly occur, and the spray recommendations for important pests (e.g. whitefly, russet mites, aphids, and two-spotted mites) as contingency plans. It also provides information regarding the *Encarsia* life cycle and how it controls whitefly, and the cost of *Encarsia*. This can be used by growers to assist their decision making process.

In the Crop Timetable, the IPM strategies are combined with the plans for other crop management activities which need to be conducted by the clients each month until the end of the season. It includes the key target dates for: planting, bumblebee introduction, monitoring of irrigation and the nutrition programme, deleafing, day and night temperature regime, insect and disease monitoring in relation to pest pressure periods, *Encarsia* introduction, harvesting, and clean-up.

Although the Crop Timetable is given to all Case Study One's preferential customers at the beginning of the season, the approach taken by Case Study One differs between inexperienced and experienced growers. With inexperienced growers, the plans are discussed on a monthly basis or before their next field visit, while with experienced growers, the discussion can be focused on a two-monthly basis.

4.1.2.2 PLANNING PROCESS

Plans for IPM strategies may be made at the strategic, tactical, and operational levels. At the strategic level, the clients must consider whether to change their pest management strategies from conventional to IPM. Case Study One encourages his clients who still use conventional pest management methods to start considering IPM, because he believes that IPM will be the standard requirement in the future. Once the clients have decided that they are willing to adopt IPM, Case Study One can move on to design the IPM strategies at the tactical level. The tactical plan comprises the skeleton strategies to manage pests throughout the year, and important targets. By explaining how various IPM strategies affect the crop, pests, and beneficial organisms at certain times of year, Case Study One reduces the clients' dependence on him for day to day (operational) management advice. The planning process described in this thesis therefore, focuses on the tactical level of IPM strategies designed by Case Study One.

The aim of the planning process is to develop IPM strategies which are tailored to the clients' specific circumstances, while still achieving the desired crop performance level. The actual planning process is shown in Figure 4.2. It is a cooperative planning process involving the consultant and his client. The consultant must design the plan, but to do this he must obtain information from the client. However, the client is responsible for making the final decision and implementing the plan (grey areas). To do this effectively, the client must understand IPM. Therefore, an important component of this process is the provision of information by the consultant to the client.

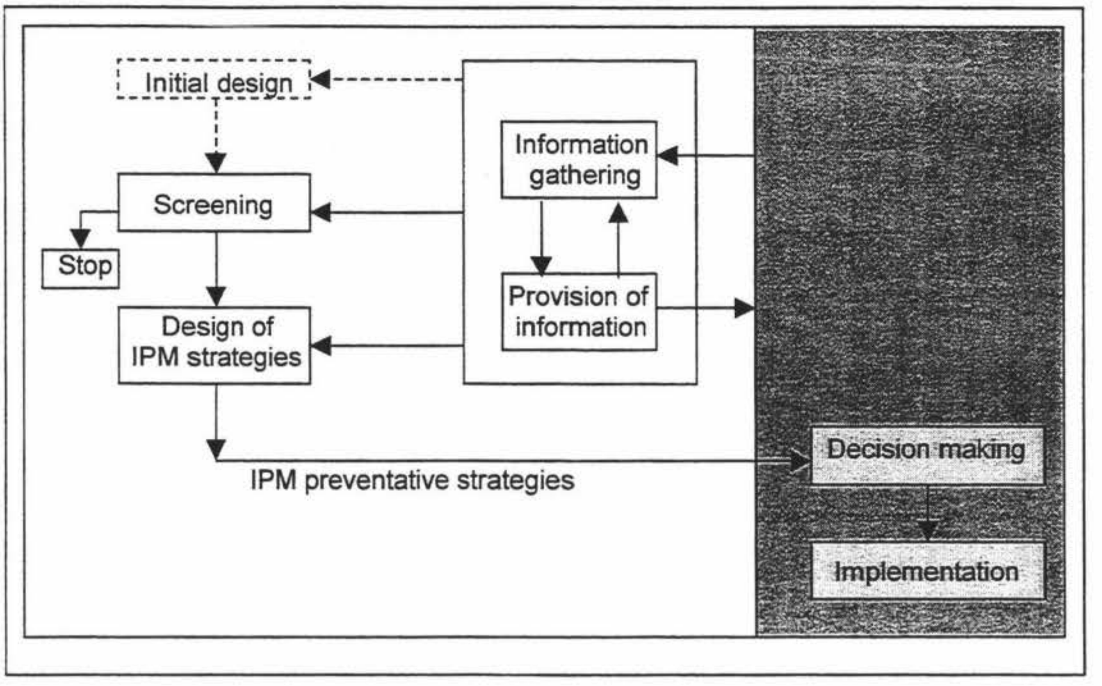

Figure 4.2 The planning process used by Case Study One to design preventative IPM strategies for a client.

Notes: The consultant's roles.
The grower's roles.
----- Conducted if initial interest is discussed on the telephone.

INFORMATION GATHERING

Information gathering is used to obtain information about the clients and their properties. This stage is particularly important for a new client. Information about a client is gathered during both the telephone call and the field visit (Table 4.1). The key information which Case Study One tries to obtain from his client is the type of greenhouse and the amount of control the client has over the greenhouse. Important information collected on the telephone usually relates to: all general aspects of the greenhouse, crop age, variety, and media, and the client's expectation, experience, chemical use policy, and attitude toward IPM. Some of this information is then scrutinized for further details in the field. While information such as the crops grown in the grower's home garden, crop duration, and the grower's decision making skills is normally sought only in the field. While not all the information he gathers is needed for the IPM design, it helps build up a 'holistic' mind picture of the client and his/her property.

Table 4.1 Summary of means of obtaining information by Case Study One.

Information		Telephone	Field visit
GREENHOUSE			
Structure		✓	
Cladding material		✓	
Age		✓	
Environment:	**Temperature**	✓	✓
	Humidity	✓	
	Ventilation	✓	
	Controller	✓	✓
Location:	**Neighbour**	✓	✓
	Garden		✓
History:	**Spray**	✓	✓
	IPM	✓	
	Pests	✓	
CROPPING SYSTEM			
Crop age		✓	
Variety		✓	✓
Crop duration			✓
Media		✓	
CLIENT			
Expectation of IPM		✓	✓
Experience		✓	✓
Policy on chemical control		✓	
Decision making skills			✓
Attitude toward IPM		✓	✓

Greenhouse

Information collected about the greenhouse can be classified under the categories: structure, cladding material, age, environmental controller, location, and history (Figure 4.3). Case Study One classifies greenhouse structure on the basis of stud height, which is related to its age. Old greenhouses typically have a low stud (2 to 2.5 m), while newer greenhouses usually have a high stud (3 to 4 m). Crops grown in old greenhouses need to have their lower leaves removed sooner than those grown in high stud greenhouses. Therefore, the black parasitised scales will be discarded before the *Encarsia* has hatched out, minimising their effectiveness.

Case Study One believes that plastic greenhouses operate differently from glasshouses. Furthermore, he believes the age of the cladding material also affects the quality of the greenhouse. "*Glasshouses tend to perform better with IPM than plastic houses. Now that could be two things. One could be due to light, better light through the glass. Probably lower humidity, or it could be lower chemical residues on the glass.*"

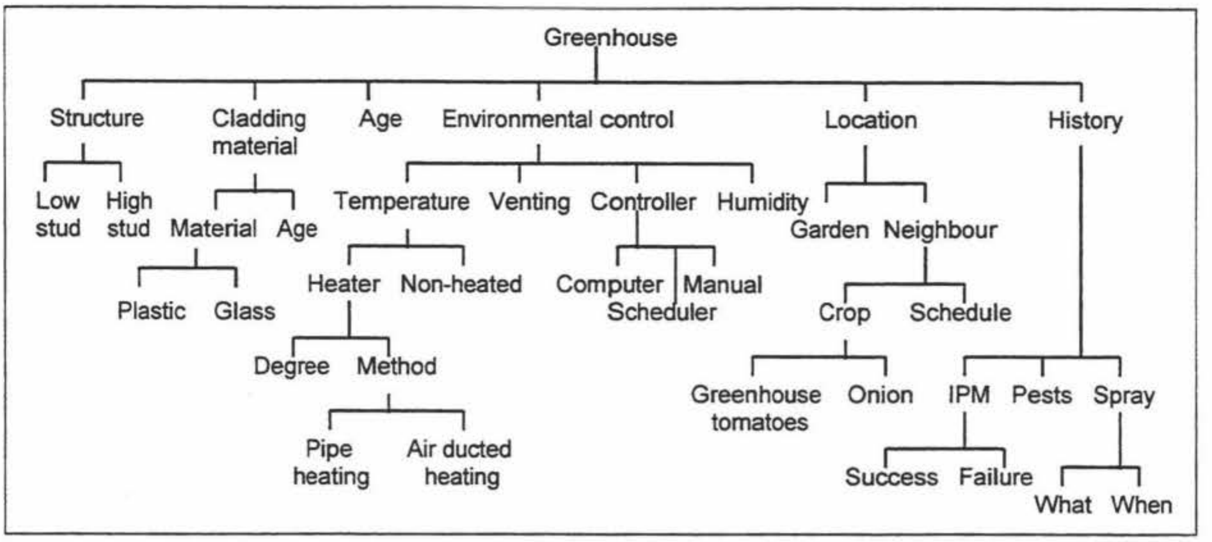

Figure 4.3 Case Study One's classification of greenhouse-related information.

There are four attributes of environmental control which Case Study One always tries to find out from his clients. The most important attributes relate to the temperature control in the greenhouse. First, he needs to know if there is any heating system or not. If there is, then he wants to know the temperature that the house's heating system can hold. From this he can establish if the greenhouse can operate within the desired temperature range for both tomato production and the beneficial organisms. He inquires also about other issues such as the way that heat is distributed and the type of heating used as these have a bearing on the system.

The second attribute of environmental control is humidity. This attribute is associated with disease pressures in the greenhouse. Higher humidity results in higher disease pressures, hence growers may have to spray more often and this will impact on the *Encarsia* population. Therefore, Case Study One needs to know the range of humidity levels in the greenhouse.

The third attribute of environmental control sought by Case Study One is to do with the ventilation system in the greenhouses. He needs to know whether they are able to set the vent temperature automatically or not, and also if they are able to purge the air. This information is used to assess the temperature and humidity management in the greenhouses. The last attribute of environmental control relates to the way the clients manage the three attributes mentioned above, whether they are controlled manually, or automatically through a scheduler or a computer.

Information about the location of the client's property is separated into the client's own garden and the neighbours'. Information about the proximity of the property to neighbouring greenhouse tomatoes or onion field crops is critical because these are sources of whitefly and onion thrips. Home gardens also provide a year-round threat of these pests, and are therefore relevant to the planning process.

There are three attributes of greenhouse history sought by Case Study One: spray history, IPM history, and past pest problems. An understanding of the spray history allows Case Study One to determine the persistence period[1] in the greenhouse. This information is more important if the cladding material of the greenhouses is plastic because Case Study One believes the residues are retained for longer on plastic than on glass. Case Study One needs to understand the IPM history (or lack of) of the greenhouse and the success rate the clients had with IPM, particularly in relation to beneficial organisms. If it was not successful, then he wants to know the reasons for failure. The incidence of past pest problems provides Case Study One with insight into possible pest problems the clients may have. For some clients, pest history problems such as pesticide resistance may become their motivation to shift to IPM.

Cropping system

The second area of information sought by Case Study One is about the clients' cropping system. This information can be classified into the categories: what crop, current crop age, variety, duration, and the media type (Figure 4.4). For tomato crop, Case Study One classified crops on the basis of age as either young (before 2nd truss) or mature (after 2nd truss). IPM strategies have a higher chance of success if introduced into a young crop because it has a lower potential of having a high pest population than a mature crop has. If the crops are already mature, Case Study One inquires about the pest pressures and the spray history, to determine the persistence period before IPM can be initiated.

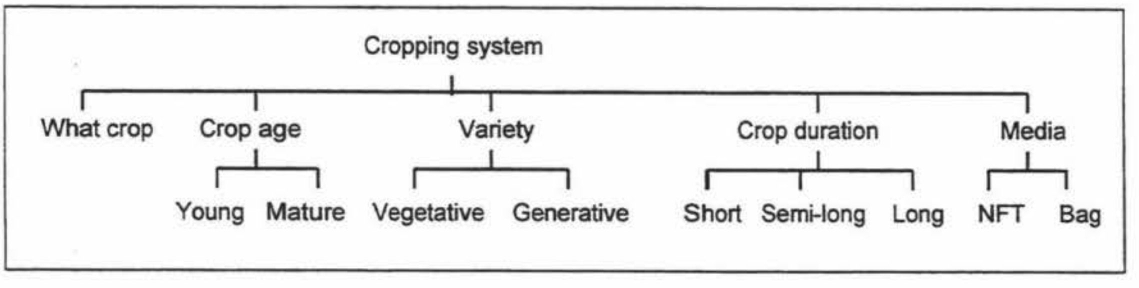

Figure 4.4 Case Study One's classification of cropping system-related information.

[1] The waiting period before (re)introducing beneficial organisms because of the residual effects of the chemical used previously in the greenhouse.

Crop variety information may be sought both during the initial telephone call and on the field visit. Although there is no direct relationship between tomato variety and its compatibility with IPM strategies, information about the variety helps Case Study One to visualise the current situation in the greenhouse. Case Study One differentiates between vegetative (vigorous growth with tight and vertical leaves) and generative (open and more horizontal leaves) varieties. Vegetative varieties tend to have higher disease pressure due to their vigorous growth, compared to generative ones. Moreover, such features complicate growers' spray activities.

Information regarding the crop duration[2] is necessary also if the clients are ready to implement IPM. This particularly relates to the stud height of the greenhouses. If the clients plan to do short cropping (6 months), then stud height will not be an issue for IPM because they will do less deleafing than if longer cropping. However if they plan to do semi-long (9 months) or long cropping (11 to 12 months) and they have a low stud height, then this information will be considered further while Case Study One designs the IPM strategies for them.

The final attribute of the clients' cropping system considered by Case Study One is the type of media used in their greenhouses. This is classified as either a NFT or a bag culture system. NFT systems tend to have higher disease pressures compared to bag culture because of the presence of extra water inside the greenhouse system which increases the humidity in the greenhouse. The situation can be exacerbated if the clients grow a vegetative type of plant in low stud greenhouses. While this information does not necessarily affect the IPM design later on, it is an important consideration for the viability of IPM strategies, and therefore is sought during the initial telephone call.

Client

The information collected by Case Study One on the client can be classified under the categories: reasons for considering IPM, experience, policy on chemical control, decision making skills, attitude toward IPM, and marketing policy (Figure 4.5). Case Study One always tries to discover the reasons behind the clients' interest or curiosity in IPM and what they expect from it. Some clients may still think that IPM is a way to eliminate the use of sprays or save a lot of money. If he finds the clients hold false expectations, he will correct them. The common reasons for the clients' interest in IPM are: concern about family health (who will have to deal with the routine chemical spray applications), the clients' dislike of regular chemical sprays, and the increasing pressure from markets which

[2] The period the crop stays in the greenhouse.

demand IPM-produced tomatoes. Further discussion regarding this issue is normally conducted in the field.

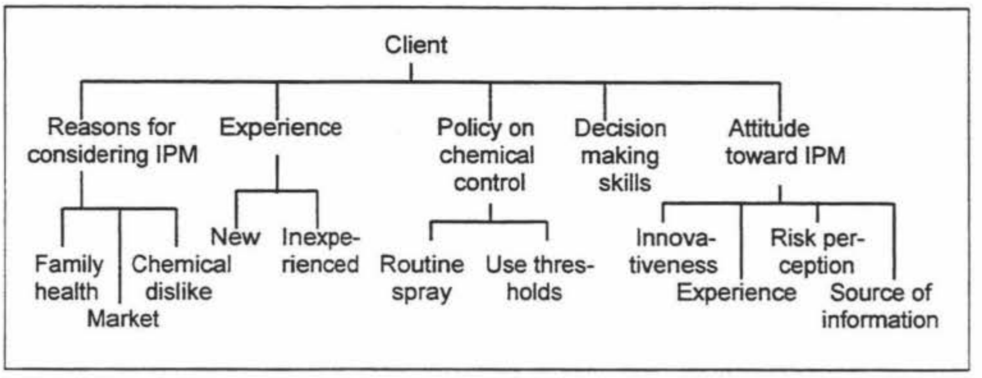

Figure 4.5 Case Study One's classification of client-related information.

Case Study One also wants to know about the clients' experience both in growing crops and implementing IPM strategies. Support from consultants is needed particularly for first-time IPM growers or inexperienced growers. Case Study One believes that experience is not absolutely necessary to implement IPM successfully as long as clients are enthusiastic and eager to learn. "*They do everything you say and they're very in tune, they do all the monitoring that you want them to do, they record things and they're very focused so there's no sort of minimum level.*"

Case Study One classifies clients on the basis of chemical control policy into those who spray regularly and those who use thresholds as the basis for chemical application decisions. Clients within the second category tend to adapt more easily to IPM strategies. By asking questions such as "What sort of decisions have you made in the past?", Case Study One can gauge the clients' ability to make informed decisions. The information is used to determine the level of support and the type of information the clients need.

The clients' attitudes toward IPM reflect how comfortable they are with the idea of not totally eliminating whitefly and of using less spray. This is used as one of the criteria to screen the clients' interest and readiness to implement IPM. Case Study One also identifies the clients' attitudes toward the use of inundation[3] levels of *Encarsia*. Case Study One is convinced that the clients' attitudes toward IPM are influenced by four factors: their level of innovativeness or interest in new things, the clients' experience, risk perception, and the clients' sources of information. Clients who have experienced difficulties in dealing with whitefly because of resistance problems, or those who know

[3] Releasing large numbers of natural enemies for immediate reduction of a damaging or near damaging pest population.

having a few whitefly in the greenhouse does not threaten their crop, may become comfortable with IPM more readily than inexperienced clients. Clients who have talked to growers who have unsuccessfully tried IPM tend to be less willing to take up IPM strategies.

PROVISION OF INFORMATION

Because the consultant is developing a plan for a client who knows little about the subject area (IPM), information provision is an important component of the consultancy processes. This information is used to assist the clients to make informed decisions and to encourage them to implement IPM. The provision of information takes place during the initial telephone call and the field visit. More detailed information is provided in the field and it covers the technical aspects to which the clients can relate. To refresh the clients' memories following the initial telephone call, some information is repeated in the field.

Regarding *Encarsia* and whitefly, Case Study One will provide an overview of their interaction and life cycles. "*.. I'll then give them an overview of the typical cycle of how things work, ... to give them an idea of how it stacks up with the whitefly, and saying that in the summer it may be a third of the time of what it might be in the winter.*" While explaining the life cycle, Case Study One will note that the clients may not see results within the first four weeks of initial *Encarsia* introduction because of its 21-day life cycle. In addition, in the field he will also show them pictures or a video of all the life stages of *Encarsia* and living samples of tomato leaf with black-scales and some instar stages of whitefly (Figure 4.6). More technical details, such as the effect of deleafing and layering to black scales and where to put the *Encarsia* cards in the greenhouse, are also explained in the field. "*Just explain about ... where to locate them* [the *Encarsia* cards] *in terms of on the more pressure points to start with, on the sunny sides or around the heaters and things like that, in the warm spots.*"

To reduce the clients' concerns about the risks associated with IPM, Case Study One encourages them to implement IPM strategies, in particular the use of *Encarsia*, in one greenhouse initially. To increase the likelihood of the clients' implementing *Encarsia*, Case Study One will discuss the support they can obtain both from him and from the technical representatives from bumblebee and beneficial organism companies. Information about the price of *Encarsia* is also provided. In addition, information about the relationship between the neighbour's crop (external environment) with the clients' is provided, if relevant.

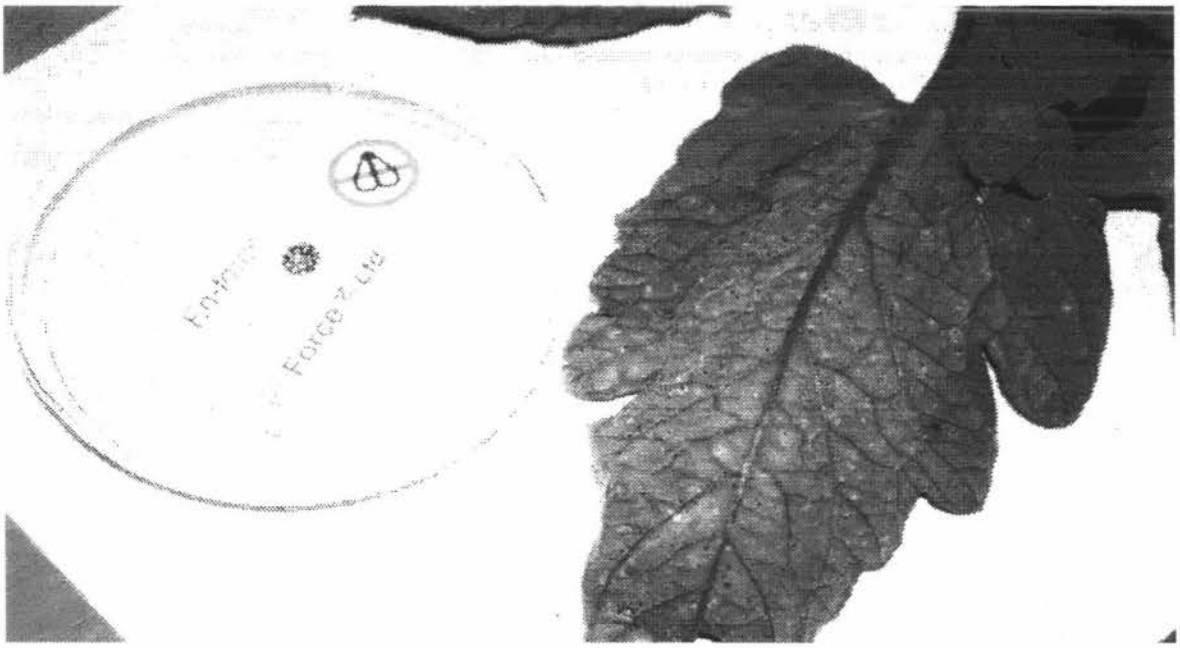

Figure 4.6 Tools used by Case Study One to provide information on *Encarsia*.

Case Study One explains about the types of sprays which are compatible and incompatible with *Encarsia*, and the persistence period before reintroducing *Encarsia* after spraying the crop. He will provide also an estimation of how often the clients will have to spray. In cases where the clients still use a vibrator to pollinate their tomato crop, he will start by encouraging them to use bumblebees, because he believes that the use of bumblebees will increase the likelihood that the clients will use other beneficial organisms and soft sprays.

INITIAL DESIGN

In cases where the initial contacts are made through the telephone, Case Study One will provide an initial plan of the IPM strategies based on the information known about the grower at that stage. The initial design of IPM strategies helps the grower to visualise the implementation in his/her situation. The plan is then mailed to the client in the form of a Grower Summary Letter after the telephone call. The letter is personalised from his Grower Summary Letter template based on his understanding about the grower and his/her property. The main focus of the plan is the predicted *Encarsia* rate to be introduced, and the period of time over which it should be introduced. The process which Case Study One follows to develop this initial design is the same as that used in the actual design process. However, not many details of IPM strategies are provided until he visits the property.

SCREENING

The aim of screening is to identify the extent to which the greenhouse is suitable for IPM and the clients' readiness to implement IPM. The clients and their greenhouses are screened based on three criteria: technical feasibility based on the greenhouses, the clients' commitment to IPM, and how comfortable they are with having some whitefly flying in their greenhouses. Old type greenhouses with no heating systems may not be suitable for IPM implementation throughout the year for technical reasons, although feasible for IPM during summer. This may be discussed in terms of the cost effectiveness of using IPM given the clients' particular circumstances. In regard to commitment, clients who are not totally committed to IPM may give up more easily as they implement the strategies. IPM strategies for greenhouse tomatoes involve the use of *Encarsia* to manage whitefly. If the growers are used to an environment free of whitefly because of routine sprays, and cannot accept having some whitefly flying around in the greenhouse to balance the system, then they might not be ready to apply IPM. "*So I'd say well look really it sounds to me like you need to have a bit of a period of seeing some other crops and how they work before you decide because you're obviously not at a stage where you're ready to implement it.*" In this case, the planning process then ceases.

DESIGN OF IPM STRATEGIES

During the design process, Case Study One tailors the IPM strategies to the clients' situations. Information obtained during the information gathering phase of the planning process is used in the design phase. The IPM strategies developed by Case Study One comprise five main areas: *Encarsia*, environmental control, cultural practices, sanitation, and preventative spot spraying. These strategies detail the sequence of activities the clients must undertake throughout the season. Case Study One also specifies both a monitoring strategy, which is used to control the implementation of the plan, and contingency plans, which can be used to prepare the clients with deviations from the plan.

The focus of IPM strategies is prevention. This is achieved both directly, through the use of *Encarsia* and spot spraying to prevent some pest problems, and indirectly, through the use of environmental control, cultural practices, and sanitation, to provide an environment which favours beneficial organisms, but inhibits pests. The following sections discuss each of these strategies in more detail.

A. *ENCARSIA*

Information obtained during the information gathering phase is used, in combination with decision rules, to modify Case Study One's *Encarsia* template plan. The template plan, which was developed only in his mind and was not in a written form, comprises hierarchically arranged factors which he considers in tailoring the *Encarsia* initial and maintenance rate to each client's specific circumstances. The initial introduction rate is the rate at which *Encarsia* should be introduced at the start of using it. Maintenance rates are the rates of *Encarsia* introduction two to four weeks after initial *Encarsia* introduction.

The decision rules used by Case Study One can be represented in a hierarchical decision tree structure (Figure 4.7). with the most important decision criteria in the upper part of the tree, which allows more efficient decision making. There are eight factors or decision criteria which are used to modify the standard *Encarsia* strategy. At the top of the hierarchy, crop type is used because this determines which template Case Study One uses, whether it is a tomato, capsicum or cucumber template plan. The next most important discriminator is greenhouse age. New greenhouses, whether they be of plastic or glass, have a high stud height (≥ 3 m). In contrast, old greenhouses have a lower stud height (2 to 2.5 m). Age is important because tomato crops in old greenhouses always need a higher initial rate of *Encarsia* due to the deleafing effect on the black scales and the chemical residues which have been built up in the cladding material.

For each branch of the decision tree after greenhouse age, the next important discriminator is the age of the crop. Case Study One distinguishes between young (less than 2nd truss) and older (more than 2nd truss) crop. Young plants tend to have low levels of whitefly. This makes them suitable for the introduction of *Encarsia*. In contrast, older crops may have high levels of whitefly, making them less suitable for *Encarsia* introduction. Therefore, the next decision rule in relation to older crops relates to whitefly population. Case Study One differentiates between low (< 2 adult whitefly per plant) and high whitefly populations (≥ 2 adult whitefly per plant).

Crops with a high whitefly population may need a clean-up spray and *Encarsia* inundation to lower the initial whitefly population. However, if the plants have produced more than 5 trusses, they are already about 1.5 m high, and in low stud greenhouses that means they are close to deleafing, which can significantly reduce the number of black scales. For a short crop, it is also close to being pulled out. Therefore, in low stud greenhouses where the crop is past the 5th truss, it is uneconomic to introduce *Encarsia*.

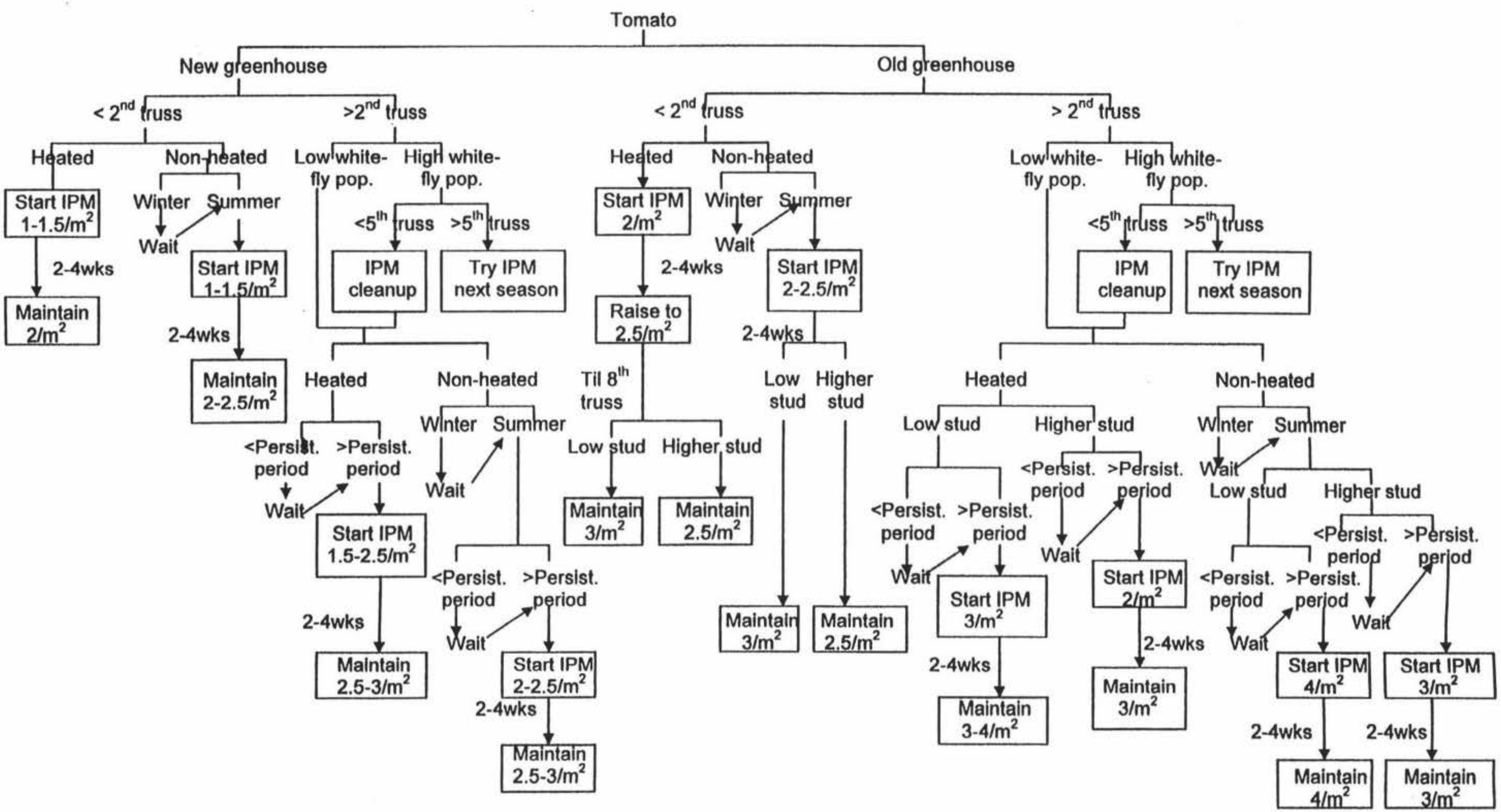

Figure 4.7 Case Study One's hierarchical decision tree for tailoring *Encarsia* template plan to a client's situation.

The next factor considered by Case Study One is the heating capability of the greenhouse. Some growers may have a heating system in their greenhouses, but for various reasons, they may not be able to maintain the temperature at the desired level. Case Study One classifies these greenhouses together with unheated greenhouses. This type of greenhouse has a low success rate for IPM during winter (May to August) because of the slow growth of *Encarsia* and the high disease pressure. " ... *because you would be doing so much disease control sprays that your Encarsia wouldn't work.*" Therefore Case Study One will recommend that they wait until summer (September to April) before starting the introduction. Season itself is not an issue for heated greenhouses, although the low light levels may constrain crop growth during winter. In general, growers with non-heated and inadequately heated greenhouses will need to use a higher rate of *Encarsia*. For clients who start while the crops are young, they can begin introducing *Encarsia* after Case Study One finished considering the heating and season.

For crops which are older than the second truss, Case Study One uses spray history information (after heating) to determine the start of *Encarsia* introduction. "*So really it's in the last four weeks for summer and maybe six weeks in the winter, what sprays had been put on.*" Chemical residues are degraded more quickly during summer or in heated greenhouses due to faster chemical reactions in high temperatures. Chemical type will determine the persistence period, e.g. endosulfan has a longer persistence period (4 weeks in summer) than methomyl (7 days in summer).

In old greenhouses with mature crops, the initial *Encarsia* rate for clients is influenced by stud height. Depending on the design of the greenhouse, the stud height may be increased up to about 2.7 m. Higher studs delay the start of the deleafing process sufficiently to give more time for the *Encarsia* to hatch out from black scales. This means that the clients can have a lower introduction rate compared to those with a lower stud height. In contrast to this, the stud height in an old greenhouse which contains a young crop will affect only the maintenance rate, rather than the initial introduction rate. This is because the deleafing activity does not occur until about the sixth truss, when the maintenance rate should be introduced. Stud height is not an issue in new greenhouses because of their high stud height (3 - 4 m).

After considering all these factors, Case Study One can then recommend an introduction rate, which varies from 1 *Encarsia*/m^2 for new adequately heated greenhouses with a young crop, to 4 *Encarsia*/m^2 for old unheated greenhouses with a mature crop. "*So basically once we've gone at that for 2-4 weeks and really it's weather dependent. If it's* *favourable weather we would probably go for 4 weeks at the lower rate. If it was cold adverse weather we would probably only do 2 weeks of that and then we'd need to climb because things would be going too slow."*

The maintenance rates recommended by Case Study One vary from 2 *Encarsia*/m^2 in new greenhouses to 4 *Encarsia*/m^2 in old greenhouses. Provided that other pressures are under control, these rates should be maintained for at least 12 weeks to achieve 80% parasitism or up to 4 weeks prior to harvest. If the crops are beyond the 10th truss and the sustainable level of 80% parasitism is achieved, Case Study One may recommend that the clients stop introducing *Encarsia* and monitor the whitefly population levels. If they need to reintroduce *Encarsia*, Case Study One will recommend that they apply the rate used previously.

Case Study One also provides advice on how to allocate the *Encarsia* cards. "*Well what we normally say to them is to put into the house 2 per metre, but focus them in areas that you know will be of greater pressure* [in warm spots]. *...They may not put any in some rows and in other rows they may put double the amount.*"

B. ENVIRONMENTAL STRATEGIES

The second component of IPM strategies provided by Case Study One relates to the clients' environmental control. "*And so.. you need to develop an environmental programme that looks at the plant management and also looks at the beneficials. And it needs to be compatible with them both..*" By managing the environment, Case Study One also attempts to provide an unfavourable environment for pests. The design of the environmental system incorporates temperature, humidity, and ventilation. Although the environmental system is affected also by the level of CO_2 and solar radiation, both parameters are mostly related to production, instead of to IPM, and therefore, are not discussed here.

Temperature

The management of temperature aims to: achieve the vegetative-generative balance of the plant; ensure an adequate duration for the *Encarsia* and bumblebee life cycles; and, in combination with humidity control, prevent disease infection. These goals are achieved by providing temperature set points as guidelines (Table 4.2) to clients with suitable heating systems. In conjunction with the set points, Case Study One will also explain to the clients the effect of temperature fluctuations on the crop system and the way they can manipulate the set points to accommodate variability in the weather.

Table 4.2 Case Study One's guidelines for temperature set points.

Season	Day	Night	Notes
Winter	18°	15°	Cloudy day
	21°	17°	Sunny day
Summer	17°	17°-19°	
	20°		Target day 12 hours
		17.5°	Target night 12 hours

The weather outside the greenhouse affects the temperature inside the greenhouse and causes variation throughout the day. "*What often happens though is that you never hold a uniform temperature, it will fluctuate and so often though you have a set point, the 12 hour average may be above that set point... You need to know what those actual running averages are because that determines plant habit. You have a set point but it's the average of the whole pattern which governs plant habit.*"

Plants tend to grow generatively, with thin stems and rapid fruit growth, if they are subject to large differences between average day and night temperatures. In contrast, the smaller the difference between day and night temperatures, the more vegetative the plants are, with thick stems and vigorous leaves. Therefore, the temperature set points may vary depending on the plant condition, stage of growth, and season. Plants younger than 6^{th} truss require generative control to avoid becoming too thick, and therefore the clients need to maintain a large difference (max 6°) between day and night temperatures. In contrast, older plants with a heavy fruiting load need vegetative control to avoid becoming too thin while carrying a heavy crop load. Therefore, a small day and night temperature difference (min 2°) is required. The differential needed for vegetative or generative balance is similar in both winter and summer.

Case Study One believes that providing a few more hours of higher temperatures than recommended in the guidelines is useful to increase the growth of beneficial organisms, particularly during winter. If the heating system is not managed by computer, then Case Study One recommends the clients compromise by trying to maintain higher night temperature at 18.5°C and manually closing the vents for one or two hours during the day to raise the temperature. Maintaining such temperatures also helps prevent *Botrytis* infections, which are more likely to occur at temperatures less than 16°C with 93% humidity for six hours. Clients with heat pipes on the floor are also told to increase the heat in that area after deleafing to dry the wounds quickly to prevent disease spread.

Humidity

During summer, humidity should be between 60% and 80%, while in winter, the range is scaled up to between 70% and 85%. Humidity above 90% is avoided to prevent the germination of *Botrytis*. Lower humidity is avoided for young plants also because they are prone to desiccation.

Ventilation

The ventilation system is manipulated to control three environmental parameters in the greenhouse: temperature, humidity, and CO_2. The ventilation set points are shown in Table 4.3. The difference between day and night vent temperature set points is similar during winter and summer, however, the set points are higher in summer due to higher light level, and thus higher metabolic rates.

Table 4.3 Case Study One's guidelines for ventilation set points.

Season	Day	Night
Winter	18°-19°	16°-17°
Summer	21°-22°	18°-19°

To avoid high humidity at night time, which may lead to *Botrytis* infestation, particularly during winter, Case Study One suggests clients open and close their vents, using either pre-set purges or controlled set points. "*Plenty of ventilation, so that can be either pre-set purges, probably every couple of hours, e.g., maybe 2-3 times each night.. five minutes max each. Or just on controlled set points. ..but I tend to prefer to use the controlled set points, because then it does it as it's needed. When you start pre-empting it and putting in pre-set purges, sometimes they're not required and you can get too big a temperature variation.*" If the ventilation is controlled manually, then Case Study One will suggest that the clients run the temperature slightly higher than the set points to offset the risk of excessive humidity and undertake purge ventilation early in the morning and late at night.

C. CULTURAL PRACTICES

Pollination

To ensure effective pollination, bumblebees should be introduced as soon as the first truss starts to flower, which normally occurs within a week of planting. One full hive (150 bees including the queen) is needed for every 2,000 m^2 of greenhouse in the beginning, and then a new hive is introduced every four weeks. "*It'll last anything up to 12 weeks, but its maximum productive period is about 4-6* [weeks] *in the summer, 3-5* [weeks] *in the winter, depending on the amount of pollen.*" Bees can be sent to the growers on a four-weekly or request basis. Once the crop is underway, Case Study One suggests also that they closely monitor the number of opened flowers. One full mature hive can pollinate about 10,000 flowers. Dividing 10,000 by the number of plants in the greenhouse will give the clients the number of maximum opened flowers which can be pollinated by a hive. If the average number of opened flowers per plant exceeds that calculation, then new bee hive should be introduced.

Deleafing and layering

Deleafing and layering are inseparable in growing greenhouse tomatoes, and are important for disease prevention in an IPM system. Deleafing should start when the plant reaches about the 6^{th} to 8^{th} truss (in low stud height greenhouses) or later if the plant is grown in high stud greenhouses. It should be conducted every one to two weeks, and preferably only two leaves should be removed (maximum of four leaves), otherwise root loss occurs. After deleafing, a period of 2-3 days should be allowed before conducting the layering process (Figure 4.8) to allow the wounds from deleafing to dry out. This reduces the risk of disease spread.

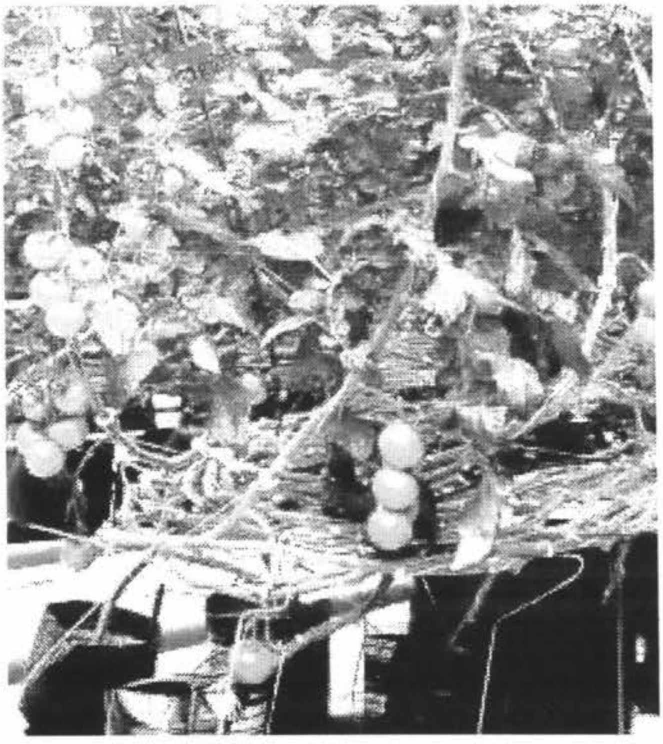

Figure 4.8 Layering of tomato crops.

Deleafing removes the parasitised scales located on the lower leaves. During the process, many of the black scales will not have hatched out and, unfortunately, will be thrown away with the discarded leaves. This will reduce the effectiveness of the *Encarsia*. However, if Case Study One has confidence in the greenhouse, he might suggest the client leave the leaves on the ground. *"If it's a new property with good control, heat pipes that can dry the leaf out and Botrytis risk is low,... I'll encourage the grower to leave those leaves, sit them on the heat pipes, or leave them on the floor, so that black scale can come up into the crop."*

Nutrition and irrigation

The nutrition and irrigation programme can contribute to plant strength and indirectly increase resistance to pests. This is discussed with clients as part of the whole management programme and is not directly associated with IPM. Therefore, it is not included in the study.

D. SANITATION PROGRAMME

The sanitation programme aims to maintain hygiene in the greenhouse and its surrounding environment. This is less difficult to accomplish if there is only one stage of tomato growth in the greenhouse. The programme comprises three elements: the clean-up programme, sanitation of the external environment, and the root zone area.

Clean-up programme

Ideally, it is best if the clients approach Case Study One regarding IPM prior to planting their crop. He recommends a pre-planting clean-up a week prior to crop removal. The aim is to eliminate the residual pests (e.g. whitefly and russet mites) and prevent their carry over to the next crop. If the whitefly population in the previous crop was not under control, then a chemical such as pymetrozine may be needed about 3-5 days prior to crop removal to kill the adults. Otherwise, if the residual pests are under control, then the crops can be pulled out and removed.

Once the crop is removed, Case Study One will then suggest that clients either fog the greenhouse with formalin or wet spray the whole greenhouse with perocetic acid, which is the preferred method. If all the crops in the greenhouses have been removed, the clients can use a complete nitric acid flush in the irrigation system. The complete clean-up programme is attached in Appendix 7. A thorough clean-up should be conducted at least once a year between crops, preferably in summer, to allow the greenhouse to dry quickly. If the clients grow short crops, then they may do one thorough clean-up and one quick clean-up, without using a lot of water, in a year.

External sanitation

Maintenance of the hygiene of the external environment is as important as maintenance of the internal hygiene of the greenhouse. *"If you've got overgrown jungles, well you're going to have a problem. So, nicely mown, sprayed edges around the greenhouse, nice and neat, tidy, the problems are less."* The external sanitation strategy aims to prevent the environment surrounding the greenhouse providing alternate hosts for the pests of the crop being grown in the greenhouse.

Root zone sanitation

Root zone disease pressure depends on the water supply and whether or not the media are reused. In order to prevent disease spread in the root zone, Case Study One suggests the clients sterilise the media before reusing it, and treat their water supply with an UV steriliser. This kind of recommendation requires the clients to make a strategic decision regarding their root zone sanitation, since it involves a commitment to long-term sanitation management.

E. PREVENTATIVE SPOT SPRAY

Case Study One believes that applying preventative sprays for disease control imposes greater risk than the risk of the diseases themselves. For him, the side effects from applying a preventative spray do not justify the potential reduction in disease incidence. *"The reason why I don't like to put preventative sprays on is they have some mortality rate on Encarsia, on black scale. They definitely reduce leaf photosynthetic activity. Basically every spray is equivalent to pruning one leaf off every plant. .. There's definitely a correlation between foliar applied sprays and reduced fruit cuticle quality ..* [the fruit] *is more likely to craze."*

However, he may make some compromise and suggest the clients spray preventatively if it is unavoidable, provided that it is sprayed locally. *".. they just have* [fungicide spray in] *a little squirter water bottle, and then I'll put a little squirt onto the wound and that's quite useful in low houses with poor environment. ... So immediately we'd deleaf, and then spray the stem, give it a fungicide. .. So then when they layer, the stems are in contact but at least they've had some protection."*

Another form of preventative spray is given for caterpillar, particularly if the crop is planted in summer-autumn. If the clients know that there is a pressure period for caterpillar in their greenhouses, a spray containing *Bacillus thuringiensis* as the active ingredient can be safely applied within two weeks of planting.

F. MONITORING STRATEGY

A monitoring strategy is designed to help a client understand which IPM-related parameters should be monitored, when they should be monitored, the frequency of monitoring, and how monitoring should be conducted (Table 4.4). The monitoring strategy is designed to make the clients aware of the situations in their greenhouses, so that they can control the implementation of IPM strategies. The monitoring strategy needs to be designed before the actual implementation of the IPM strategies because it will be used soon after implementation. The monitoring parameters include pests (insects and diseases), beneficial organisms, and environmental parameters.

Whitefly population is an important parameter which should be monitored weekly throughout the growing season. About ten sample plants were taken for every 1,000 – 2,000 m^2 greenhouse to be monitored. Case Study One suggests growers always include plants in the hotspot areas (e.g. corners of greenhouse, near the doors, etc.) to be sampled. The adult whitefly count on the sample plants is used to monitor the whitefly population. The results may be written in the Pest Monitoring Sheet (Appendix 8), or noted on a layout map of the rows in the greenhouse. This is conducted either during a regular crop walk, or as work is carried out among the plant rows. Other tools, such as the yellow sticky trap, can be used to provide a rough estimate of the whitefly population (Figure 4.9). Whitefly monitoring should be conducted more often (every two days) while the plants are still in the propagation stage.

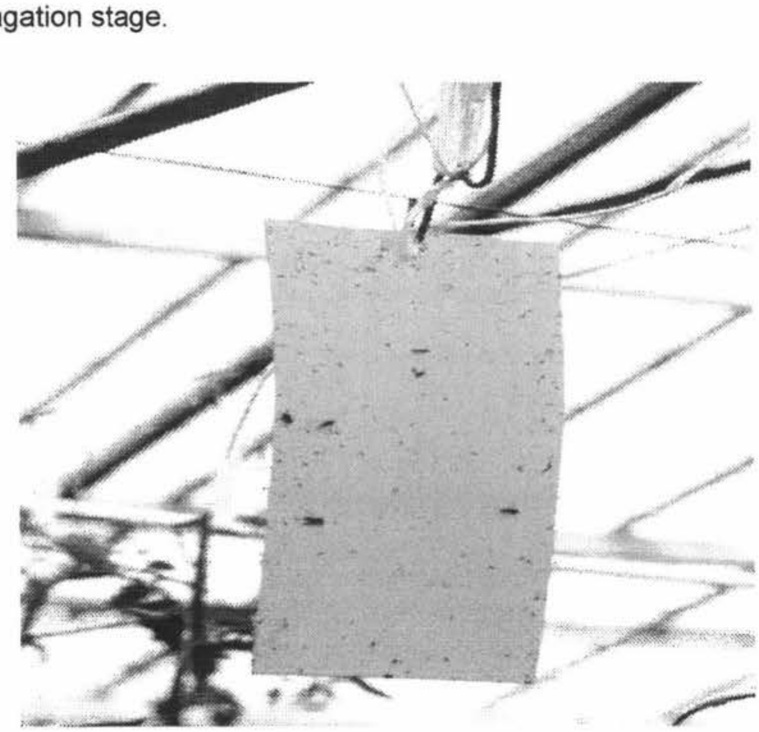

Figure 4.9 Yellow sticky trap.

Table 4.4 Summary of Case Study One's monitoring strategy.

Parameters	When	Frequency	Methods	Threshold/Standard	Notes
Whitefly	All year.	Weekly crop walk.	Count adult whitefly in the head of sample plants & use yellow trap as guide.	< 5 whitefly/plant. 5-7 whitefly/plant. Closer to 10 whitefly/plant. >10 whitefly/plant.	The threshold levels should only be used as a guide.
Russet mite	Particularly in autumn (3rd – 5th truss of short crop & 18th-19th truss of long crop).	Weekly crop walk.			Winter (July) planted crop.
Caterpillar	All year, particularly 0-2nd truss.	Weekly crop walk.	Look for symptoms (holes in the leaf) and or caterpillar.	At first signs on the leaf.	Summer/autumn planted crop only.
Aphid	All year, particularly in summer.	Weekly crop walk.	Look for aphids at head of plants.		If symptoms are found, they have been in there for quite a while.
Thrip	All year, particularly in summer.	Weekly crop walk.	Use blue traps as guide. If found, monitor more carefully.		Problems if neighbour pull out their onion (Jan-Feb). If the attack is bad, stop IPM.
Stemborer	All year, particularly 0-2nd truss.	Weekly crop walk.	Look for symptoms [sawdust on the side of the stem].		Summer/autumn planted crop only.
Botrytis	Start at 1st deleaf & layering, then all year, particularly in winter.	On going + weekly crop walk.	Look for symptoms.		
Leaf mould	Start at 3rd truss.	Weekly crop walk.	Check sides of leaves.		
Blight	Start at 4-5th truss stage.	Weekly crop walk.	Look for symptoms.		Early blight starts in summer, late blight starts in autumn.
Root health & vigour	All year, particularly at planting & between 6th to 10th truss.	Weekly crop walk.	Look at the root, pull the stem to assess root strength. 1 sample/row.		Pressure depends on water supply and media.
Encarsia	All year.	Weekly	% parasitism, adult number.	80%-90% parasitism.	Monitor 10 plants/row. See Section E form.
Pollination	Start at first setting, then all year.	Daily	Monitor flower number & bee marking.	10,000 flowers/hive at any given time.	
Temperature	All year.	Min. once per day.	Automatically by computer, or check thermometer.		
Humidity	All year.	Daily	Automatically by computer.	1-3rd truss > 60%, preferably 70-80%. The rest: 60-85%	Only applies if computer controlled.

Case Study One specifies threshold levels a client can use to assess their situation. The threshold levels indicate when the client needs to initiate certain actions such as increasing the rate of *Encarsia* or spraying the crop. *"I'm always quite comfortable if I see one or two adults in a head, per plant. ... but it's when you get up to more than a dozen or that sort of end of the scale, more than six, we start to have to beef things up and if you're in more than ten or a dozen, then you're into real pressure."* Case Study One recommends the client be careful when trying to interpret whitefly population monitoring results because of the possibility of sampling error. To minimise this, he recommends threshold levels which are slightly higher than the norm.

Case Study One tailors the threshold levels to the client's situation. Factors such as greenhouse stud height, location, temperature, *Encarsia* parasitism level, crop age, other pest infestations, and the client's risk perception and experience, may influence the whitefly threshold levels. Clients with low stud greenhouses, or in tomato growing areas, or who are not able to maintain the desired range of temperature, are given lower threshold levels because they will need to react more quickly.

Case Study One will increase the whitefly threshold levels if there are high levels of parasitism by *Encarsia*. "*..but* [if] *we've got 90% parasitism, I would again be less concerned about it* [6-10 whitefly adults per plant], *because I know there's a huge buffer there. There's a lot of black scale ready to just come up and chomp their way through it. But if we've only got 10% black scale than I know we're in trouble..*" In addition, crop age also may influence the threshold levels. Mature plants tend to have lower threshold levels because of their larger leaf area, which potentially carries more white scales than young plants.

Furthermore, the presence of other pests also may lower the threshold level, particularly if the clients need to spray to overcome the problem. Such spraying may kill some of the *Encarsia*, reducing their efficacy. The clients' risk perception and experience in dealing with whitefly is also important. Growers who are used to calendar-based spraying tend to have lower threshold levels, and therefore in dealing with them, Case Study One tends to stick to his pre-determined threshold levels, instead of waiting for the environment to govern the pathosystem[4] balance. Actual threshold levels are specified in Section 4.1.3.2 on control.

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[4] The interaction of host and the pest parasite population, which makes up a part of a cropping system (Dent, 1995).

Monitoring of other insects is carried out while clients and their workers are conducting their regular whitefly crop walk. Common tools used in the monitoring of other insects are coloured clothes pegs, which are clipped to overhead wires in areas where a pest is found to indicate pest problem areas. Insects are monitored weekly, particularly during the pressure periods such as during summer for aphids and thrips, or during autumn for russet mites. Other insects such as caterpillars and stemborer attack the plants when they are young (0-2nd truss).

The three main diseases which are regularly monitored are: *Botrytis*, leaf mould, and blight. Of these, *Botrytis* is the most significant. Therefore, although it can be monitored while doing the crop walk, Case Study One suggests clients continually monitor it. Monitoring for diseases is conducted by looking for the presence of disease symptoms.

The root zone also is monitored for diseases on a weekly basis, particularly during planting and between 6th to 10th truss, "*.. because that's the time when there's maximum fruit load and you have root loss.*" Monitoring is conducted by easing down the side of the bag a little and checking for disease symptoms. Also, the stems are pulled to get a feel for root strength. The disease pressure in the root zone depends on whether or not the media are reused and water supply is sterilised.

Beneficial organisms which require regular monitoring are *Encarsia* and bumblebees. *Encarsia* is monitored using the Pest Monitoring Sheet. The introduction rate, *Encarsia* card position on the trusses, and percentage of parasitism are monitored weekly. While for measuring the pollination activity of the bees, growers and their workers need to count the average number of opened flowers on a daily basis and check the bee marking (brown tip on flower).

The environmental parameters, temperature and humidity, are best monitored automatically by computer. If the clients enrich their greenhouses with CO_2, this should be monitored using an automated continuous checking system, or they may run the risk of toxicity.

G. CONTINGENCY PLANS

Unlike the previous strategies (A-F) which are designed to prevent problems, contingency plans are designed to enable clients to react quickly in possible pest problem scenarios. The contingency plans are provided in the Grower Summary Letter along with other IPM strategies prior to implementation. The contingency plans comprise brief spray programmes for pests (e.g. whitefly, russet mites, aphids, and two-spotted mites), such as what spray to use, the rate, and method of application. Should a pest problem occur, then more detailed plans are required from Case Study One to integrate such use of chemicals for curative purposes with other preventative strategies, particularly the use of beneficial organisms. The clients then may need to ring Case Study One to ask for further curative actions to deal with the pest. This is particularly important for clients who lack experience in IPM. Experienced growers, on the other hand, normally already know how these chemicals affect the beneficial organisms, and may need less support from Case Study One.

DECISION MAKING

The decision to implement the IPM strategies is solely the clients' responsibility. Some clients may decide to implement only part of the plan. For example, a client may want to implement only the strategies regarding the environmental system, and decide not to use *Encarsia* at all, while others may decide to fully implement all the IPM strategies. According to Case Study One, several factors influence a client's decision to implement IPM. These include whether (s)he is comfortable with the idea of IPM, his/her expectations, cashflow and labour situation, experience, and support offered by Case Study One.

The decision making process through which clients work to decide whether or not to adopt the IPM strategies is shown in Figure 4.10. First, they will consider how comfortable they are with the IPM strategies provided by Case Study One. If they feel comfortable with the strategies, then they will gauge the ability of the strategies to meet their expectations, either that in terms of healthier crop or better crop production. Following that, using the information provided by Case Study One, they will also gauge the cost effectiveness of using IPM strategies in their particular circumstances and how the strategies can be implemented within their labour situation. The final consideration usually relates to their experience in growing greenhouse tomatoes, and in particular with IPM. The provision of support by Case Study One is the final factor which may convince clients to adopt IPM.

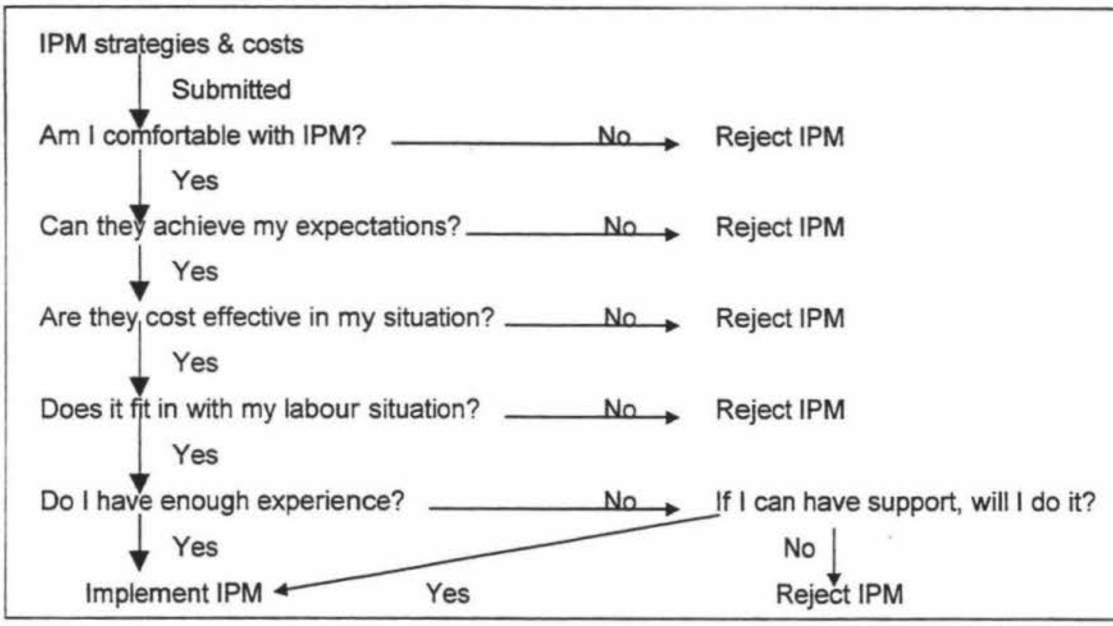

Figure 4.10 Case Study One's version of a client's decision making process to implement the IPM strategies.

4.1.3 CONTROL

4.1.3.1 PHYSICAL ACTIVITIES

The client is responsible for the implementation and monitoring of the preventative IPM strategies designed by Case Study One. Case Study One's involvement in the control process varies between clients. Support to the clients may occur over the telephone, during a field visit, or through a regular newsletter (Appendix 9) which he provides to 'educate' the preferential customers and keep them up to date with developments in the greenhouse industry.

Clients may telephone Case Study One for: confirmation, problem solving, and making appointments. Normally, prior to making major decisions the clients, particularly the inexperienced ones, will ring Case Study One to confirm their decisions. Other clients used the telephone call to confirm their interpretation of their monitoring results. Through telephone calls, clients can also ask for suggestions or solutions if they think they have problems with their cropping system, based on their monitoring results. In addition, clients, particularly one-off ones, ring and ask Case Study One to visit the property to discuss their problems. Preferential customers also may get an additional visit if it is required.

In cases where growers ring Case Study One because of their concerns about the monitoring results, Case Study One likes to gather more information to validate the information, particularly if he is dealing with either inexperienced growers or new clients.

The validation aims to ensure that the problems do exist, and if they exist, he will further assess the level of seriousness of the problems. Only after knowing this is Case Study One able to design the appropriate curative IPM strategies for the pest problem. Explanations as to the cause and effects of the problems also are provided to clients. If he considers that the problem is threatening the crop, then a visit may be needed to discuss the problem further and design the solutions. In such a case, an appointment is then made.

For the preferential customers, field visits are conducted regularly. During a regular field visit, Case Study One follows a particular procedure (Figure 4.11). Typically, after meeting the client, a very short ice-breaking conversation follows. Case Study One then quickly reviews the client's cropping progress and finds out what has happened since his last visit. At this stage, Case Study One may also analyse the client's records of crop nutrition and irrigation. After assessing the client's current situation, Case Study One undertakes a crop walk with the client. The crop walk may be used to gather information about the problem, explain how it occurred and what can be done to improve the situations. Sometimes new issues, which have been overlooked by the client, are identified. In most control purpose visits, the crop walk takes most of the time of the visit.

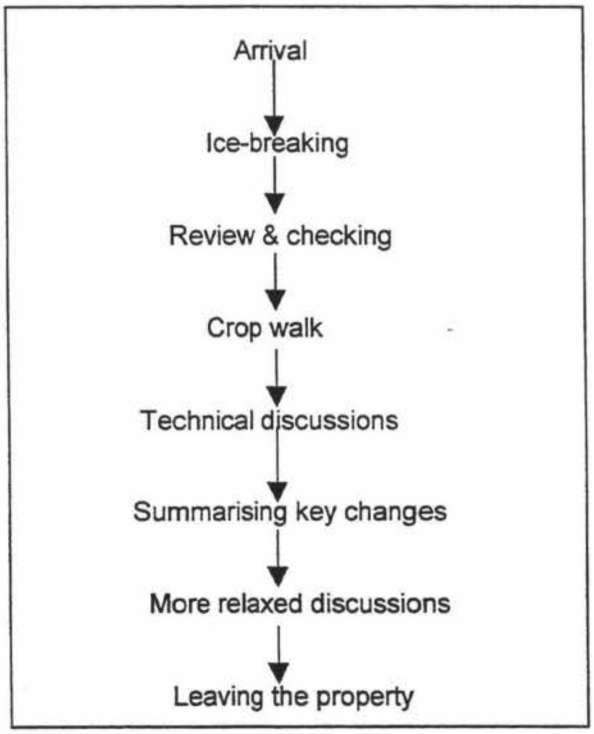

Figure 4.11 Physical activities conducted by Case Study One on the property during the control stage.

During the crop walk, Case Study One also observes the crop health, pollination, and pest infestations to validate the information he has received from the client, and obtain a mental picture of the client's current situation. Notes are made about crop performance, and the temperature pattern in the greenhouse. "*I need to get as much of that historical information as possible, so you can then project forward.*" Curative IPM strategies can be made at this stage if the problems are related to pests. To reinforce his suggestions, Case Study One often suggests that the client visits his other clients with similar greenhouse structures, who have successfully solved similar problems with IPM strategies.

After the crop walk, Case Study One will return to the place where he can talk to the growers with few distractions. More detailed technical information about the issues identified in the greenhouse are discussed. Assessment of the crop performance is written down in the Tomato Recording Sheet. Should modification to the preventative strategies be needed, the key changes also are written in the Tomato Recording Sheet. "*So in your visit report we may make a comment on adjusting it for the month ahead, or we may just carry on as per initially set out ...*" The curative IPM strategies or the modifications of the previous strategies are discussed in more detail at this stage. If this particular visit is that conducted at the end of the cropping season, then the discussion phase is used also to conduct a final evaluation of the performance of the strategies designed by Case Study One, and to plan the strategies for the next cropping season. All key changes discussed with the clients are written in the Tomato Recording Sheet. Personal and non-professional conversation is left to the end of the visit. If the clients are in the Preferential Customer Programme, then an appointment for the next visit is made. This can be conducted either by giving a date or a week in the following month. If they agreed on a given week, then a telephone call will be made by Case Study One prior to that given week to confirm the appointment.

4.1.3.2 CONTROL PROCESS

Once the plan has been implemented, regular communication between Case Study One and his clients is important to ensure effective implementation. "*It's a team thing and they have to, I guess, agree to be communicative about where the crop's at, otherwise we can't do the best for them. ... But normally we don't try to breed dependence, but we do emphasise it is a partnership thing ...*" The 'partnership' nature of the control process is shown in Figure 4.12 The grey boxes show the client's roles, and the white boxes the consultant's. The client is responsible for deciding to implement the IPM strategies and their actual implementation and monitoring. The success or failure of monitoring activities is dependent on the client and his/her greenhouse situation. The greenhouse situation plays a big role in determining the likelihood of success in IPM monitoring. New greenhouses tend to be able to provide more favourable environments for beneficial organisms and plant growth, compared to older greenhouses, and create fewer problems for the growers to be concerned about. In addition to that, the clients' attitude toward monitoring is critical because some clients do not like spending time monitoring. "*Some growers just don't consider they've enough time, or, if the property is too big, they just may not bother with it.*" If monitoring is undertaken, success is still dependent on their ability to react quickly to problems. For this to occur, growers must be able to interpret the results from their monitoring activities and react accordingly.

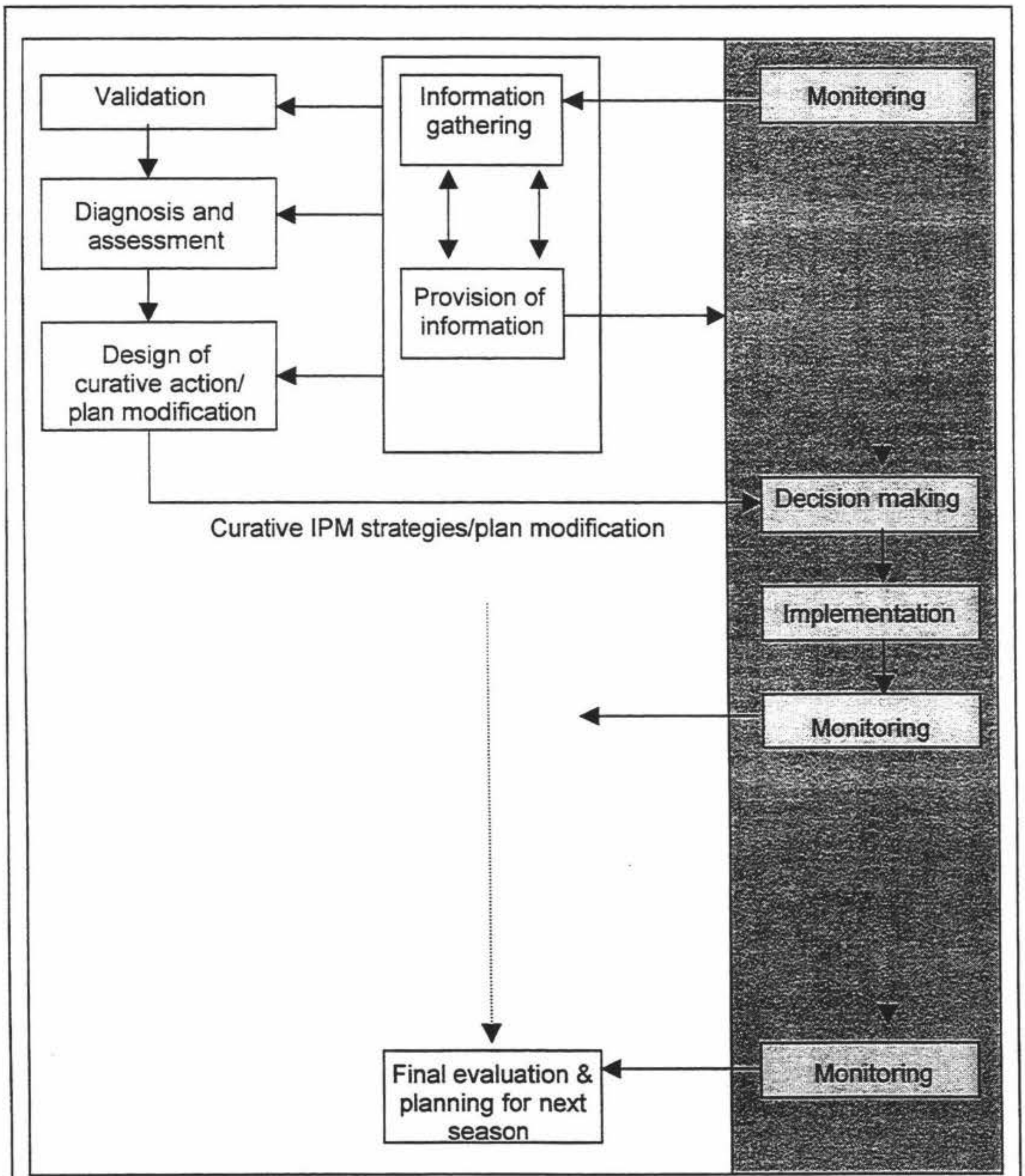

Figure 4.12 The process used by Case Study One in the control stage.

However, if a problem occurs (i.e. threshold levels are exceeded) then the client may contact Case Study One. This may occur over the telephone or during a regular visit. Case Study One then goes through an information gathering phase either on the telephone, or through a field visit. Before making any suggestion about how the client should react in a given situation, Case Study One likes to validate the information he obtains from him/her. This can be done either through observation on the property, or by asking specific questions over the telephone which verify the existence of a problem. "*But I generally like to see evidence of an increase in pressure as a result of say, a high outside temperature before I would actually put on spray, for example.*" Based on these two phases, information gathering and validation, Case Study One then can diagnose the cause of the problem and assess the seriousness level of the problems.

Problems tend to result from changes in the situation which could not have been accurately predicted during the planning phase. Case Study One then either modifies the previously designed IPM strategies, or provides more details to his contingency plans. The reasons for plan modification can be: changes in the environment (weather), external pressure (e.g. thrips attack from the neighbour's onion crop), internal pressure (e.g. the presence of pests which requires the use of harsh chemicals), lack of monitoring, or mistakes made by Case Study One in the plan. Modifications to the plan may result in, for example, changes in the night and day temperature balance to accommodate changes in the weather pattern, changes in *Encarsia* rate, and the use of curative actions to bring the situation back to a desired level.

Adding more details to the contingency plans, which have been given prior to implementation in the Grower Summary Letter, results in the design of curative action plans. The plans are used if certain threshold levels are exceeded. The curative action plans provide more information and details, which are particularly needed by inexperienced growers before they can implement the contingency plans. Some experienced growers also often ask for confirmation before implementing their interpretation of the contingency plans. "*Generally it's normally an informed explanation, probably more verbal than anything, rather than written.*" Due to the time constraints imposed by the study, limited detail was obtained on the design of curative action plans. Pest-related problems, caused by whitefly, other insects, and diseases, are selected as the focus for discussing the design of curative action plans because of their importance in greenhouse tomato production.

A. Whitefly

The curative actions used to overcome whitefly problems ranged from doing nothing through to the use of harsh chemicals. Case Study One uses decision rules (Figure 4.13) to select the appropriate curative action. If there has been an increase in whitefly population, Case Study One will consider firstly whether the increase is significant enough to trigger an action. If he thinks that the current *Encarsia* rate can control the whitefly population, then no action should be taken, provided that the growers keep monitoring the population. If action is required, then the first priority is to increase the *Encarsia* rate and keep monitoring the population. However, if the whitefly problem cannot be overcome by the increased *Encarsia* rate, then growers need to apply chemicals. If chemicals are required, then priority is given to IPM-friendly chemicals and harsh chemicals are applied only as a last resort.

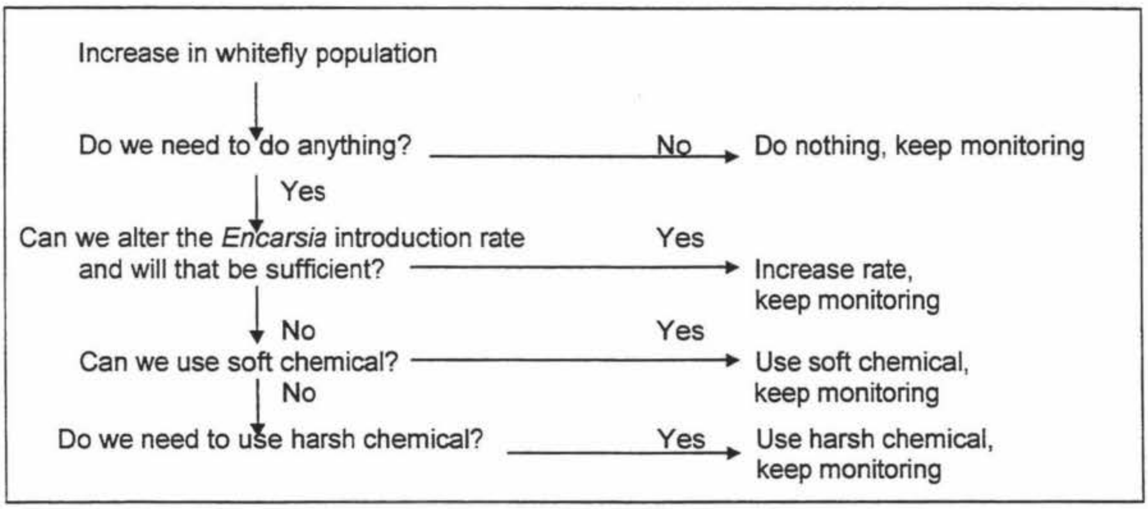

Figure 4.13 Decision rules used by Case Study One to determine the appropriate curative actions for whitefly problems.

The number of chemical sprays used is determined by whitefly population and its trend, historical spray use (chemicals such as pymetrozine and buprofezin can be used a maximum of only three times per cropping period to prevent resistance problems in the future), and the level of parasitism. It is always important to combine the use of chemicals with high introduction of *Encarsia* after the persistence period of the chemical has finished. "*.. and if we have to use a harsh chemical, what's going to have an effect on our black scale population, and what's going to be the stand-down time before reintroduction, and what will that reintroduction rate be at to try and compensate?*"

The following actions, which are provided as a guideline to control whitefly problems, show an example of how Case Study One uses the decision rules in Figure 4.13 to solve whitefly problem. If the whitefly population increases up to 4 per plant, then no action should be taken, however, Case Study One will ensure that the growers carefully monitor the population to see the trend in the following week. Then if the whitefly population increases up to 7 per plant, Case Study One will suggest growers increase the rate of *Encarsia* to $4/m^2$ for 2 weeks then monitor the result. If whitefly trend decreases, the clients can come back to their previous rate of *Encarsia*. However, if the increased *Encarsia* rate is insufficient, and the whitefly population remains uncontrolled and gets closer to 10 per plant, then Case Study One suggests growers inundate at 8 *Encarsia*/m^2 for two weeks and monitor the results. If the whitefly trend decreases, they can come back to their previous rate of *Encarsia*.

If the problem remains uncontrolled after inundation, then the use of a soft chemical is unavoidable. Gradual actions need to be taken in this situation. In week 1, Case Study One suggests the growers apply two sprays of pymetrozine on the top 30 cm of the plant and have *Encarsia* inundation at the rate of $8/m^2$ in between the two sprays. In the following weeks (until week 4), the same rate of *Encarsia* should be kept introduced while monitoring the results. In cases where whitefly have caused honeydew problems, then during the summer, the clients can do wet sprays with soft detergent or fatty acid-based chemicals. If the whitefly trend decreases, they can come back to their previous rate of *Encarsia*. However, if the population remains uncontrolled, then they have to re-spray the crop with pymetrozine to kill the adults, and buprofezin to kill the eggs only when necessary, and keep introducing *Encarsia* at the high rate ($8/m^2$) until control is achieved. "*.. if we can, we'd like to retain those [whitefly] eggs because then we can parasitise them, which then means we've got this wonderful big reservoir to use as a natural population to build up on. And then it can almost be self-sustaining. ... Once you kill those eggs out* [with buprofezin] *you then .. it can almost be a self-defeating exercise.*" If, after six weeks since the whitefly population reached more than 10/plant, control is still not achieved, then the last resort, a harsh chemical such as abamectin, is needed. Similar gradual actions can also be applied if there was a sudden increase in whitefly population within a week.

One decision rule sits over the top of those shown in Figure 4.13 and that is related to the client's attitude to risk. If the client is not comfortable with the whitefly population at whatever level in the decision hierarchy of whitefly curative action, then he/she may decide to give up using *Encarsia* and undertake spray application directly. The main reasons for the grower's concerns are usually economic and to do with reduced fruit quality. "*If the fruit is now sticky, the packhouse will charge them more to grade it and they'll get paid less for it. So at about that stage the grower will then say look, I'm just* *losing too much money, I'm just not prepared to carry on and then you basically have to go on to a clean-up type programme. If there's a lot of honeydew on the fruit we can use soap, detergents, to try and wash it off. If that's still not successful then you're normally looking at abandonment stage at that point."*

B. Other insects

Curative control plans for insects other than whitefly are relatively simpler than those for whitefly. These insects are controlled directly through chemicals (Table 4.5). If the monitoring process is accurate and timely, insects, or their symptoms, can be detected early enough to allow spot and targeted sprays, such as those for stemborer and aphid. Control action for caterpillar with *Bacillus thuringiensis* spray will not cause a concern for growers because it does not have any effect on the *Encarsia*. Where harsh chemicals are required, Case Study One will remind the clients to wait until after the persistence period before reintroducing *Encarsia* and add up the number of *Encarsia* which they had missed out. "*So if we're putting in at say 1.5 per week, if we missed two weeks, it means that we have to put in 3 to make up for the 1.5 we've lost.*"

Table 4.5 Summary of Case Study One's curative action plans for insects, except for whitefly.

Insects	*Treatments*	*Notes*
Stemborer	Localised infected area with abamectin (spot spray initially or whole crop potentially).	Reintroduce *Encarsia* after the persistence period finished.
Aphids	Spot spray with pirimicarb	Compatible with *Encarsia*, low persistence.
Caterpillar	Spray with *Bacillus thuringiensis* at first signs of leaf damage.	No effect on *Encarsia*
Russet mites	1. Stem spot spray with fenbutatin-oxide 2. Isolate infected area with sulphur powder on the floor. 3. Wet spray whole infected plants with fenbutatin-oxide or abamectin	1. If there is higher mortality on *Encarsia*, double the rate for 2 weeks. Tag the pressure area 3. Both chemicals have high mortality on *Encarsia*. Reintroduce after the persistence period finished.
Thrips	1. Detergent or fatty acid-based spray and blue sticky trap 2. Organo-phosphate spray	2. Only used in a very bad case of thrips attack. Usually leads to give up *Encarsia*.

Two sets of decision rules however, are used by Case Study One to determine the appropriate control actions for russet mites and thrips. If detected early enough, russet mites can be controlled by stem spot spray application. Should a high mortality of *Encarsia* occur, then growers need to double their *Encarsia* rate for 2 weeks to compensate for the reduction in the adult *Encarsia* numbers. If the problem persists, then the infected area needs to be isolated with sulphur powder to prevent further spread. If this treatment fails to control russet mites spread, then the infected plants require a wet spray, in which case the introduction of *Encarsia* should be temporarily stopped due to the high toxicity of the chemical used.

IPM-friendly chemicals, e.g. detergent and fatty acid-based spray, and blue sticky traps are used jointly to overcome average numbers of thrips. In cases where a large number of thrips suddenly attack the crop (e.g. when onion growers pulled out their crops in Pukekohe), then a harsher organo-phosphate spray is required. In such cases, *Encarsia* use ceases.

C. Diseases

Most diseases are handled using environmental systems and cultural practices. Fungi, particularly *Botrytis*, are controlled by providing an unfavourable environment for their growth. "*The best way to kill a Botrytis spore .. is to dry it out on the leaf. Just raise your temperature and dry it out. ... and cut and paint with fungicide in stem.*" Leaf mould an blight can be treated with a fungicide containing *Stobilurus tenacellus*, which is compatit with *Encarsia*. In addition, removal of infected leaf can also reduce leaf mould. Root z diseases such as *Fusarium oxysporm, Pythium*, and *Phytopthora* are treated fungicides into the media.

Once Case Study One has developed the curative action plans, the client m decide whether he/she is going to implement the plans. Then, once the curative plans have been implemented, the client needs to monitor the progress of the curative action and report it to Case Study One as necessary. The control cycle is repeated again if other problems occur.

At the end of the cropping period, Case Study One normally takes some time with the client to discuss and evaluate the IPM strategies. Of particular interest is the ability of the strategies to handle problems. "*Key ones were, were there any disasters, hopefully there weren't. But if there were, how were they handled and you know, number of sprays that we used, and I guess the reactive time for the control period to take effect. So if you were doing an increased Encarsia application and then a spray programme, how long really did it take to get control. So hopefully that information could be used for next time to give you a little bit more predictive .. to respond quicker or better.*" Whenever possible, Case Study One also shows the client how the IPM strategies have helped him/her achieve his/her expectations which were set at the beginning of the season.

Quality and quantity of the yield are then evaluated, followed by whether or not the client's financial situation has been improved as the result of the IPM strategies. The lessons learned from the evaluation can be used to improve the IPM strategies for the following season. Personally, Case Study One will also review his over-all strategies based on the number of complaints he received, whether or not he lost any clients because of that, and how happy the clients are with their current situations.

4.2 CASE STUDY TWO

4.2.1 CASE DESCRIPTION

Being brought up in a family greenhouse tomato business, Case Study Two has experienced various horticulture-related businesses following his graduation as a Bachelor of Horticultural Science from Massey University. Since May 1994 Case Study Two obtained employment with a greenhouse crop consultancy firm and currently has developed skills in day-to-day management of greenhouse crops.

Case Study Two's interest in IPM grew because of his realisation that, as a consultant he had to become knowledgeable about current developments in the industry. His knowledge of IPM is gained through experiences from visiting the clients and seeing their problems, reading journals and IPM-related websites, and also having discussions with people from the supply companies and with other consultants. The work of IPM in greenhouse tomatoes is mostly related to whitefly problems. The IPM work is included as part of the pest and disease diagnoses service, and contributes about 2-3 % of time allocated in the field visits.

The client base of Case Study Two ranges from Auckland, Bay of Plenty, Hawkes Bay to Nelson and Marlborough in the South Island. Most of these clients are commercial greenhouse growers, more specifically they produce greenhouse tomatoes, peppers, cucumbers, and lettuces. Case Study Two's greenhouse grower clients' properties range from less than 1,000 m^2 to more than 10,000 m^2. The majority of his clients, however, posses between 1,000 m^2 to 3,000 m^2 of greenhouse.

The consultancy firm for which Case Study Two works offers a planned consultancy service to its regular clients. The aim of this service is to improve the performance of the clients' business throughout the growing season. Based on his understanding of the clients' goals, performance and limiting factors, and together with the clients, Case Study Two then can make plans, strategies, and targets for the next season to anticipate and avoid problems. The service includes regular visits throughout the year, either on a monthly basis or from 3-7 times per year.

Beside the planned consultancy service, Case Study Two provides also the one-off type of consultancy services, which include the feasibility assessment of a new property, assistance in the layout and design of greenhouses, budgeting, modification of the cultural methods, nutrient analysis, and pest and disease diagnosis. Both the planned consultancy service and the one-off service take about 50% of Case Study Two's time on visiting the clients' properties. About 10% of the consultancy services are conducted through telephone and e-mail.

Case Study Two sees his role in consultancy as providing the information his clients need. "*More as a facilitator, technology transfer, to give the grower the information (s)he requires to make the decisions and suggest new ways of doing it that (s)he may not thought of before.*" He will also take roles of encouraging and educating them.

4.2.2 PLANNING

4.2.2.1 PHYSICAL ACTIVITIES

Growers can indicate their interest in IPM to Case Study Two during a field visit or over the telephone. Only in a few cases does Case Study Two initiate discussion on the issue. Whatever the mode of communication, the physical process is similar. If a telephone call is used to indicate the grower's interest, Case Study Two will start by gathering basic information about the client and his/her property, followed by the provision of IPM-related information. The screening process may, or may not, occur during this initial contact. Normally, regardless of whether they are new or existing clients, the growers will not form favourable/unfavourable attitudes toward IPM straight after such discussions. If the growers are new to Case Study Two and they sound interested, following the telephone call Case Study Two will send the firm's prospectus to the growers. Growers who ring back are normally the ones who have formed favourable attitudes toward IPM after their previous discussion with Case Study Two. An appointment for a visit can then be made. On average, the time gap between making the appointment and the visit to discuss IPM further ranges from two to three weeks, depending on the time they call and his visiting schedule to their area.

If existing clients want to discuss IPM during the visit, then the discussion is conducted in conjunction with other control activities conducted in the field (Figure 4.1 on page 76). On arriving in the field, Case Study Two will have a short ice-breaking conversation with the client. This is followed by conducting the physical activities for control purposes such as review and checking, crop walk, and discussions, which do not relate to IPM, since the client is still using conventional pest methods. If the visit is made to a new client, who has already mentioned his/her interest in IPM during the telephone conversation, then Case Study Two will still follow the same activities in his first visit to the property. However, the first three activities following arrival on the property are not conducted for control purposes. Instead, these activities are conducted to familiarise himself with the new client, the property, and the client's cropping systems.

From the greenhouses, Case Study Two leads the grower back to the place where they reviewed progress. For existing clients, the IPM planning activities such as information gathering, provision of IPM-related information, screening, and design of preventative IPM strategies, can be conducted in tandem with the control activities mentioned above, and are focused during the discussions stage. Less information is collected from existing clients, compared to new clients. For all clients, information about IPM is provided during the discussions phase. Tools such as pictures of whitefly and *Encarsia* may be used to assist the grower in visualising the strategies. Screening questions to find out the client's acceptance to the risks involved in IPM may be asked. On the property, Case Study Two will then design the preventative IPM strategies based on the specific circumstances of the client's systems. Once the discussions are complete, Case Study Two will write down on a piece of paper the key changes which have been discussed during the visit, and give it to the grower. Similar notes are written down also for his own record. More relaxed discussions, such as about family or the greenhouse tomato industry, take place before Case Study Two leaves the property.

If the client with whom Case Study Two is dealing is an experienced grower, then the whole plan for the year can be designed and discussed during this visit. However, if the client is inexperienced, then the plan is given gradually, a little at each visit, depending on the client's level of understanding. In addition to this verbal discussion, some written material can also be given in the visit, or sent after the visit. "*So you write a list of things to do and a list of things to look after for the next month .. before the next visit.*" He also gives the client some reading materials, which are mass produced by photocopying, regarding the activities that (s)he needs to do in the following month as part of educating the client.

4.2.2.2 PLANNING PROCESS

The IPM planning process aims to develop IPM strategies which are able to fit in with the growers' specific circumstances. The IPM plan designed by Case Study Two for growers is focused at the tactical level and contains the general overview for the year. Such plans provide information for growers' decision making at the operational level and are normally discussed with clients prior to implementation. To ease the interpretation of the plan, it may be divided into four quarters and discussed during regular visits to the clients' properties.

The planning process (Figure 4.14) starts by obtaining information from the growers, which is used to screen the growers and their properties, and develop an IPM plan. In conjunction with these activities, information regarding IPM also is provided for clients to help them to decide whether they will use IPM or not. Based on this information and upon Case Study Two's explanation about the way IPM strategies can be implemented on their properties, the clients can then make their decisions about implementing or rejecting the strategies.

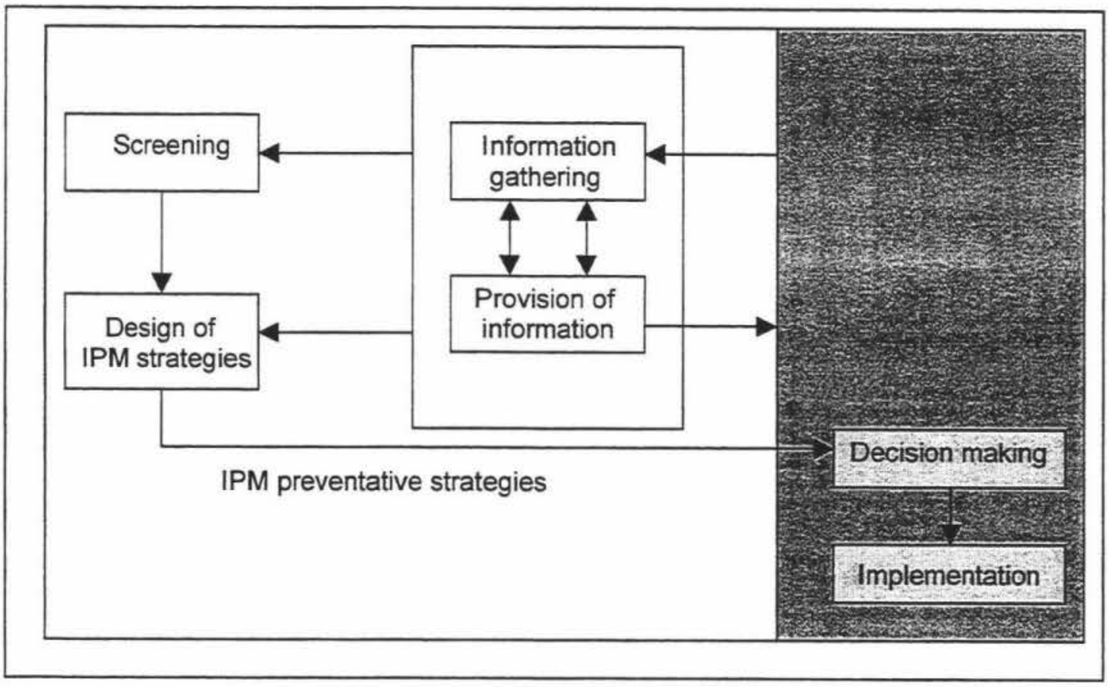

Figure 4.14 The planning process used by Case Study Two to design preventative IPM strategies for a client.
Notes: The consultant's roles.
The grower's roles.

INFORMATION GATHERING

Information about the clients and their properties is obtained through conversation on the telephone and from visit, and through observation over time (Table 4.6). If the phone call is made by a new client, Case Study Two prefers to collect most of the information he requires during a visit to allow him to better understand the circumstances. Information is collected in three areas: greenhouse, cropping system, and the client. Information collected through the initial phone call is used to give Case Study Two an initial understanding of the client's background, and may include: greenhouse location, age, heating, and spray history, the crop to be grown, and the grower's budget allocation for pest control, understanding, experience, age, and information availability. Some of this information, such as that regarding the heating system, spray history, and the next crop to grow, is sought for further detail in the field. While in the field, he also gathers information about the greenhouse cladding material, height, humidity management, the current crop and media, and the grower's skills to implement a plan, attention to detail, and willingness to learn. The last two attributes of the grower are also obtained through observation, along with the grower's other attributes such as innovativeness, patience, and managerial ability. Unless stated, most of the reasons for seeking a given attribute are not described again here because of their similarity with the ones given by Case Study One (Section 4.1.2.2).

Table 4.6 Summary of means of obtaining information by Case Study Two.

Information	Telephone	Field visit	Observation
GREENHOUSE			
Cladding material		✓	
Age	✓		
Technology: Stud height		✓	
Humidity management		✓	
Heating capacity	✓	✓	
Location	✓		
Spray history	✓	✓	
CROPPING SYSTEM			
Current crop: What crop	✓	✓	
Age		✓	
Health		✓	
Next crop: What crop	✓	✓	
When to plant	✓	✓	
Media		✓	
CLIENT			
Management ability: Find information			✓
Problem solving skills			✓
Implementation		✓	✓
Control			✓
Budget allocation for pest control	✓		
Risk perception: Age	✓	✓	
Understanding	✓		
Experience	✓		
Innovativeness			✓
Information availability	✓		
Patience			✓
Attention to detail		✓	✓
Willingness to learn		✓	✓
Level of interest	✓		

Greenhouse

Greenhouse information is classified by its cladding material, greenhouse age, technology suitability for IPM, location, and spray history (Figure 4.15). Greenhouse-related information is used to find out how feasible IPM is for the particular greenhouse(s). While Case Study Two believes that plastic greenhouses and glasshouses operate similarly, he acknowledges that there is a higher risk of chemical persistence on plastic greenhouses, which may harm the *Encarsia* if they are used. Information about greenhouse age obtained on the telephone helps him to develop a mental picture of the greenhouse because greenhouses built within a certain period of time are typically the same in their structure.

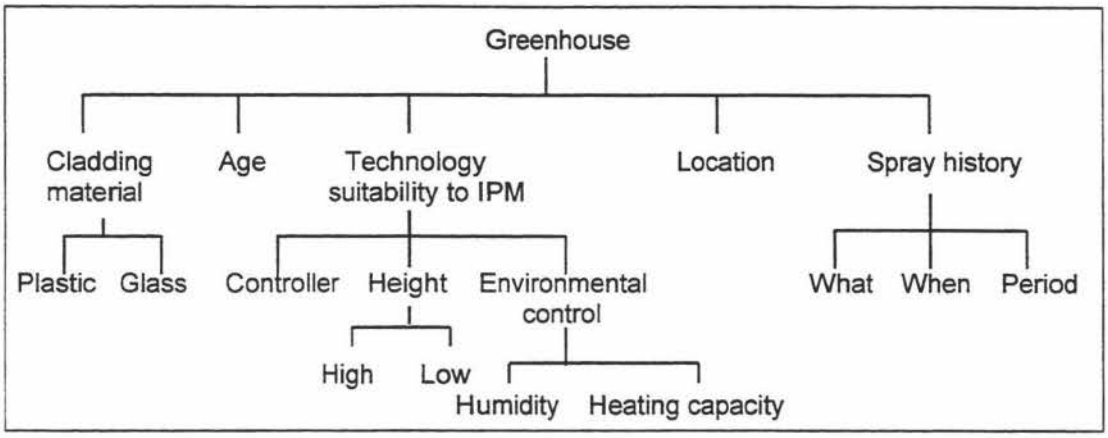

Figure 4.15 Case Study Two's classification of greenhouse-related information.

Information about the level of technology employed in the greenhouse is classified into: the control system, whether it is computer or manually controlled; the height of the greenhouse, whether it is low or high stud; and the ability to manipulate the environment, which comprises the management of humidity and heating capacity, or the degree of temperature which can be maintained in the greenhouse.

Information about the location of the property may reveal the potential of greater threats faced by the clients, such as whitefly in Auckland, because of the many greenhouse properties, and thrips in Pukekohe because of the high number of onion growers. Spray history is the final attribute of the greenhouse sought by Case Study Two. Regarding this attribute, he tries to find out the type of chemicals used previously in the greenhouse, how long such sprays have been used, and when the last spray was applied. This information is critical for Case Study Two to develop his early understanding of the spraying habit of the client.

Cropping system

Information regarding the client's cropping system is classified by the: current crop, next crop, and media (Figure 4.16). Regarding the current crops, Case Study Two needs to know about: the kind of crop grown, the age and health of the crop. If the crop is already at the mature stage and close to harvest, he then suggests IPM be started in the next crop, and discusses when that might commence. This information relates to season and stud height. *"If it's winter, then it's harder, it's colder, and then the wire height starts to become more important."*

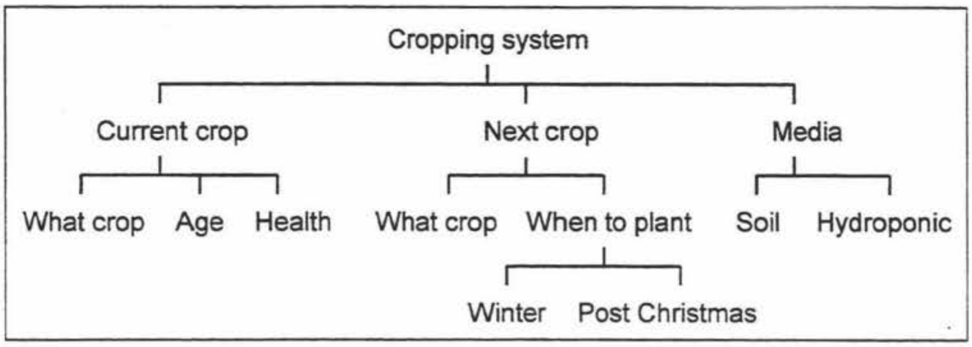

Figure 4.16 Case Study Two's classification of cropping system-related information.

Client

Information about the client is classified into: management ability, budget allocation for pest control, and attitudes (Figure 4.17). Most of this information is collected for Case Study Two's own mental picture and does not directly affect the IPM strategies which he designs. Case Study Two believes that a grower's management ability is made up of the abilities to find information he/she needs, analyse and solve problems, implement the strategies and control them.

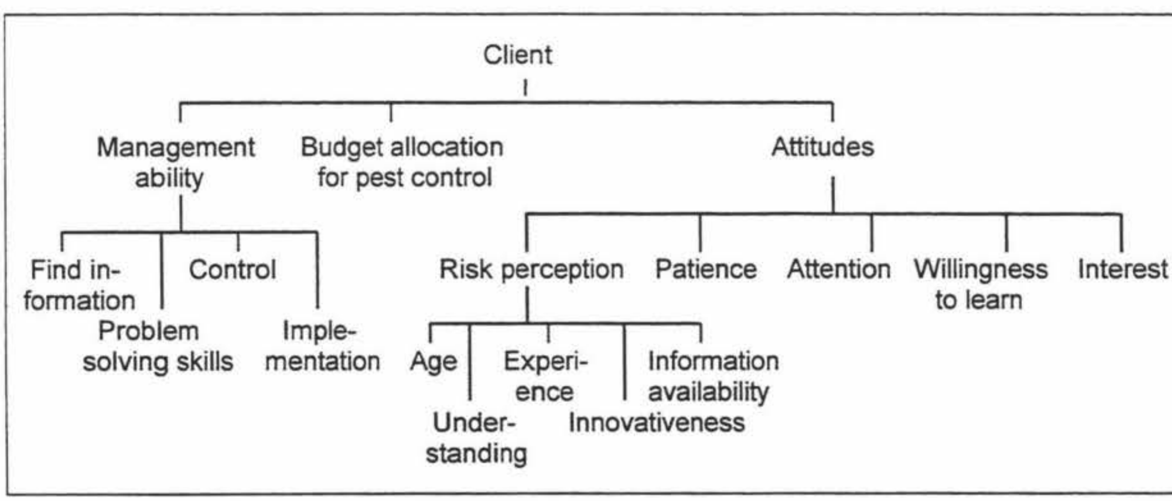

Figure 4.17 Case Study Two's classification of client-related information.

Case Study Two also attempts to find out about the client's budget allocation for pest control. Because of its sensitivity, such information may not be directly sought over the phone. By providing the client with information about the cost of *Encarsia*, or recommending that (s)he talks to beneficial organism suppliers, Case Study Two gauges his/her readiness to spend the money needed for IPM strategies. Such readiness is important particularly for those with old greenhouses and poor environmental control, where the use of *Encarsia* can be quite expensive due to the technology gaps which need to be overcome by increasing the numbers of *Encarsia* used.

The client's attitude information is classified into: risk perception, willingness to try, patience, attention to detail, and level of interest. Information about the client's risk perception of IPM is gauged through the combination of the client's age, understanding of IPM, experience, innovativeness, and the availability of information for the client. While most of these attributes of risk perception can be measured quite objectively, Case Study Two can get only a general feeling about the client's innovativeness level. In combination with the client's budget for pest control, risk perception of IPM influence the client's willingness to try to implement IPM.

Information about the client's patience can be understood only through observation over time, while a grower's attention to detail is mirrored through the tidiness of the property and its surroundings. In addition, the grower's willingness to learn is shown through his/her enthusiasm in asking questions on topics (s)he does not understand. These three attitudes can make a difference between success and failure of IPM strategies' implementation. Case Study Two assesses the clients' interest in IPM by their level of preparation before they ring him, which is shown in the questions they asked. For new clients, the clients' interest in IPM can also be gauged from their response to the consultancy firm's prospectus sent after the initial call. If they still want assistance, the process will continue from that point.

PROVISION OF INFORMATION

In conjunction with information gathering, Case Study Two also provides information needed by the clients, which aims to assist them to learn about IPM so they can make informed decisions. The information is provided both on the phone and during field visits. More detail and technical information is provided in the field. Information provided by Case Study Two is about: *Encarsia*, whitefly, sprays, cultural practices, external environment, monitoring, cost, and support available for the clients.

While most information is provided verbally, Case Study Two also uses a book with pictures of *Encarsia* and whitefly life stages to assist him in his explanation in the field. In addition, he provides growers with a spray programme handout, which consists of information about greenhouse spray management, such as: guidelines for chemical use, pesticide resistance management, fungicide management, formulating a spray programme, and details of spray compatibility with beneficial organisms.

SCREENING

Through discussion with the clients during his information gathering phase, Case Study Two conducts some sort of screening of them. Screening does not aim to totally rule out the option of IPM whenever their circumstances are less favourable for the implementation of IPM strategies. Instead, it aims to find out the clients' acceptance of the risks involved in adjusting the strategies given the limitation imposed by their particular situation, and prepare them for the risks by providing them with the information they require. Such limitation may mean that, for some clients, IPM, particularly the use of *Encarsia*, may be recommended for summer crops only, as it would not be feasible for winter crops. Normally, the client's favourable/unfavourable attitudes toward IPM do not develop after a single discussion, either on the telephone or during a visit. If the client can accept the risk and favourable attitudes have developed, then the planning process for IPM strategies can proceed. However, if the risks are unacceptable for the clients and unfavourable attitudes toward IPM have formed, then it will not be discussed further, unless the client brings up the subject again.

DESIGN OF IPM STRATEGIES

Using all the information he has gathered from the clients and his knowledge and experience, Case Study Two then designs the IPM strategies. Most of the design process occurs in the field. The strategies consist of: the use of *Encarsia*, environmental strategy, cultural practices, sanitation, preventative spray programme, use of resistant varieties, monitoring strategy, and contingency plans. Case Study Two considers growers have the most trouble deciding upon their *Encarsia* programme. In particular he feels that apart from deciding what initial rate to use, growers have problems deciding whether or not they need to continue using *Encarsia*, and how their use of it integrates with other management strategies.

A. *ENCARSIA*

The design of *Encarsia* strategy for a client is conducted by modifying Case Study Two's *Encarsia* template plan (Figure 4.18), which was hierarchically structured in his mind, according to the circumstances in the client's property. "*A lot of it I do it unconsciously, naturally. You don't actually know the process you go* [through]. *When you make a decision, you don't say, where am I now? You just do it.*" There are seven factors considered by Case Study Two in personalising this template plan to determine the appropriate rate of *Encarsia* in the clients' situation. In decreasing order of importance, they are: the kind of crop grown, crop age, whitefly population, season, ability to heat, stud height, and persistence period.

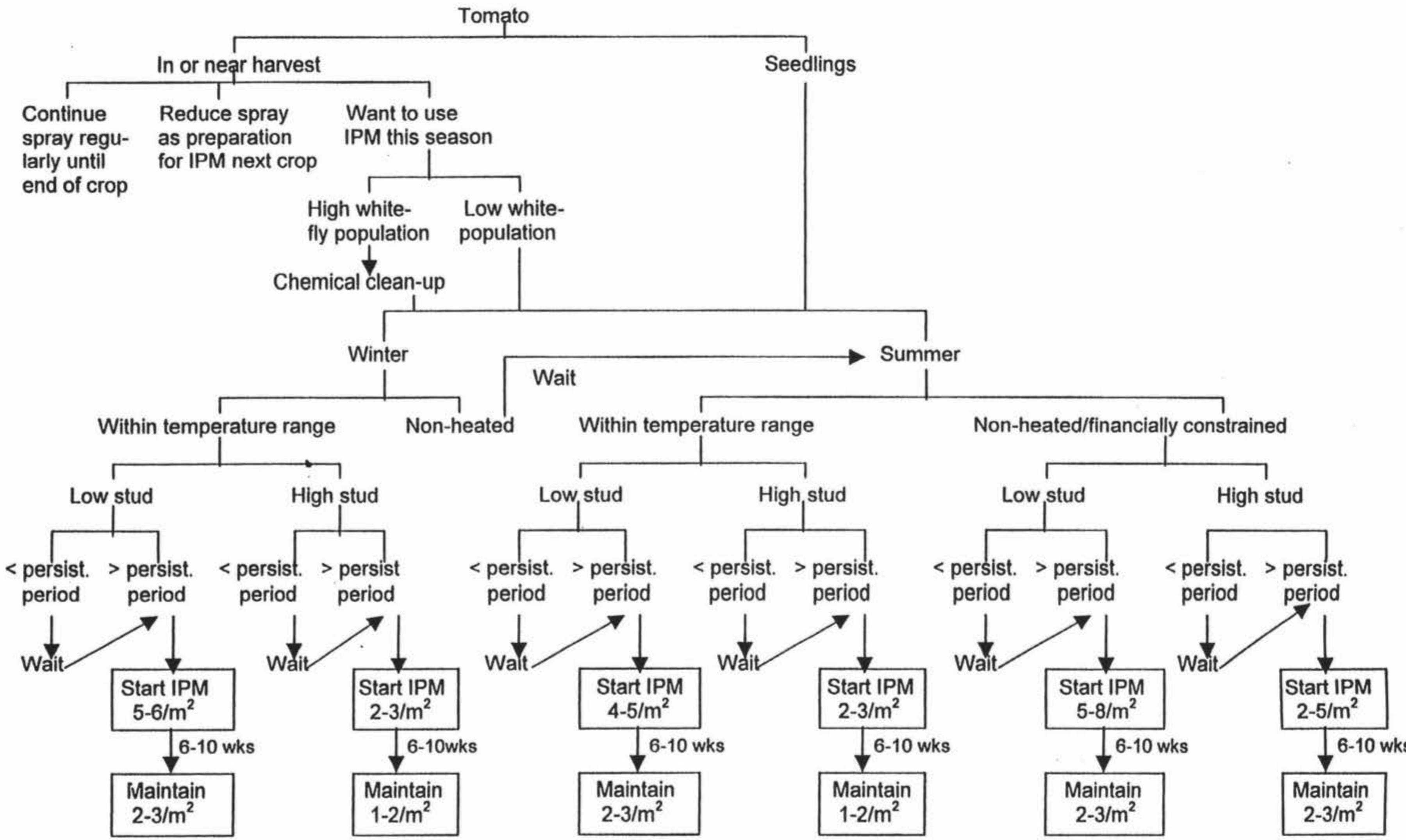

Figure 4.18 Case Study Two's hierarchical decision tree for tailoring *Encarsia* template plan to a client's situation.

The type of crop at the top of the template determines which template should be used, which in this case is tomato template. Following the crop type is its age. Growers whose crops are in or near (first) harvest may be asked to reconsider their interest in implementing IPM strategies. At this stage, they can decide either to continue using spray regularly, reduce spray application in preparation for implementation of IPM in the next season, or insist upon using IPM immediately. If *Encarsia* is to be introduced at this stage, then the current whitefly population should be monitored. Ideally, the whitefly population should be less than 2 per 20 plants before introducing *Encarsia*. If the whitefly population is higher than that, then a clean-up is necessary. *"Delay the Encarsia for a couple of weeks, do say three soap sprays four or five days apart. By doing it four days apart, the new hatch of whitefly will have been killed before it has a chance to lay new eggs."* Other growers may prefer to use IPM-friendly chemicals such as pymetrozine or buprofezin, in which case Case Study Two will recommend that they delay the *Encarsia* introduction until after the persistence period has finished. However, in cases where growers plan to introduce *Encarsia* soon after the plants have been transferred to the greenhouse, then Case Study Two may recommend that they tell their propagator to use as few sprays as possible.

Season becomes the next factor considered by Case Study Two for both crop ages. Case Study Two distinguishes seasons into winter (April to August) and summer (August to March). Light level becomes the weakest link in the chain during winter. The next factor, which is also related to temperature, is the ability to heat the greenhouse and maintain the desired temperature continuously. Greenhouses which are located in the northern part of New Zealand (e.g. Keri Keri), obviously can be heated more cheaply than those in the southern areas, making IPM more cost effective for the northern growers.

Growers who do not posses any heating system, and who would like to try and implement IPM, are recommended to wait until summer, when the temperature is higher. Although the growers can install insulation or extra plastic inside the greenhouse walls, it may still not be adequate to increase the temperature sufficiently to support the growth of *Encarsia*. Growers, who, for whatever reason, (either technical or financial constraint) are not able to heat their greenhouses to maintain the desired temperature, are grouped together with those who do not have a heating system, but who are willing to introduce *Encarsia* during summer.

The next factor considered by Case Study Two is the stud height of the house. The greenhouses are classified into low and high stud. Although a low stud greenhouse does not provide optimum conditions for *Encarsia* because of deleafing activities, Case Study Two believes the chance of success can be increased if the greenhouse is adequately heated.

The final factor which determines when *Encarsia* can be started is related to the client's spray history. Should the crops have been sprayed either regularly or occasionally, then *Encarsia* will be introduced only after the persistence period has finished. The persistence period varies depending on type of chemical and temperature in the greenhouse.

After considering all those factors, Case Study Two then can determine the *Encarsia* initial rate which fits in with the growers' circumstances. "*Start with the high level, get it established. If it's not established, go up. If it's established, go down, and then just monitor the hot spots.*" The initial rates vary from 2 to 8 *Encarsia*/m^2. Clients who own high stud greenhouses can introduce *Encarsia* at lower levels, 2 - 3/m^2. However, if their heating is inadequate, then the rate can be slightly increased up to 5/m^2, while the lowest initial rate for low stud greenhouses is 4 - 5/m^2 during summer with adequate heating. The highest initial rate is recommended for introduction in non-heated/inadequately heated greenhouses during summer. The *Encarsia* initial rates should be maintained until 80% to 90% parasitism is achieved, which normally takes about 6 to 8 weeks during summer, or in adequately heated greenhouses, and 8 to 10 weeks during winter.

In cases where 80% to 90% parasitism level is not achieved after 8 weeks and the current *Encarsia* rate is still below 5/m^2, then Case Study Two recommends the growers either: increase the rate; spray the top part of the plant with pymetrozine or detergent; or deleaf higher to take off more whitefly scale, although this also means taking off the black scales. If the current *Encarsia* rate is already higher than 5/m^2, then Case Study Two seldom recommends an increase in rate, as he is concerned with the cost the clients will need to pay. Following either of these actions, growers need to keep introducing *Encarsia* at the previous rate until the 80% to 90% parasitism is achieved. Once it is achieved, the *Encarsia* introduction rate can be reduced to 1 - 2/m^2 in high stud greenhouses with adequate heating, or else at 2 - 3/m^2 for the rest of the season. During this period, Case Study Two suggests also that the growers concentrate the *Encarsia*, introduced in bulk, in the hotspot areas (Figure 4.19).

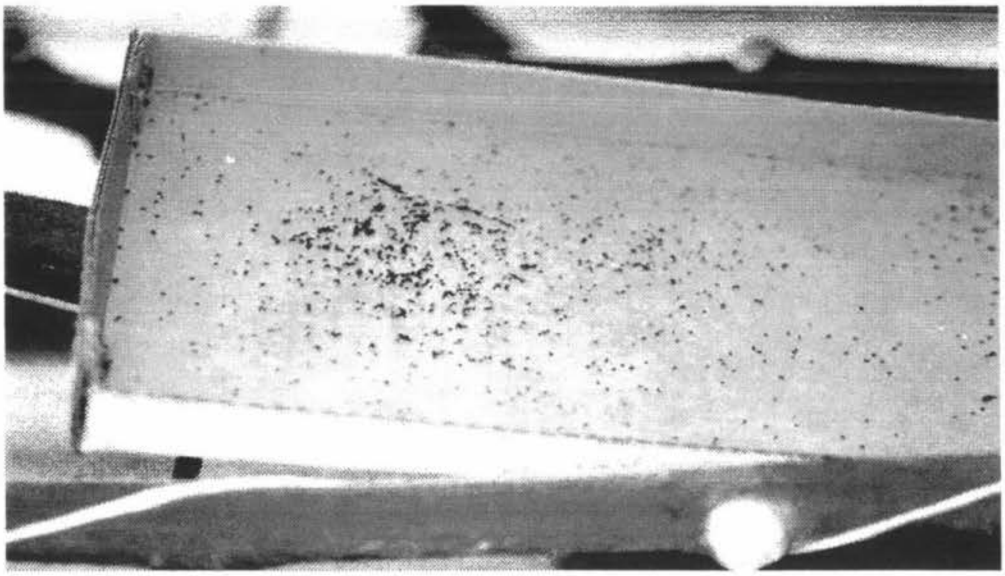

Figure 4.19 Bulk introduction of *Encarsia* in hotspot area.

B. ENVIRONMENTAL STRATEGIES

Environmental strategies are used by Case Study Two both for encouraging crop growth and discouraging disease development. The strategies comprise methods for managing temperature, humidity, and CO_2 level. However, since the management of CO_2 is not necessarily related to pest management, it is not included in the discussion.

Temperature in the greenhouse is controlled by setting up the heater and managing the vents. Case Study Two suggests his clients maintain 18°C in the day and 13°-15°C at night, and use 21°- 23°C ventilation set points, irrespective of crop age and season. Vents are also used to manage the humidity, which preferably can be maintained between 85% during day time and 88% - 90% at night time. While all vents are normally open almost all day during summer and half shut at night, in winter they need to be opened only for a short period to get rid of the high humidity in the greenhouse.

Case Study Two suggests also that the clients manage temperature and humidity with misting, if such equipment is available. Misting is required if the humidity level drops to less than 80%. The use of misting to reduce temperature is preferred compared to shading because it does not block the sunlight, which is required for photosynthetic activity.

C. CULTURAL PRACTICES

Cultural practices discussed with greenhouse tomato growers cover topics such as: spacing, pollination, deleafing and layering, irrigation, nutrition, and harvesting. However, only pollination, deleafing, and layering activities are included as part of the IPM strategies. In addition, Case Study Two also always suggests the clients avoid having more than one crop stage in each greenhouse to prevent carry over of pests from older to younger crops.

Pollination

Case Study Two encourages growers to start introducing bumblebees when the first flower opens, approximately one week after planting in the greenhouse. The flowers may open sooner in summer than in winter. New bee hives should be introduced every four weeks, or if the brown tip pollination marks fall below 85%. Case Study Two reminds growers also to take the bees out whenever they are spraying.

Deleafing and layering

Deleafing activity starts when the plant reaches the wire, which occurs after approximately six weeks of planting in low stud greenhouse, or about 8 to 9 weeks in high stud greenhouses. Depending on the quality and degree of temperature inside the house, the leaves may be left on the floor to give more chance for the black scales to hatch out. If layering activity is about to start, then Case Study Two suggests growers do it a week after the deleafing activity.

D. SANITATION PROGRAMME

Case Study Two's sanitation programme consists of strategies to maintain hygiene inside and outside the greenhouse, and a clean-up programme. Hygiene inside the greenhouse is begun by covering the floor with plastic or sterilising the soil with chemicals such as methyl bromide, and then maintaining it by ensuring that all debris is always taken out. Case Study Two considers maintaining a tidy external environment is important to prevent infestation on alternate hosts. He suggests clients mow and spray the weeds surrounding the greenhouse, and burn or bury the summer-grown field crop residues.

The clean-up programme comprises prior-to-crop removal and in-between crop activities. If a high whitefly population is found toward the end of the crop period, then spraying is required to prevent carry over and spread to other greenhouses. At least once a year, before planting a new crop, preferably in summer, in between crops, Case Study Two requires the grower to thoroughly clean up the whole greenhouse, including the irrigation system if all plants are out. "*Well there was advantage in doing it in summer because you can then use some of the chemicals that rely on high temperatures to be like a fumigant, and if it's low, cooler temperatures, they won't vaporise and so won't do so well.*" If short crops are grown then a quick clean up by sweeping out the greenhouse with water is also necessary after the second crop.

E. PREVENTATIVE SPRAY PROGRAMME

Case Study Two preferred growers to drench the crop while it is still young, particularly during winter, to avoid many pest problems. By drenching or applying chemicals through the irrigation system, instead of spraying, and using systemic chemicals, the persistence period before *Encarsia* can be introduced is shortened because the chemicals do not pose any threat to *Encarsia*. If wet chemical spraying is applied as prevention, then IPM-friendly chemicals are preferred, along with increased rate of *Encarsia* for about two weeks to compensate for the loss in *Encarsia* number.

Case Study Two also encourages growers always to start with local spray instead of blanket spray. For example, young plants in hot spot areas in the greenhouse may need to be sprayed with procymidone or dichlofluanid to prevent *Diddymella*. The use of preventative sprays such as chlorothalonil, copper-based solution, and Mancozeb for young plants during winter to prevent blight problems is normally suggested by Case Study Two. In the spray programme hand out given to clients, he provides information about the list of chemicals which they can use for various potential pests, along with their compatibility with beneficial organisms and rates of application.

F. RESISTANT VARIETIES

Growers whose properties are located in pest susceptible areas are informed about the presence of spotted wilt resistance varieties. "*There are some varieties which would be good for Pukekohe growers for thrips, you know. So then if you get thrips you're not so concerned because the main virus they have is spotted wilt, and you know it's not going to worry your plants.*" However, because at present these varieties are still in the trial stage, their fruit quality and yield statistics are unknown.

G. MONITORING STRATEGY

As part of IPM strategies, Case Study Two discusses the monitoring method with the growers. He encourages them to use their workers as the eyes for monitoring, which he believes will also make the workers feel involved in the process. Although he favours the use of coloured clothes pegs for marking the infected areas, Case Study Two also suggests that they provide their own recording or check forms and control graphs. "*In a way, it's* [clothes peg] *better than writing things down, because it's a visual tool .. and dynamic and because it's always a changing situation. Encarsia can be in this part of the greenhouse this month, next month they might be over there, and so you follow where the Encarsia are going.*" IPM-related parameters to be monitored are: pests, beneficial organisms, and environmental systems (Table 4.7).

As a major insect, whitefly population is monitored throughout the year. Growers are required to conduct special weekly crop walks for whitefly. "*Whitefly is the big insect, so they have special control times. The walk would be to put up the Encarsia. The information is gathered by the workers and then there will be a time where the information will be analysed, where are the hot spots, and then they go and do the control procedure.*" The monitoring is conducted by counting the number of adults per row of plants and by using yellow sticky trap as a guide to determine the population roughly.

Case Study Two determines whitefly threshold levels both subjectively and objectively. "*To a certain extent, it's a little bit unknown. Like it would be nice for me to be able to say okay, in your type of greenhouse, if you've got 3 whitefly per leaf, then you do two soap sprays. ... but I can't say that because ... the information easily available is not there.*" He believes that the threshold levels are influenced by the stud height and season.

Apart from monitoring whitefly and russet mite, growers do not normally conduct special regular crop walks to monitor the presence of other insects such as thrip, aphid, or caterpillar. Therefore, Case Study Two stresses the importance of training the workers to recognise insects and their symptoms, so that if they find any of them while working along the row, further monitoring can be conducted. Growers are more concerned about insects during summer (e.g. for russet mites, caterpillar, and aphid) and while the plants are still young (stemborer and sciarid fly).

Three types of disease which cause concern are *Botrytis*, leaf mould, and blight. With diseases, normally Case Study Two does not give any threshold levels. Whenever any disease symptom is found, then he will recommend growers to take action to prevent it from developing further. In addition, he also asks them to check root health and vigour weekly. "*Just if there is some dead, how bad it is. But it's a scale, from perfectly right to totally mushy.*"

Table 4.7 Summary of Case Study Two's monitoring strategy.

Parameters	When	Frequency	Methods	Threshold/Standard	Notes
Whitefly	All year.	Weekly crop walk.	Count adults per row, compare with previous 2 wks. Use yellow sticky trap.	1 whitefly/20 plants or 2 whitefly/row.	
Russet mite	Summer	Weekly crop walk, if found.	Look for the red stem symptoms.	One infected plant.	Easily spread.
Caterpillar	Summer	Irregular, only when found.	Find holes in leaves or caterpillars underside of leaf.	Few (3-5) holes in most leaves in every row.	If one hole is found, changes are there will be more.
Aphid	Summer	Irregular, only when found.	Find insects at the head of plant and symptoms.		Quite rare.
Thrip	All year, particularly early period of summer crop.	Irregular, only when found.	Find symptoms or thrips. Blue sticky trap as a guide.		Quite rare, except in Pukekohe.
Stemborer	Transplant stage during summer.	Irregular, only when found.	Find symptoms (plants wilted).		Quite rare.
Sciarid fly	Transplant stage particularly during summer.	Irregular, only when found.	Find symptoms.		
Botrytis	All year, particularly in winter.	Weekly	Find symptoms.	If plants are dying and cause growers to worry.	
Leaf mould	All year, particularly in autumn & spring.	Irregular, only when found.	Find symptoms.	If it has developed above the deleafing area.	Stress disorder. Starts in older leaves.
Blight	All year, particularly in winter.	Irregular, only when found.	Find symptoms.		
Root health and vigour	All year, particularly in winter.	Weekly	Asses root health. One crop per greenhouse.		
Encarsia	All year.	Weekly	Check under side of leaves.	80%-90% parasitism.	
Pollination	All year.	Weekly	Check for bee marking on 20 flowers per greenhouse.	85% pollination.	
Temperature	All year.	Twice daily.	Check thermometer reading.	See environmental strategy.	
Humidity	All year	Twice daily.		ditto	If equipment permits.
Ventilation	All year	Twice daily.		ditto	

Beneficial organisms used such as *Encarsia* and bumblebees also require monitoring. Case Study Two suggests growers monitor their activities on a weekly basis, and use a given standard to determine their performance levels. The standards used are 80% - 90% parasitisms for *Encarsia* activity and 85% pollination for bumblebee activity.

The IPM-related environmental parameters monitored include temperature, ventilation, and humidity. These parameters are most easily monitored using a computer. "*Otherwise normally they don't record it, they'll just think* [based on their experience], *oh it's getting warm in my greenhouse. They'll look at the thermometer, which is located in an aspirated screen at the head height of the plant.*" Case Study Two recommends growers monitor humidity only if they have the equipment to do so. "*If they don't have a computer the only way that they can tell if their humidity's too high at night is because you'll get Botrytis.*"

H. CONTINGENCY PLANS

Case Study Two does not formally provide contingency plans for his clients. However, to a certain extent, the spray programme hand-outs, if given and discussed prior to implementation, can act as contingency plans for growers in case pest problems occur. Normally, such plans are discussed with the growers in the beginning of the crop season. The discussion can encompass topics such as the neighbour (sudden attack of whitefly or onion thrips) and weather scenario. "*Then we might talk about the effect of weather at different times of year and how, you know .. and so if they have a cloudy period and it's cold, if the spring's cold, then they may have to introduce more Encarsia per square metre. So there's the effect of the weather on the different environments you have, whether it's a cold environment or a warm.*"

DECISION MAKING

The personalised IPM strategies designed by Case Study Two are then discussed with the clients. The decision making process of the clients is shown in Figure 4.20. According to Case Study Two, there are three factors considered by clients before making a decision to implement IPM. First, they will consider how the IPM strategies fit in with their budget allocation for pest control. Then they will gauge their willingness to take the risk of trying something new to them. Finally, they need to assess their perceived managerial ability to implement the IPM strategies. If they are convinced they have the ability, then they may decide to implement the strategies.

Throughout this process, the clients' knowledge about IPM, whether it comes from Case Study Two or from other sources of information, influences their decision making. For some growers, the consultant is not their sole information provider. Often prior to making a decision regarding IPM implementation, growers seek other opinions, normally from other growers. "*There have been times where they may have been talking to a couple of the local growers and say no, stop, and we'd say carry on. So opinions differ, and often we will say, you know, do carry on. So, in a way we will make the decision for them, but only usually if it's a newer grower.*" If they decide to implement the IPM plans designed for them by Case Study Two, then they can carry on to implement the plans.

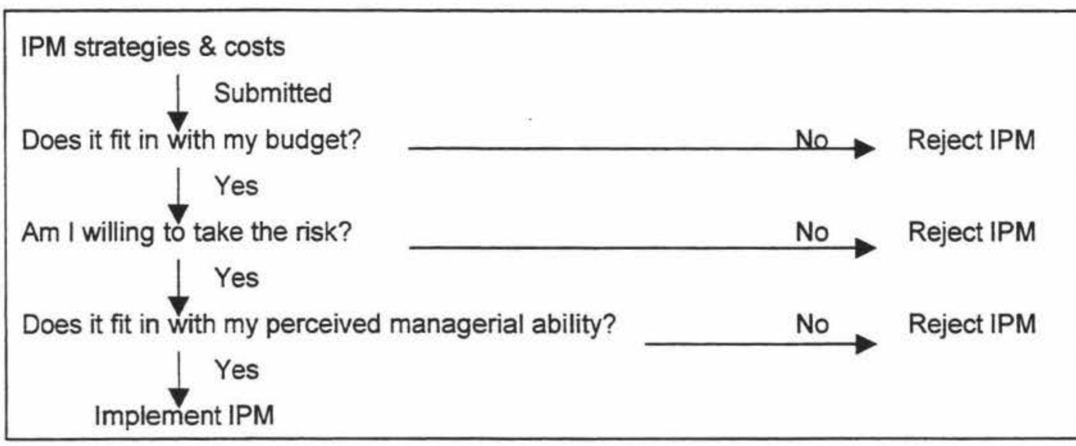

Figure 4.20 Case Study Two's version of a client's decision making process to implement the IPM strategies.

4.2.3 CONTROL

4.2.3.1 PHYSICAL ACTIVITIES

The physical activities during the control process may involve telephone conversation, field visit and email. Telephone consultancy is generally initiated by clients to ask for: confirmation, solutions for the problems in their properties, and an appointment in regard to their problems. Both Case Study Two and his employer have a regular schedule of the areas they visit at certain weeks of the month, which is known to their clients. Prior to his visits to a given area, he will email or send faxes to his regular clients to ask whether or not they want him to visit them while he is in their areas. If, after three consecutive emails or faxes, the clients never ask for a visit, then on his next schedule he will just wait for their call, instead of sending them email or faxes.

Normally, the problems he handles over the telephone are those which require quick and simple solutions. Major modification to the previous preventative strategies is not normally conducted by telephone. During a telephone conversation, a grower may express his/her concern about the monitoring results. Case Study Two will follow this up by gathering more information to validate the existence of the problems and assess their levels of seriousness. Relevant information on the causes and effects of the problems is also given by telephone. In most cases, the pest problems can be solved by designing the curative IPM strategies and discussing them with the client bby telephone. The client will then need to make decisions whether or not the curative strategies will be implemented. Once implemented, monitoring of the strategies should be initiated. The monitoring results then can be reported to Case Study Two again if the client feels that the problems have not been solved, or if a new problem arises, in which case a visit may be required. If there are specific issues or rare pest problems which the client wants to discuss during the visit, then Case Study Two may undertake some self-preparation activity by reading literature or having discussions with his employer.

While on the client's property, Case Study Two follows certain procedure (Figure 4.11 on page 102). Once he has arrived in the property and found the client, Case Study Two starts with a very short ice-breaking conversation. The consultancy then starts by reviewing the progress and current situation in the field based on the client's monitoring results. At this stage, the client may or may not have identified the problem (s)he has. This activity may be conducted in the grower's kitchen, garden, or near the car. Following the review, Case Study Two conducts a crop walk checking in the greenhouses. Whenever possible, Case Study Two prefers to move from greenhouses with young crops to those with mature crops. During the crop walk, discussions take place and observation of crop performances, pollination activity, pest and beneficial organism populations, is conducted. After finishing his observation in the greenhouses, Case Study Two leads the client to the previous place where the review phase took place, sometimes over a cup of coffee, to discuss some of the issues found during the review and crop walk further. "*They want us to go to the site for objective opinion ... to a certain extent, some of the visits are like a quality check.*" Normally in a visit, IPM is only one of the topics discussed with the client. If plan modification or design of curative IPM strategies is needed, then it will be conducted mostly at this stage. To reinforce his suggestions, Case Study Two sometimes quotes his employer's opinions on a given matter. During this stage, new issues may be brought up by either the grower or Case Study Two. Some hand-written notes about the key changes required, can be given by Case Study Two. He also makes some notes for his own record. The conversation at this stage is more relaxed, and an informal atmosphere is maintained. At the end of the season, several field visit activities such as crop walk, discussion, and summarising key changes may also be used to conduct the final evaluation of the whole strategies (IPM and crop management) and discuss the planning for the next season if required by the grower. Case Study Two leaves the personal and non-professional topics to be communicated toward the end of every visit. Finally, Case Study Two will leave the property after he ensures that all the grower's questions have been answered and the grower has understood what (s)he should do until the next visit.

In addition to telephone calls and field visits, the volume of email consultancy has increased in the past few years. Case Study Two's firm has set up an email address through which clients who are connected with the internet can correspond with him.

During the control stage, Case Study Two also applies different approaches to growers depending on their experience. "*Some of the growers that already use IPM, they're quite good. Rather than instructing, we discuss, that's more two friends talking than a teacher and a student. ... If it is a young person, a new grower, do this and do that approach.*" Once the new growers gain adequate confidence and experience, then the approach changes slightly to discussion.

4.2.3.2 CONTROL PROCESS

Case Study Two's involvement in the control stage of IPM management consultancy is conducted only if the clients have requested such services after implementation of IPM strategies. His involvement at this stage includes: obtaining information from and providing information to the clients, validating it, making diagnosis and assessment of the problem, designing the curative action plan to solve the problem, and evaluating the IPM strategies at the end of the crop season (Figure 4.12 on page 104).

Following the implementation of the plan, monitoring activity is solely the clients' responsibility. Growers need to start monitoring within a week after they have implemented IPM strategies. Although it has a major role in determining the success of IPM strategies, some clients do not like writing information down, or even if they want to, they reason that they are too busy to monitor their crop. "*You can have a grower whose got a good greenhouse, good heating and everything, but it still doesn't work. And it's their level of monitoring and their eye for detail which often can be the difference between failure and success.*" Therefore, Case Study Two stresses to his clients the importance of conducting monitoring activities.

Progress and the monitoring results are then informed to Case Study Two. This is conducted either by asking questions of the clients or through direct observation while

Case Study Two is walking among the crops. Case Study Two always attempts to obtain as much information as possible so that he can validate the information and make appropriate diagnosis about the problems and their urgency, before giving clients his opinion about any given issue. "*We might say how's it going? Good. You know, the whitefly is under control? Yes. We'll go and have a look and make sure that what they say is true and the story is finished.*" Case Study Two then provides them with some information regarding the cause of the problem and what to expect if such situations remain uncontrolled.

The problem may require control actions to bring the situation back quickly to its previously balanced level. The control action strategies may occur in the form of: using the contingency plans which have been discussed prior to implementation; slightly modifying the original plan, such as altering the *Encarsia* introduction rate; and designing some curative actions to accommodate the changes; or giving up IPM and shifting back to conventional methods. The common reasons for using such strategies are economic, and increased internal and external pressures. "*A common comment by growers is why am I spending all this money on producing good quality fruit* [with IPM] *when the market isn't prepared to pay for them? .. You can't argue with that because it's still legal to spray, there's nothing wrong with it, really.*" The strategies made should consider two major factors, the crop and the IPM. "*The first thing you've got to look after is the crop .. the future money, which is the new fruit. And then you've got to look after the IPM, and tied in with the IPM is the cost of it.*"

To a certain extent, Case Study Two has prepared the clients for possible worst scenario through his spray programme hand-out given prior to IPM implementation. However, when such problems occur, a more detailed curative action plan to solve the pest problem may be required. Curative actions may involve the use of chemicals, and whenever they are applied, Case Study Two always urges the clients to check the effect of the spray on beneficial organisms before using it. The curative actions are designed for the clients to overcome pest problems caused by whitefly, other insects, and diseases.

A. Whitefly

Case Study Two offers his clients two options to control increased whitefly populations: first, by increasing the rate of *Encarsia*, and second, by applying sprays. In cases where the clients are introducing less than 3 *Encarsia*/m^2, he suggests they double the *Encarsia* rate. However, if the current rate is already high (4-6/m^2), then the cost of doubling the rate becomes a major concern for Case Study Two. To overcome such problems, he suggests that the clients allocate *Encarsia* more effectively in the greenhouse. "*What they could do is in some areas of the greenhouse where there is no problem, decrease the rate, say down to 2. And in the areas where there is a problem, increase it up to say 8 or 9. And so their number of Encarsia they're putting into the greenhouse won't change, but they're concentrating those Encarsia more effectively.*"

The use of increased rate of *Encarsia* often needs to be combined with spray applications. Some IPM-friendly chemicals such as soap and fatty acid-based spray, pymetrozine, and buprofezin become favourable options in these circumstances. *Encarsia* can be introduced straight after applying the first two sprays because they do not have any persistence period. These sprays need to be applied as wet spray, and therefore need to be done while the temperature is warm enough to dry the plants quickly. The other two chemicals, though currently effective in killing whitefly, must not be used more than three times per crop period to prevent resistance problems. They also have a few days persistence period for *Encarsia*. To reduce the number of *Encarsia* killed by pymetrozine and buprofezin, Case Study Two suggests the clients spray only the upper 25% of the crop, where most adult whitefly are concentrated. "*You'd probably kill some* [adult *Encarsia*], *but at least you're still introducing some new ones.*"

The extent to which the two types of curative actions are needed to overcome whitefly problems depends on the whitefly population. "*If you've got more than one* [whitefly] *per plant, you'd have to do the same sort of thing as if you've got 50. Except if you've got 50, you'd have to do it more radically. You've still got to spray, but you'll be doing it for longer.*" High whitefly numbers per plant means that the problem has been left for longer before a decision has been made to control it. In such situations, Case Study Two prefers to start with pymetrozine to kill whitefly scales, followed by soap sprays to kill the adults, and then to increase the rate of *Encarsia* to compensate for the number of adult *Encarsia* which may have been killed by the spray.

Season and temperature inside the greenhouse also affect the number of sprays needed. "*Only because in summer the temperature is warmer so the whitefly establish more quickly. So if there is a problem and they do spray, chances are that in summer they may have to do three sprays. In winter they may only do one.*"

B. Other insects

All insect populations start locally. Therefore if they can be detected early, the curative action will normally just be a local or spot spray (Table 4.8). If a total wet spray (from top to bottom of all plants in the greenhouse) is used, growers have to wait until the persistence period has finished before starting to reintroduce *Encarsia*, and then, if the previous rate was below $3/m^2$, their reintroduction rate should be double their previous rate. However, if the previous rate was already above $4/m^2$, *Encarsia* should be reintroduced at the same rate. Tomato crops grown in Pukekohe may endure severe attack by thrips originating on neighbouring onion blocks. If such incidents occur, then Case Study Two suggests they temporarily stop introducing *Encarsia*, because a total wet spray of the whole greenhouse is required to control the thrips.

Table 4.8 Summary of Case Study Two's curative action plans for insects, except for whitefly.

Insect	Curative actions	Notes
Russet mite	Spot spray the infected plant and its neighbour plants with abamectin or dicofol.	
Caterpillar	Spray with *Bacillus thuringiensis*	No effect on *Encarsia*.
Thrip	1. Spot spray with either fenbutatin-oxide, endosulfan, or dichlorvos. 2. Spray the whole greenhouse.	1. Endosulfan & dichlorvos are harmful to *Encarsia*. 2. Stop introducing *Encarsia*.
Aphid	1. Local wet spray with pirimicarb. 2. Total wet spray.	The chemical kills 75% adult *Encarsia*. May need to increase the reintroduction rate of *Encarsia*.
Two-spotted mite	Spray with propargite or fenbutatin-oxide.	Low residual effect on *Encarsia*.

C. Diseases

The four common diseases, *Botrytis*, leaf mould, *Didymella*, and blight, are normally treated by environmental and cultural strategies (Table 4.9). Environmental control treatments for diseases are normally conducted by using the ventilation and heating systems to lower the humidity to provide an unfavourable environment for the growth of the diseases. Control of *Botrytis* is conducted by leaf pruning (taking off the infected leaves). To prevent the spread of the spores on the fresh deleafing wounds, leaf pruning should be conducted prior to deleafing. Leaf mould is normally controlled through the deleafing activity. "*Often deleafing will remove it, but if it goes further up the plant where they're still keeping the leaves then they have to spray..*" In cases where the plant has to be removed because of disease presence, then the clients may need to grow laterals from the neighbouring plant to fill in the space.

Table 4.9 Summary of Case Study Two's curative action plans for diseases.

Disease	Curative actions	Notes
Botrytis	1. Environmental and crop management 2. Spray with vinclozolin or thiram	Some resistance problem with vinclozolin
Leaf mould	1. Environmental and crop management 2. Spray with triforine or thiram, or benomyl through irrigation system	Only if unmanageable with action1. Triforine has low effect on *Encarsia*.
Didymella	Plant removal and stem spray all plants with benomyl, dichlofluanid, or procymidone	Only spray lower part of the stem.
Blight	Leaf pruning or plant removal (if rotten in stem)	The spores spread easily.

Besides providing information on the cause and effect of the problem, Case Study Two provides also information and an explanation about the control strategies which he has designed for the clients. The clients then have to make decisions as to whether or not they want to implement the curative strategies. Once the strategies are implemented, they need to monitor the progress, and inform Case Study Two if other problems occur. The control cycle then can be repeated every time a problem occurs.

At the end of the season, Case Study Two, together with the clients, informally evaluates the season. Some parameters are used to gauge the effectiveness of the IPM strategies. The first criterion is the number of interventions conducted throughout the season. The smaller the number of times the clients needed to change the plans, the more successful the strategies are perceived to be. The number of interventions shows also the validity of the plan.

The second criterion is the number of whitefly population at critical times of the year. "*You know sometimes they can work a row and there's only one or two whitefly, and it's the middle of summer, so there should be a problem. ... Or if you walk into a greenhouse and it's full of coloured pegs, then you know things aren't under control.*" The cost involved in implementing the IPM strategies, in contrast to the clients' budget, becomes the third criterion. The last criterion is the benefit perceived by the clients, such as health benefit for using less chemical, increase in knowledge, experience, and confidence. If the clients' perception of IPM becomes negative at the end of the season, Case Study Two considers that he had given them a false impression initially. Based on this evaluation, improvements for planning of the next crop, which is normally conducted in tandem with the final evaluation, can be made. Together with his employer, Case Study Two also conducts overall evaluation of their strategies.

CHAPTER FIVE

DISCUSSIONS

In this chapter, findings from each case study are compared and contrasted in the cross-case analysis (Section 5.1). The general models drawn from the case studies are then compared to the literature review in Section 5.2.

5.1 CROSS-CASE ANALYSIS

The cross-case analysis starts by presenting the general models of the consultancy processes at the planning stage (Section 5.1.1) and the control stage (Section 5.1.2). Following each general model, similarities and differences of the physical activities and the processes between the case studies are compared and contrasted. Finally, a comparison of the consultancy styles of the consultants is discussed in Section 5.1.3

5.1.1 PLANNING STAGE

The general model of the planning stage was derived from the two greenhouse consultants interviewed and observed in this study. The planning stage for IPM strategies consists of the physical activities (pre-visit, field visit, and post-visit) and the planning process which the consultants used in tailoring their IPM strategies template/standard to suit a client's circumstances (Figure 5.1). Although the activities and process are presented in a linear fashion, they tend to be iterative in nature and in practice.

5.1.1.1 PHYSICAL ACTIVITIES

The physical activities at the planning stage of IPM strategies involve the use of the telephone and field visit for consultancy. New clients use a telephone call to indicate their interest in the consultancy service and IPM strategies. While some existing clients may also use the telephone to indicate their interest in IPM, most of them express the interest while the consultant visits their property.

The consultants use a similar physical process when they develop a plan for a client. Following the initial contact by a grower on the telephone regarding his/her interest in IPM, a visit may be required to discuss the issue further. Prior to the visit, the consultants normally undertake some self-preparation activities. Case Study One sends his initial design of IPM strategies based on his knowledge about the grower and the property, while Case Study Two sends the firm's prospectus to his new clients. Case Study Two

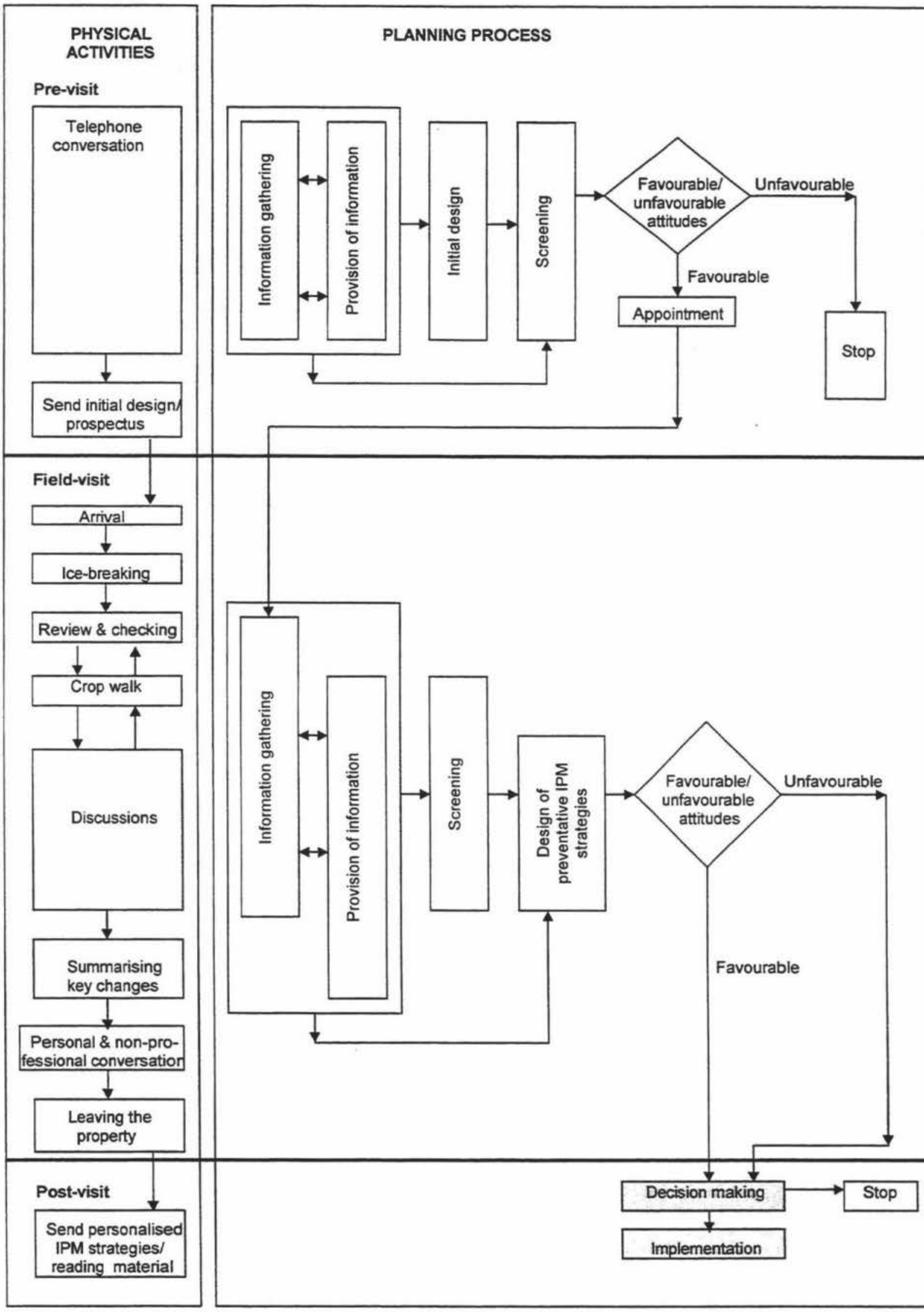

Figure 5.1 A general model of the physical activities and planning process used by the consultants at the planning stage.

Notes: ▭ The consultant's roles.
▭ The grower's roles.

prefers to design the strategies after he gets a full understanding of the property, therefore, his self-preparation activity does not involve an initial design of IPM strategies. In addition, on the day when the consultants will visit a client and discuss a plan for IPM strategies, both consultants will ensure that they carry all the tools they need to provide the IPM-related information to the clients.

Both consultants undertake the same physical activities during the planning process of IPM strategies in the field (Figure 5.1). Upon arrival, the consultants conduct short ice-breaking conversations with existing clients, and slightly longer ones with new clients. When visiting existing clients, the review, crop walk, and discussions are conducted as part of the consultants' involvement in the control stage of the clients' crop management. However, if they are new clients, then these three activities, particularly the review phase, are conducted to gather as much information as possible about the client, the property, and the cropping system. The review of the current crop situation and discussions are normally conducted in places where growers have less distraction, such as in the office, adjacent to the greenhouse, packing shed, corner of the greenhouse, garden or kitchen. The discussion phase is used by the consultants to discuss in more detail the issues discovered during the review and crop walk phases, including the planning of IPM strategies. At the end of the discussion, the consultants write down the key changes they have recommended to the grower on that visit. IPM strategies designed by the consultants during the discussion phase, are also written down for the grower. More relaxed conversation about personal and non-professional matters is left toward the end of the visit, prior to the consultants' leaving the property.

Following the visit, Case Study One also formalises his design by typing the IPM strategies up, and sending them to the clients. Unless specifically requested by the client, Case Study Two does not normally send the typed IPM strategies to the client because he considers that adequate details of the strategies have been provided in his verbal explanations and hand-written notes during the visit. However, following a visit where IPM planning is involved, Case Study Two may also send some necessary reading materials to growers, particularly inexperienced ones, if they have not been provided during the visit.

5.1.1.2 PLANNING PROCESS

In both case studies, IPM consultancy is conducted as part of the crop management consultancy. The planning process of IPM strategies requires good co-operation and communication between the consultant and the client throughout the process. Both consultants follow similar phases throughout the planning process (Figure 5.1). The first step in the planning process involves the collection of information from the clients and the provision of IPM-related information to the clients. These two phases continue throughout much of the planning process. Both consultants screen clients in terms of their suitability for adopting IPM through such factors as: the suitability of their properties, their readiness, interest, and reasonableness of their expectations. Case Study One may however, provide the client with an initial design of IPM strategies prior to the screening phase in order to give the clients a better idea of how the strategies can be tailored to their properties. Following the screening phase, if the consultants think that favourable attitudes toward IPM have not been developed, then the planning process ceases. However, if the clients are still interested, then the consultants will design the IPM strategies for them. The clients are involved in the planning process, particularly in relation to decision making and implementation.

Information is collected during the telephone call and then throughout the field visit by both consultants. The information is used to get a mental picture of the clients and their properties. For IPM planning purposes, less information is collected from existing clients than new clients because of the consultants' familiarity with these clients and their systems. The two consultants collect information regarding the greenhouse, cropping system, and the client's attributes. Case Study One collects more background information on the telephone than does Case Study Two. The information obtained on the telephone is used by Case Study One later on to provide the initial design of IPM strategies to the clients. Case Study Two, who does not provide the initial design on the telephone, does not need to collect as much information in this way, and prefers to obtain most of the information during the visit. The consultants collect similar information about the greenhouse, cropping system, and client (Table 5.1).

Names for the attributes of the three areas of information collected are taken directly from the consultants. Some attributes, although different in name, may refer to similar things, such as: 'spray history' and 'pest history'; 'decision making skills' and 'problem solving skills'. Others may be closely related to each other and therefore, in collecting data on one attribute, information about the other attribute can be gleaned. For example, by asking the 'greenhouse age', the consultants can almost derive the 'stud height' and 'cladding material'. The client's level of 'risk perception' can also point to his/her 'attitude toward IPM'. Another example is that, by knowing the client's 'budget allocation for pest control', the consultant can gauge the client's 'policy on chemical control' and 'attitude toward IPM'. 'Heating capacity' is closely related to 'ventilation' and 'controller', while 'what crop' leads to obtaining information about 'variety' and 'crop duration'. The 'decision making skills' attribute is also related to 'information availability', and 'understanding', while 'information availability' to the client may reflect his/her 'understanding of IPM'. Therefore, if from Table 5.1 the consultant does not seem to collect information about a given attribute, it does not necessarily mean that the attribute is not important or is neglected by the consultant, because to some extent, the attribute may have been derived or obtained from the other attributes which he collects.

Table 5.1 A comparison of information collected and means of collection by the consultants during the planning process.

Information	Case Study One		Case Study Two		
	Telephone	Visit	Telephone	Visit	Observation
GREENHOUSE					
Cladding material	✓			✓	
Greenhouse age			✓		
Stud height	✓			✓	
Humidity management	✓			✓	
Heating capacity	✓	✓	✓	✓	
Ventilation	✓				
Controller	✓	✓			
Location & neighbour	✓	✓	✓		
Spray history	✓	✓	✓	✓	
IPM history	✓				
Pest history	✓				
CROPPING SYSTEM					
What crop	✓		✓	✓	
Crop age	✓			✓	
Variety	✓	✓			
Crop duration		✓			
Media	✓			✓	
Crop health				✓	
When to plant			✓	✓	
CLIENT					
Expectation of IPM	✓	✓			
Experience	✓	✓	✓		
Policy on chemical control	✓				
Decision making skills		✓			
Attitude toward IPM	✓	✓			
Information availability	✓	✓	✓		✓
Problem solving skills					✓
Ability to implement plans				✓	✓
Ability to do control/eye for detail				✓	✓
Budget allocation for pest control			✓		
Risk perception	✓	✓	✓	✓	✓
Age			✓	✓	
Understanding of IPM			✓		
Innovativeness	✓	✓			✓
Patience					✓
Willingness to learn				✓	✓
Level of interest			✓		

However, compared to Case Study One, Case Study Two collects more information about the client's personal attributes such as patience, attention to detail, and willingness to learn, to complete his mental picture about the client. Field visits and observation through time are used to collect this type of information. To a certain extent, such understanding of the client may assist the consultant to predict the likelihood of success or failure when growers with a given characteristic implement IPM strategies. For example, growers who have an eye for detail may do a better monitoring job than those who do not posses such a characteristic.

In conjunction with information gathering is the provision of information to growers. IPM-related information, such as that regarding *Encarsia* and whitefly life cycles, spray compatibility, cultural practices, external environment, availability of support, and the cost of *Encarsia,* is given to clients. To give the clients a better idea of the extra work required for IPM, Case Study Two may, in addition, provide information about the monitoring strategy. Such information is provided both on the telephone and during a visit. Detailed and technical information is normally explained in the field. In providing information about *Encarsia* and whitefly in the field, Case Study One uses more tools, such as pictures, video, and living samples, compared to Case Study Two, who usually uses a book with pictures to assist him in his explanations. All tools used by the consultants are used to help the grower visualise the IPM implementation. The IPM-related information is provided to enable clients to make informed decisions.

Case Study One, if he is dealing with the clients on the telephone, will then provide an initial design of IPM strategies, which focuses on the predicted rates of *Encarsia* introduction. A more thorough design may be made at this stage if he is familiar with the property. Such an initial design, particularly if it is formalised, typed, and sent to the growers, helps them to visualise IPM implementation on their properties. Case Study Two tends to omit this stage and proceeds directly to screen the clients. The reason for this is because Case Study Two believes that a better design can be made during the visit, and therefore a very limited design phase occurs on the telephone.

Besides identifying the suitability of the greenhouse for IPM implementation, the two consultants differ in their aim with regard to the screening process. For Case Study One, the screening is aimed to find out the client's readiness to implement it. Case Study Two sees the screening process as a way to identify the grower's acceptance of the risks involved in implementing IPM strategies in his/her particular circumstances. The screening phase is conducted by using mostly the client-related information. If the consultants consider that the grower is ready, can accept the risks, and has developed favourable attitudes toward IPM, then the consultants can proceed to the next phase in the planning process: designing the IPM strategies, which normally occurs in the field.

If the screening phase occurs on the telephone, and favourable attitudes have developed, normally an appointment for a visit to further the discussion is arranged to suit the consultant's timetable. Some clients may develop unfavourable attitudes toward IPM and reconsider their initial interest in IPM based on the information provided by the consultants. If this is the case, then the process ceases until the issue is brought up again by the growers. Such favourable or unfavourable attitudes toward IPM may be developed either following a single call, or after a longer period of time. Most of Case Study One's clients can arrive at this appointment phase on the initial telephone call because Case Study One resides in Auckland, where most greenhouse tomato properties are located, and hence, he is easily able to visit most clients. Case Study Two, who is based in the southern part of the North Island, prefers to let the clients take some time to consider whether or not they want him to visit them to discuss the issue further.

The IPM strategies designed by the consultants in the planning process are focused at the tactical level and serve as the basis for the grower's operational plans. These strategies tend to be preventative in nature, and comprise: the use of *Encarsia* to maintain whitefly population below the threshold levels, environmental strategies, various cultural practices, a sanitation programme, preventative spray programme, and a monitoring strategy. In addition, Case Study Two may also suggest growers, particularly those whose properties are located in pest susceptible areas, use of resistant varieties (e.g. tomato spotted wilt resistant variety). Contingency plans to prepare growers for pest problems are also provided by the consultants in the form of spray lists. No significant difference is found between Case Study One's and Case Study Two's IPM strategies, except for the approaches used by the consultants in modifying their *Encarsia* template plan to suit the grower's specific circumstances.

Both consultants use decision rules, which can be tabulated in a hierarchical decision tree structure, to determine the *Encarsia* introduction and maintenance rates. In order to determine such rates, there are eight important factors considered by Case Study One, and seven factors by Case Study Two. The seven factors in common are: the type of crop, which will determine the template plan used; crop age; whitefly population prior to *Encarsia* introduction; ability to heat; season (winter and summer); stud height; and the persistence period of the pesticides used. In addition, Case Study One uses also greenhouse age as one of his decision criteria. Greenhouse age is used by Case Study One because it relates to the requirement for higher rates of *Encarsia* for crops grown in older greenhouses, due to the low stud height of the greenhouses and the chemical accumulation on the cladding material.

The consultants agree on some principles of *Encarsia* introduction, such as the need for a low whitefly population, and waiting until the pesticide persistence period has finished prior to *Encarsia* introduction, and avoiding the need to use *Encarsia* during winter in non-heated greenhouses. The contrast occurs regarding the approach proposed when using *Encarsia*, and the effect of greenhouse stud height on the *Encarsia* rates recommended. Case Study One prefers to start with a low level of *Encarsia* for 2 to 4 weeks, and then increase the rate and maintains it there until a sustainable level of parasitism is achieved. In contrast, Case Study Two prefers to start with a high level of *Encarsia* for 6 to 10 weeks, and then decrease the rate and maintain it until a sustainable parasitism level is achieved. Although the approach proposed by Case Study One may result in lower numbers of *Encarsia* required throughout the season, the strategy may also carry higher risks. By having lower initial *Encarsia* rates, a longer time may be needed by the beneficial organisms to establish a sustainable population in a greenhouse. If the whitefly population increases quickly during the early period of *Encarsia* introduction, then quick action needs to be taken, either by increasing the *Encarsia* rates or by applying chemicals, to decrease the whitefly population levels. By having higher initial *Encarsia* rates, a sustainable *Encarsia* population may be established sooner to prepare for the increase in whitefly population towards the middle of the season, and hence, lessen the risk of an outbreak. The trade-off for Case Study Two's approach is that more *Encarsia* are required throughout the season, resulting in a relatively higher cost of using it, compared to Case Study One's approach, given that no inundation is required throughout the season.

Regarding the stud height effect in old greenhouses, Case Study One believes that stud height will affect only the *Encarsia* maintenance rates, unless introduction is started once the crop is mature. He reasoned that if *Encarsia* is introduced when the crop is still young (< 2^{nd} truss), there is no need to differentiate between the *Encarsia* rates because the deleafing activity will not have started within the 2 to 4 weeks of the initial *Encarsia* introduction. Whereas for Case Study Two, because his initial *Encarsia* rates are used for 6 to 10 weeks, then the deleafing activity will have started during that period, and therefore, a higher initial rate is necessary to compensate for the loss from the deleafing activity.

In regard to the monitoring strategy, Case Study One provides clients with a guideline for whitefly threshold levels, although the numbers are still affected by factors such as greenhouse stud height, location, temperature, parasitism level, crop age, other pest infestations, and the client's risk perception level. Case Study Two, on the other hand, fails to provide similar guidelines for his clients. He believes that such threshold levels are influenced by the stud height and season. This difference may occur as the result of Case Study One's having direct access to the information provided by the affiliated consultancy firm and research centre in Belgium. Such information, however, may need to be carefully adapted to the local condition in New Zealand, such as shorter daytime during summer than in Belgium and different greenhouse structure characteristics. Although Case Study Two does not have such direct access to the research centre, he has access to one of the most experienced greenhouse consultants in New Zealand, who can provide him with informed discussions about a given pest-natural enemy population balance. Both consultants encourage growers to undertake monitoring. To facilitate this, Case Study One provides a whitefly monitoring form for growers to write down their monitoring results, and encourages them to have the form ready for checking every time he visits. Case Study Two encourages growers to write the monitoring results in whatever form they are comfortable with, which may involve a piece of paper, a book, a control graph, or a map of the greenhouse layout. By doing this, Case Study Two hopes that growers will be more motivated to conduct the monitoring activity.

In terms of the contingency plans provided for clients, both consultants provide a similar spray list for pests. Case Study Two provides more detailed contingency plans for his clients because he is not sure whether or not the clients require him to visit them in the following months. This is different from Case Study One, who just briefly discusses the contingency plans at the beginning of the season, because with the Preferential Customer Programme, he is sure that he will visit the clients at a later stage and guide them then should a pest attack occur.

Once the IPM strategies have been designed and discussed with the clients, it is then their responsibility to make the decisions regarding implementing or rejecting the strategies. The consultants differ in their perceptions of how a client goes through his/her decision making process. Because Case Study One stresses to his clients that IPM is not the way to reduce their pest control costs, he believes that costs will not be the first consideration for them in making the decisions. Case Study Two however, who is more concerned with the growers' budget situation, considers cost as the first factor influencing their decision making. Then, once they have decided to implement either the whole strategies or parts of the strategies, they can start implementing IPM in their properties.

5.1.2 CONTROL STAGE

As in the planning stage, the control stage of IPM strategies consists of the physical activities (pre-visit and field visit) and the process used by the consultants (Figure 5.2). The activities and phases in the control process presented in Figure 5.2 occur in iterative in practice.

5.1.2.1 PHYSICAL ACTIVITIES

After the planning stage, the consultants' involvement may be extended into the control stage (Figure 5.2). For Case Study One, his involvement in the control stage with the preferential customers becomes automatic because of the annual contract between them. However, for Case Study Two, his involvement in the control stage is conducted only at the client's request. Unlike those in the planning stage, the physical activities in the control stage consist only of the pre- and field visit phases, because of the repeated cycle between the two phases throughout the control stage of IPM strategies. Most support from the consultants comes in the form of telephone consultancy and field visits. Both the telephone call and field visit serve similar purposes for the clients, which may include confirmation of the monitoring results and problem solving. However, telephone calls are normally used by clients to deal with day-to-day (operational management) problems, and therefore, the problems solved on the phone are normally the ones which require quick and simple curative solutions. If the pest problems require the consultants to conduct major modifications to the plan, then an appointment for a visit is made. Because Case Study One resides in Auckland, an urgent visit to most of his preferential clients can be made relatively easily when required because of his close proximity to the clients' properties. Such an urgent visit may be more costly for Case Study Two's clients because of the long distance between his location and Auckland, where most of his clients reside.

Because of the nature of the clientship with Case Study Two, a telephone call from the client is normally required before a visit is conducted. On the other hand, for the Preferential Customers of Case Study One, the visits during the control stage have become part of their regular consultancy. Such a programme gives Case Study One a greater opportunity to be involved in the client's management through regular

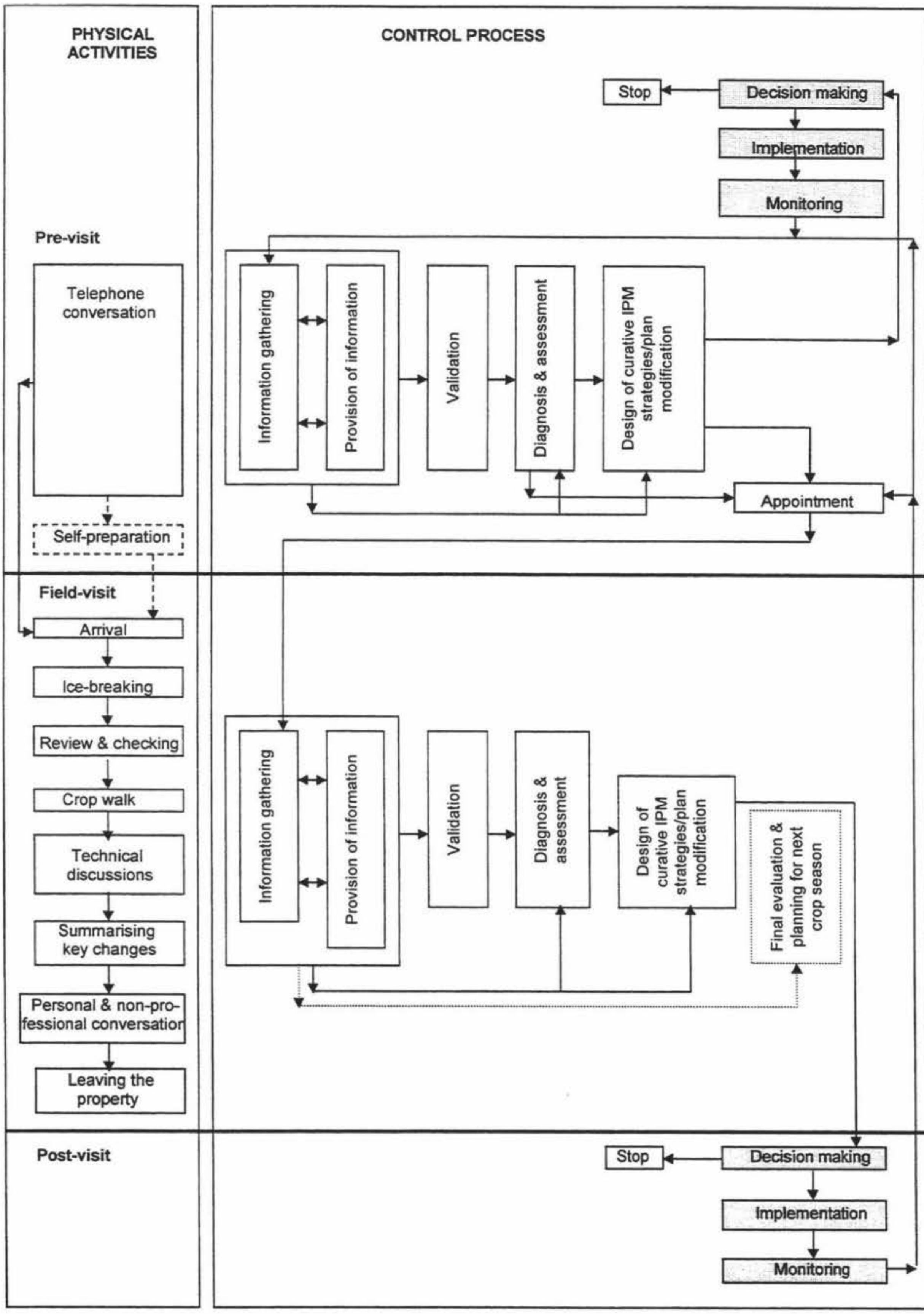

Figure 5.2 A general model of the physical activities and control process used by the consultants at the control stage.

Note: ············ Conducted toward the end of the crop season.

------ Conducted only when necessary.

participation, and hence, increases the likelihood of success of the IPM strategies in the client's property. Prior to the visit, the consultants may undertake some preparation to make sure that they carry all the tools or information which may be required, or has been requested by the clients during the telephone call or in the previous visit.

The consultants follow the same procedure while they are in the field (Figure 5.2). The topics discussed during a visit may encompass all aspects of crop production, with IPM as one of them. The procedure starts after the consultant arrives in the property, finds the grower, and has a short ice-breaking conversation with the grower. The consultant then begins reviewing and checking the current situations in the property. This activity is normally conducted in places where the grower can have minimal distractions. More time is spent at this stage by Case Study One looking at the grower's monitoring results. For Case Study Two, the review may be conducted prior to, or in conjunction with, the crop walk activity. If the review is conducted during the crop walk, then further checking of the grower's monitoring results is normally left until after the crop walk.

During the crop walk, activities such as: observing the crop general health, whitefly population, and pollination activity of the bumblebees, discussing the crop problems, providing suggestions or recommendations to solve the problems, are conducted. The consultants use different techniques to reinforce their suggestions on a given problem. Case Study One often provides examples of how such suggestions have solved similar problems at his other clients' properties. In giving such examples, Case Study One stresses the similarities between the grower's situations with that of the other client. Case Study Two tends to use his employer's recommendations to reinforce his suggestions. This can be important because Case Study Two and his employer take turns in visiting almost the same clients, and some growers may perceive the employer as having more experience than Case Study Two. Although both consultants take some notes during the crop walk, Case Study One takes more notes regarding the crop conditions during the crop walk, than Case Study Two, because he needs to fill in his Tomato Recording Sheet form based on his estimation of the grower's crop performance.

After finishing the crop walk inside the greenhouses, the consultant leads the grower back to the place where they had had the review activity to discuss in more detail the technical issues found during the review and crop walk. Some further checking of the grower's monitoring results is conducted at this stage, particularly by Case Study Two. For Case Study One, further checking of the monitoring result is also useful in completing the

Tomato Recording Sheet form. Design of the curative IPM strategies is focused at this stage.

At the end of the crop season, the technical discussion phase and, to a limited extent, the crop walk, is also used to conduct a final evaluation of the performance of the strategies designed by the consultants, and to plan the strategies for the following season. Both consultants also provide the growers with hand-written notes about the key changes which need to be conducted by the grower. The key changes for the next season may also be written down for the growers. More personal and non-professional conversations are conducted toward the end of the visit, before the consultants leave the property.

In addition to the telephone consultancy and field visit, Case Study Two provides consultancy through email to those of his clients who are connected to it. The email can be used to answer simple questions asked by growers. The advantage of using email for Case Study Two's clients is the relatively cheaper cost compared to telephone consultancy, due to the distance between Case Study Two and most of his clients. Another form of consultancy at the control stage used by Case Study One is to provide growers with the information he perceives they require through a newsletter. The topic selected for each newsletter issue is adjusted to the activity in which most greenhouse growers are engaged at that particular time. For example, the effect of night humidity is selected as the topic for winter publication, where many growers are having humidity-related diseases. However, unlike a telephone call, visit, or email, such a newsletter does not provide a two-way communication, although its content may assist in solving the growers' problems.

5.1.2.2 CONTROL PROCESS

The interactive nature between the consultants and the clients is still maintained during the control process for IPM strategies. Both consultants follow the same phases of involvement during the control stage with the clients (Figure 5.2). They believe that growers are responsible for the actual decision making, implementation and monitoring of IPM strategies, although Case Study Two may have a greater influence during the decision making phase for an inexperienced grower, than has Case Study One. During the control process, the consultants undertake activities such as obtaining information from, and providing information to, the client, validating it, making diagnosis and assessment of the problem, and designing the curative IPM strategies or plan modifications. The first two activities are conducted continuously throughout the control stage and may occur iteratively with other phases. The phases are repeated every time a problem occurs, until the end of the crop season, when the consultants conduct a final evaluation.

Growers need to initiate monitoring activities soon after the implementation of the preventative IPM strategies. If the monitoring results concern the growers, they may then inform the consultants and ask for their help. Both telephone calls and visits can be used by growers to inform the consultants about the monitoring results. The consultants like to validate the information which they receive from clients, particularly if it is obtained over the telephone. For the consultants, the validation phase is important to ensure that the problems do exist, and that the clients have the same perception of the problems as do the consultants. Based on this information, the consultants can then make appropriate diagnoses and can assess how serious the problems are. These two phases are conducted by asking questions and, if they are in the field, also by checking the monitoring results and observing the problem areas. As a result of these phases, new problems which were overlooked by growers can sometimes be identified. The consultants always attempt to provide explanations to the growers regarding the causes and effects of the problems.

The design of the curative IPM strategies or plan modification can be done after the pest problem is well understood. Both consultants solve most pest problems by modifying the preventative IPM strategies (e.g. increasing the *Encarsia* introduction rate, modifying the environmental set points to control diseases), or by designing the curative IPM strategies, which, to a certain extent, is conducted by providing more detail to activate the contingency plans. For both consultants, preference for the curative IPM strategies is always given to non-chemical methods, or to use of IPM-friendly chemicals.

In dealing with whitefly problems, to determine the appropriate solutions Case Study One consciously uses decision rules, which he develops only in his mind. Case Study Two, in contrast, is not conscious of the process which he goes through to determine the appropriate strategy, although he practises such use of decision rules. Case Study One always prefers to increase *Encarsia* rate, unless the grower opposes, until spray application is unavoidable. For Case Study Two, because he is more concerned with the cost of *Encarsia* inundation, he may recommend growers who have already introduced *Encarsia* at a high rate (4-6/m^2), to allocate the *Encarsia* more effectively if possible, or use IPM-friendly chemicals. This strategy is cheaper than *Encarsia* inundation. Case Study One, on the other hand, believes that cost should have not become the obstacle to use high rate of *Encarsia* to control whitefly problems. If spray application is unavoidable, then Case Study One determines the number of sprays required based on the whitefly population, historical spray use, and the level of parasitism. Case Study Two determines the number of sprays based on the whitefly population, season, and temperature in the greenhouse. Case Study One's higher threshold levels may result in lower spray use than Case Study Two's strategies.

For insects other than whitefly, both consultants use a similar curative strategy approach. The insect problems are dealt with using chemicals, which are preferably given as spot or localised sprays, unless the pest has spread and threatens the whole crop, in which case a total wetting spray may be required. However, the consultants differ in their recommendations for the *Encarsia* reintroduction rate after the chemical persistence period has finished. Case Study One suggests growers add up the number of *Encarsia* introductions which they had missed out during the persistence period and apply them, while Case Study Two suggests growers double their rate if the previous rate was below 3 *Encarsia*/m^2 or reintroduce at the same rate as the previous rate if it was already above 4 *Encarsia*/m^2. Both consultants recommend growers use environmental systems and cultural practices to control diseases.

Both the curative IPM strategies and plan modifications are discussed with the clients and/or hand written toward the end of a visit. The clients then need to make the decisions about implementing or rejecting the curative IPM strategies or plan modifications designed by the consultants. At this stage, Case Study Two may have a greater influence in clients' decision making, compared to Case Study One, particularly if the clients are inexperienced growers. If the clients decide to implement the strategies, then the implementation needs to be followed by monitoring the performance and the ability of the strategies to solve the problems. Should the problems persist, or new ones emerge, then again the consultants may be informed, and the control process cycle is repeated.

At the end of the crop season, a final evaluation of the IPM strategies is undertaken as part of the normal evaluation of the crop production strategies. The two consultants use different parameters to evaluate the success or failure of their strategies. Case Study One uses the effectiveness of the strategies, fruit quality and quantity, and the growers' financial improvements as the parameters. In addition, he also personally evaluates his strategies by the overall clients' satisfaction with their current situations. Case Study Two uses the number of interventions to the preventative strategies, size of whitefly populations, cost of IPM strategies in regard to the growers' budgets for pest control, and the benefits perceived by the clients, as the parameters for evaluation of his IPM strategies. Together with his employer, Case Study Two also evaluates their overall strategies by the number of satisfaction comments or complaints from their clients. The results from the evaluations can be used to improve the IPM strategies for the following season, both for the clients and as an input for the consultants.

5.1.3 CONSULTANCY STYLES

Although both consultants follow similar phases during the planning and control stages of IPM strategies, they use different styles of consultancy. Case Study One approaches clients in a formal way, particularly during the planning stage, by providing clients with typed and personalised IPM strategies in the form of the Grower Summary Letter and Crop Timetable, in addition to the verbal method and hand-written notes which he provides. Furthermore, he provides the growers also with the Pest Monitoring Sheet for whitefly monitoring purposes. From the growers' perspective, through the Preferential Customer Programme, they are also more committed to Case Study One and are assured of having the priority of his attention. Case Study Two in contrast, prefers to approach clients in a more informal and relaxed style, by providing them with IPM strategies explained either mostly verbally, or in hand-written form. He reasons that, unless the grower is a corporate type of client, who prefers to have every detail structured in a report instead of in hand-written notes, then most of his clients are comfortable with his approach. To educate the clients, Case Study Two provides them also, particularly inexperienced growers, with handouts, which are mass-produced by photocopying, on relevant topics.

During a visit, Case Study One uses his Tomato Recording Sheet to write down his assessments of the client's crop performances. By using a standard form, Case Study One can have the same information about attributes of crop performances for every client. Once filled in, the Sheet is then left with the growers so that they can reread his assessments on their crops. Major changes which he suggests growers undertake, are also written down on the Sheet. In contrast, Case Study Two writes down all notes which he has made during the visit, together with his recommendations on the major changes suggested, on a blank sheet of paper. He reasons that a more formal approach had been used with the growers previously, but concluded it was unnecessary for them, particularly for experienced ones, who can perform proper assessment on their crop performances. More detailed notes and recommendations can be written down for inexperienced growers. By writing all these on a blank sheet of paper, the approach then can be tailored to the client's preference.

In providing and discussing the plans with the clients, Case Study One submits the preventative IPM strategies which he has designed for the clients prior to their implementation. For inexperienced growers, the plans are discussed focusing on a monthly basis, and for experienced growers, on a two-monthly basis. This can be done because, with the Preferential Customer Programme, Case Study One is certain about when he will visit the clients again. Case Study Two tailors the ways in which the IPM strategies are submitted to his clients. For inexperienced growers, the strategies are given gradually, depending on their level of understanding. However, if he is dealing with experienced growers, then the whole strategies are discussed in one visit because he is not sure whether or not they will require his service again within that crop season.

Case Study One admits that he has relatively higher threshold levels, particularly for whitefly, compared to the levels perceived by the industry as appropriate. For example, he believes that growers can start introducing *Encarsia* to the young tomato crops if there are up to 2 whitefly per plant. Case Study Two, in contrast, suggests growers maintain whitefly population below 1 per 10 plants before *Encarsia* is introduced. Such a high threshold level may increase the risk of using *Encarsia* because, by the time the *Encarsia* hatch out from the black scales on the card, the whitefly population will have increased in relatively higher numbers than would have been the case if the starting whitefly population had been lower, particularly if an environment favourable for *Encarsia* growth is not provided. Higher whitefly threshold levels are also used by Case Study One in designing the curative strategies for whitefly problems, and in some cases have proved to be working well. Although the two consultants might suggest different curative IPM strategies to solve a given whitefly problem, at the end, it is still the growers who have to make the final decisions. Risk taker growers may not hesitate to implement Case Study One's curative strategies, but risk averse growers may decide to jump quickly to pesticides, without considering increasing the *Encarsia* rates.

Despite the difference, both consultants use a similar approach in dealing with inexperienced and experienced growers during the control stage. With inexperienced growers, the "do this do that" approach is used. In this case, the suggestions made by the consultants almost always become the decisions for the growers. As the inexperienced growers learn while implementing the strategies, and while being educated by the consultants, the approach used is slightly modified towards the "discuss" approach. With the "discuss" approach, suggestions are discussed, rather than provided as directions.

5.2 COMPARISON OF CROSS-CASE ANALYSIS WITH LITERATURE

In this section, the results of the cross-case analysis are compared with the literature. Important similarities and differences between the case study findings and the literature are highlighted. The comparison encompasses two areas, the IPM consultancy processes (Section 5.2.1), and the components of the IPM strategies for greenhouse tomatoes (Section 5.2.2).

5.2.1 IPM CONSULTANCY PROCESSES

The traditional view of farm management is that a farm manager undertakes a cyclical process of planning, implementation, and control (Barnard & Nix, 1979; Boehlje & Eidman, 1984; Parker *et al.*, 1997). However, in this study, unlike the traditional farm management model, the consultants[1] undertook the planning function and some aspects of the control functions, such as designing the corrective actions and undertaking evaluation. In contrast, the growers were responsible for the implementation and monitoring of the plan. Similar findings have been reported by Grieshop *et al.* (1988), Lambur *et al.* (1989), Martin (1990b), McNamara *et al.* (1991), and Beck *et al.* (1992). Through any one season, the consultant is involved in a single planning exercise for the grower, and then the consultant provides sequential advice on control. The number of times the consultant has to provide advice on control depends on the problems confronted by the client. These results are similar to those reported by McCosh (1995), Rogers, N. (1995), Williams (1997), and Gray *et al.* (1999), who found that consultants were involved in problem solving (either planning or control problems), but not in implementation or regular monitoring.

When assisting a grower with the planning and/or control of IPM, the process used by the consultants can be separated into a sequence of physical activities (Section 5.2.1.1), and separate, but interdependent, planning and control processes (Section 5.2.1.2).

5.2.1.1 PHYSICAL ACTIVITIES

The physical activities undertaken by the greenhouse consultants were similar to those undertaken by farm management consultants (McCosh, 1995; Rogers *et al.*, 1996; Williams, 1997; Gray *et al.*, 1999), as seen in Figure 5.3. However, unlike in those other reports, this study distinguishes between the planning and control purpose physical activities.

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[1] Throughout this chapter, the terms consultants/consultant are used interchangeably with the greenhouse consultants/consultant, who were studied in the thesis.

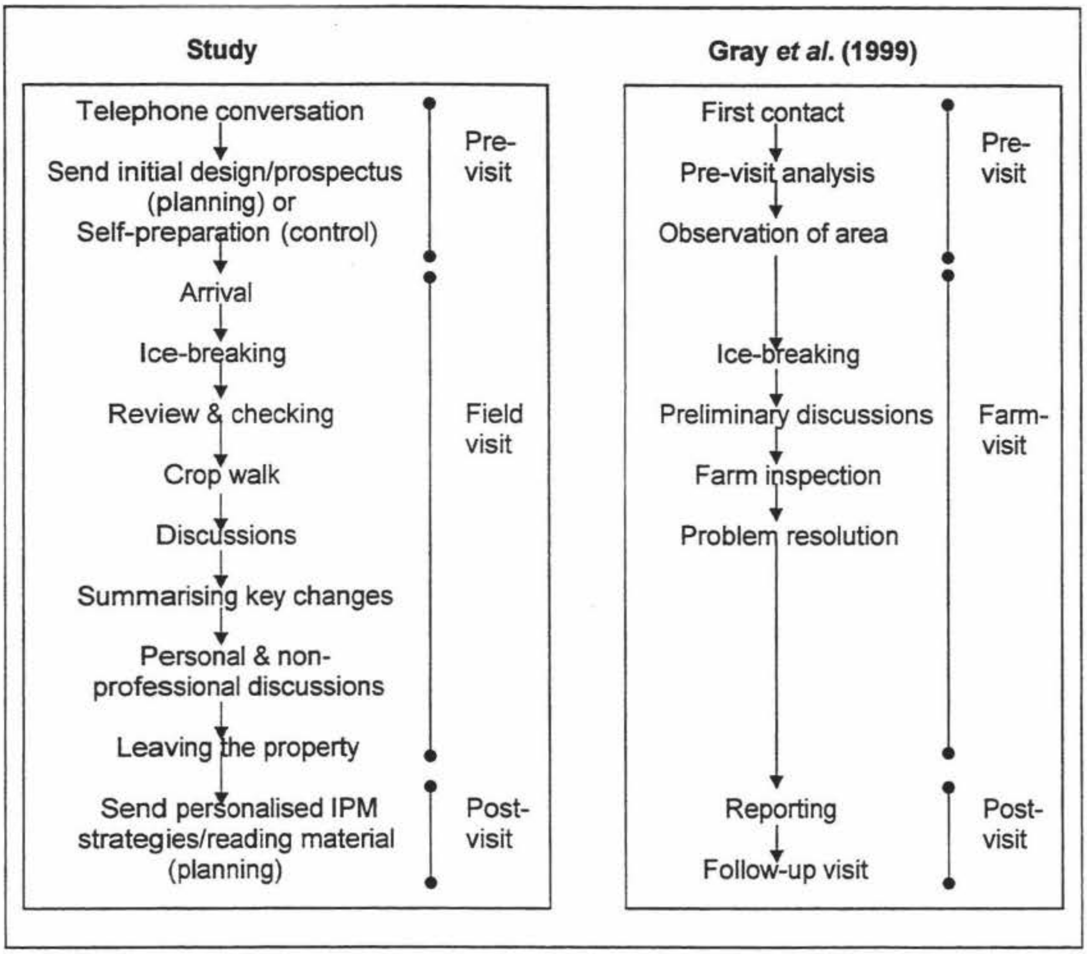

Figure 5.3 A comparison of the physical activities conducted by the greenhouse consultants during a planning/control purpose visit and those conducted by by farm management consultants during a regular problem solving visit.

For the planning purpose, the physical activities undertaken by the greenhouse consultants can be separated into three stages, pre-visit, field visit, and post-visit, while the control purpose activities comprise only pre-visit and field visit steps. The pre-visit tasks involve initial telephone contact and a self-preparation activity which the consultants undertake prior to the visit. The self-preparation activity conducted by the greenhouse consultants varied depending on the purpose of the visit to be conducted. These two pre-visit activities have been reported also by McCosh (1995), Rogers *et al.* (1996), Williams (1997), and Gray *et al.* (1999) from their studies of farm management consultants in New Zealand. In addition, these farm management consultants also conducted observation of the surrounding district on their way to the client's property. This activity was not identified in this study of greenhouse consultants. This may be because of the nature of farming properties, which allows the farm management consultants to observe pastures and livestock on neighbouring farms from a moving vehicle. However, because of the isolated nature and small size of most greenhouse tomato properties, it is almost impossible for the greenhouse consultants to make such observation on their way to a property.

The field visits conducted by the greenhouse consultants may serve either the planning or the control purpose, or both purposes, depending on the client type. The planning purpose visit is normally conducted at the first visit to a new client, while for an existing client, a visit is normally conducted either for control purposes, or for both planning and control purposes. Such differentiation of the visit purpose was not reported in other farm management consultancy studies (McCosh, 1995; Rogers *et al.*, 1996; Williams, 1997; Gray *et al.*, 1999), except for a brief mention of "follow up" visit. However, whatever the purpose of the visit, the greenhouse consultants undertake similar activities to the farm management consultants during the field visit. This starts with an ice-breaking conversation with the client. The review and checking phase in this study, if it is conducted on the consultant's first visit to the client's property, when the consultant attempts to find out as much information as possible from the client, serves a similar purpose to the preliminary discussion phase in Rogers *et al.* (1996) and Gray *et al.* (1999). However, if the review and checking phase is conducted during the control stage, then it is used to review the progress in the property since the consultant's last visit.

The next activity, the crop walk, is conducted by the consultants to observe the crop situation to validate the information which they have obtained from the client previously. A similar phase was termed farm inspection by Rogers *et al.* (1996) and Gray *et al.* (1999), or farm walk by McCosh (1995) and Williams (1997). In addition, this activity is used also by greenhouse consultants to make appropriate diagnosis and assess the problem during the control stage. Following the crop walk, the greenhouse consultants conduct more technical discussions with the clients and design the preventative (during the planning stage) or curative (during the control stage) IPM strategies. This phase was described as problem resolution in Rogers *et al.* (1996) and Gray *et al.* (1999). However, McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999) found that the farm management consultants, as well as proposing their own solutions, asked the client about possible solutions to the problem. This did not happen with the consultants in this study. This difference may occur because the clients lack the knowledge and expertise needed to provide suitable solutions. Once the consultants have developed the IPM strategies, they are then explained to the client, and discussion about details of the strategies occurs.

The studies by McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999) reported that the farmers made the decision to adopt the solution proposed by the farm management consultant at the end of the visit. However, in this study, the growers did not decide to adopt the IPM strategies, both preventive and curative, until after the greenhouse consultants had left. It may be that the shift from chemical spray dependence to IPM, particularly reliance on *Encarsia*, is seen as quite daunting by growers, and hence, they need more time to make the decision.

Toward the end of the discussion phase, the greenhouse consultants will summarise all the key changes recommended during the visit and write them down for the client. This is different from the farm management consultants reported in Rogers *et al.* (1996) and Gray *et al.* (1999), who provided a written report which was sent to the client after the visit. However, one consultant studied by McCosh (1995) and Williams (1997), wrote down the important issues and the recommendations on the carbonised pad before leaving the property. This simple reporting process saves the greenhouse consultants a lot of time in report preparation. Each greenhouse consultant studied in this thesis serves more clients on a more regular basis than those reported upon by McCosh (1995), Rogers *et al.* (1996) and Gray *et al.* (1999). Therefore, this may limit the amount of formal report writing which they undertake. However, in the planning stage some documents may be sent by the consultants (Grower Summary Letter and Crop Timetable by Case Study One, and reading materials by Case Study Two) to the clients after the visit.

The greenhouse consultants finish the visit by having relaxed conversations about personal and non-professional topics. The studies conducted by McCosh (1995), Rogers *et al.* (1996), Williams (1997), and Gray *et al.* (1999) did not mention how the farm management consultants end their visit to the farmer. Limited use of a newsletter with Case Study One and email consultancy with Case Study Two, which was not reported in other farm management consultancy studies, was found during the control stage.

5.2.1.2 PLANNING AND CONTROL PROCESSES

The farm management literature on the consultancy processes was written from either a problem solving (McCosh, 1995; Rogers, N., 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999) or a rapport building (Williams *et al.*, 1997) perspective. No mention was made of the farm management consultants' role in relation to planning or control, though it could be assumed that many of the problems encountered by consultants in these studies could be classified under these two categories. Therefore, the literature review used in this study was derived from the consultancy problem solving literature and the management planning and control literature.

COMPARISON WITH THE CONSULTANCY PROBLEM SOLVING LITERATURE

More recent studies (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999) of the farm management consultancy processes have investigated this from a problem solving perspective. These authors identified that the farm management consultant and client had different roles in the process. The farm management consultant undertook the problem solving process, while the client was the problem owner, and responsible for the decision to implement the solution and the actual implementation. No mention of control was made in these papers. However, follow-up visits were mentioned, and it may be during these visits that control aspects are discussed. Research conducted for this thesis found that the client was not only responsible for making and implementing the decision, but also for monitoring the control process.

Williams *et al.* (1997) stressed the importance of rapport throughout the consultancy processes to build a trusting relationship between the client and the consultant. By having the client comfortable with the consultant and confident of his/her skills, sensitive information may be acquired from the client without creating tension (Rogers *et al.*, 1996; Gray *et al.*, 1999). Although this aspect is not the focus of the thesis, the consultants agreed that good rapport plays important roles in obtaining information from the clients and gaining their trust so that they will be more likely to accept the consultants' recommendations as to the most appropriate IPM strategies for their situations.

The findings from this study are consistent with the literature (McCosh, 1995; Rogers, N., 1995; Williams *et al.*, 1997, and Gray *et al.*, 1999) in that, in consultancy, the consultant is not the owner of the problem and may be seen as an outsider by the client. Therefore, the consultancy processes, whatever framework is used, should start by gathering information from the client as the problem owner. In the problem solving framework, problems were identified based on the farm management consultant's hypothesis of the cause of the problems, which were then tested by asking more questions and confirmed to the clients (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). This is similar to the way greenhouse consultants identify the pest problems during the control stage, by gathering more information and undertaking observation in the field to validate the existence of the problem, make appropriate diagnosis of the cause of the problem and assess its level of seriousness. In addition, information is collected during the control stage also to update the consultants' knowledge on the changes in the property since the last visit. However, during the planning stage, the problem is already clear, the client is interested in IPM, but lacks knowledge of it, and therefore the consultant's assistance to provide him/her with feasible IPM strategies is needed. If the clients are new to the consultants, a large amount of information is collected during the planning stage in order for the consultants to design the preventative IPM strategies.

An important finding in this study which has not been reported in the previous consultancy problem solving studies is the existence of the "provision of information" phase, a critical step in any consultancy processes. This step was implied in the farm management consultancy studies by McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999), but it was not made explicit in their models. The provision of information phase is found to be important in relation to the complex nature of IPM, and because the majority of growers lack the knowledge required to plan and control an IPM system.

In addition, this study also identified the importance of the "screening" phase in the planning process and the "validation" phase in the control process. The screening phase is important for the consultants to ensure that the client's favourable attitude toward IPM has developed before the consultants proceed to design the preventative IPM strategies for the client. Such favourable/unfavourable attitudes are developed as a result of the information provided by the consultants regarding the advantages and disadvantages of IPM implementation in the client's specific circumstances. The importance of the development of favourable attitudes prior to the adoption of an innovation has been mentioned by Rogers, E. M. (1995). Through the consultants' explanations, the client can understand the relative advantages/ disadvantages of IPM compared to conventional pest control methods, the complexity of IPM, and how compatible it is with his/her perception of pest control management. Moreover, Case Study One also suggests growers try IPM, particularly the use of *Encarsia*, in one greenhouse only, to reduce the risk and yet still give the client the opportunity to observe the results of using it. This finding concurs with E. M. Rogers' (1995) argument on the characteristics of an innovation which may affect the decision to adopt or reject the innovation. This screening phase has not been mentioned in other consultancy problem solving studies (McCosh, 1995, Rogers, N., 1995, Gray *et al.*, 1999).

In regard to the validation phase during the control process, the consultant collects additional information to validate the client's belief that a problem exists on his/her property. This step was not explicitly identified in the studies by McCosh (1995), Rogers, N. (1995), Rogers *et al.* (1996), and Gray *et al.* (1999). In their studies, they mentioned a sub-step in the problem solving process referred to as "problem definition", which was not identified in their models. There were also several references to the farm management consultants' postulating hypotheses about the existence of potential problems based on information from the client. These were later confirmed or refuted through the collection of further information. The validation phase becomes particularly important if the problem is raised by the client over the telephone, where the consultant does not have the opportunity to observe the problems for himself, and hence has to rely on the further information he collects to validate the existence of the problem.

There are similarities and differences in the approach used by the greenhouse consultants in providing solutions to the problems during the planning and control processes as compared with those used by the farm management consultants in the problem solving process. The consultants in both studies tailored the solutions to fit the client's circumstances. However, while greenhouse consultants have only a single IPM strategies template for greenhouse tomatoes, farm management consultants in contrast, began by having multiple options which were then narrowed down using the client's circumstances until the feasible solution emerged. In addition, farm management consultants often asked clients for their opinions as to the possible solutions (McCosh, 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). This is unlikely to be the case in IPM since knowledge and expertise, which growers often lack, is required to undertake the design of IPM strategies. Little was reported on the process of selecting the best options for the farmer. This study, in contrast, provided detailed information on how the consultants use decision rules to tailor the template to the specific situation of a client, although less detail was obtained for the control process due to the time constraint in the study.

The IPM strategies designed by the greenhouse consultants detail how the strategies can be implemented in the client's property, and include a monitoring strategy and contingency plans for the control purpose. The IPM monitoring strategy provides greenhouse tomato growers with the list of parameters which need to be monitored, and which serve as the basis for pest control decision making during the control stage. Moreover, the presence of monitoring strategy also creates an additional role of the client, to undertake monitoring activities, which has not been reported in the previous study (McCosh, 1995; Rogers, N., 1995; Rogers *et al.*, 1996; Gray *et al.*, 1999). Contingency plans are provided to prepare growers for possible pest scenarios. The farm management consultants studied by McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999) also planned the implementation for the client. However, there was no mention of standards or contingency plans in these papers. Some of the farm management consultants studied by Rogers, N. (1995) did use financial tools for controlling the client's financial situation, but this was on an annual basis.

In summary, the adoption of a planning and control framework in this study, rather than a problem solving framework, has identified several new aspects of the consultancy processes which have not been mentioned before. It thus may have provided a broader insight into the client/consultant relationship.

COMPARISON WITH THE MANAGEMENT PLANNING AND CONTROL LITERATURE

As mentioned earlier, in this study the processes used by the consultants were viewed from the management perspective, which involves the basic functions of planning, implementation, and control. It was found that greenhouse consultants are involved only in the planning and control functions. However, the planning and control functions in the farm management literature focus on the processes used by farm managers (e.g. Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987), rather than by consultants. This difference results in the need for the inclusion of phases which require interactions between the consultant and the client, such as information gathering and provision, screening, and validation (Figure 5.4). The existence of these phases has not been reported in other planning and control process studies in farm management literature. The interactive nature of the planning and control processes in IPM consultancy is important because the consultant, as an outsider, requires growers' knowledge of their systems in order to develop the strategies most likely to be implemented successfully by the growers. The growers on the other hand, also require the consultant's knowledge, experience, and expertise to provide the IPM strategies tailored to their circumstances.

During the planning stage (Figure 5.4), the consultant is responsible for understanding the client's system, and thus needs to gather information from the client. This is subtly different from the management literature where the farm manager gathers the information from his/her own farm (Barnard & Nix, 1979; Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987). The consultant is responsible also for providing the specific IPM information to the clients because they lack expertise, which is necessary for deciding whether to firstly, adopt IPM, and secondly, implement the IPM strategies successfully. In addition, the consultant is responsible for screening the clients, and designing the preventative IPM strategies for them, who may not be able to undertake this with their own knowledge. This aspect of sharing the responsibility was not mentioned in the farm management literature because it is assumed that planning is undertaken solely by the farm manager.

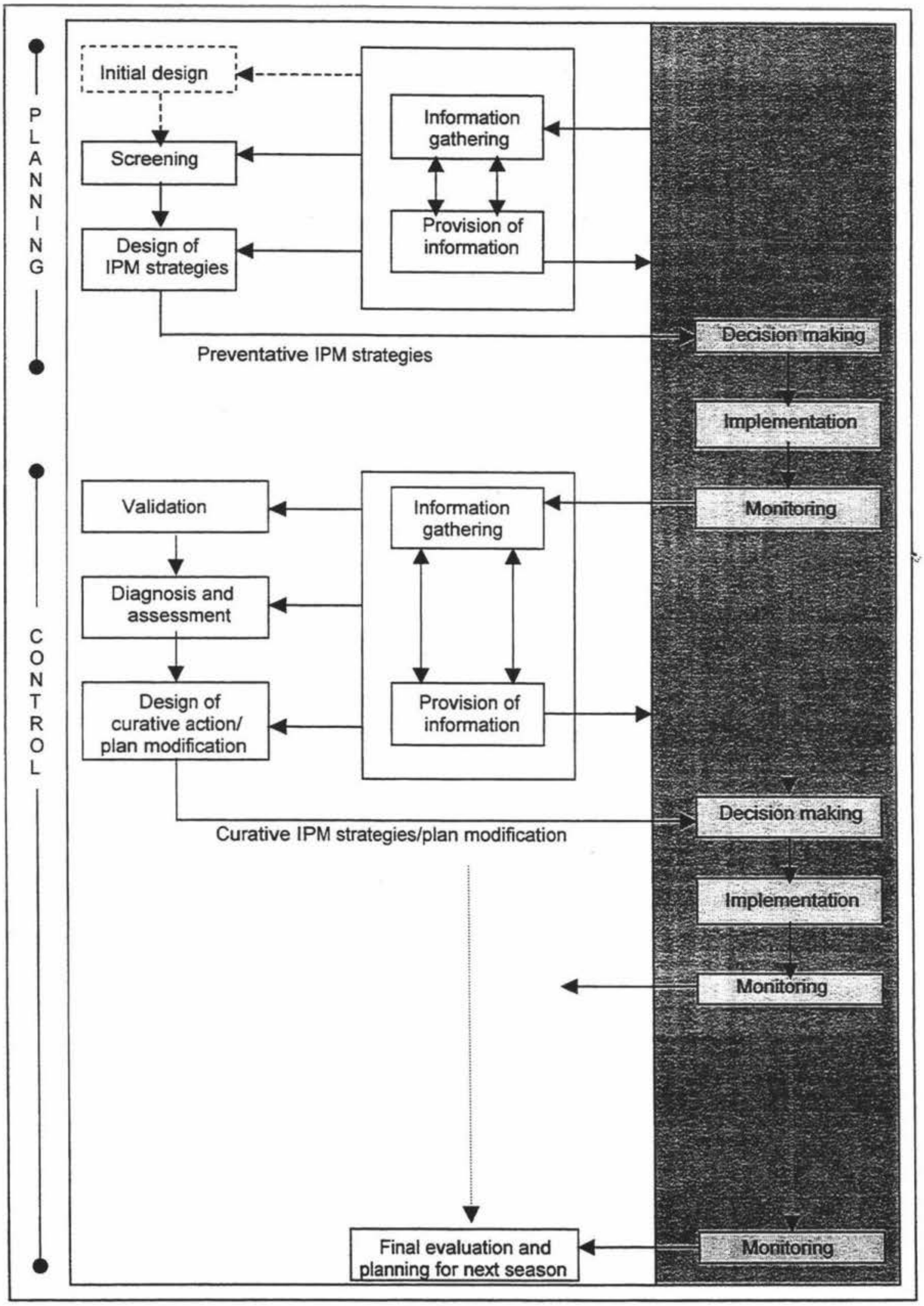

Figure 5.4 Planning and control processes of IPM strategies used by the consultants to assist greenhouse tomato growers.

Notes: ▭ The consultant's roles.
▭ The grower's roles.
------ Conducted if initial interest in IPM is expressed on the telephone.
.... Repeated control process until the end of the crop season.

If the aspects of the planning process which are attributed to the client/consultant relationship are separated out, then the planning process which the consultants use is similar in a number of areas to that reported in the literature. Boehlje and Eidman (1984) and Wright (1985) proposed that information in the planning process is used by the manager to analyse the current situations and predict possible future situations. For the consultants, included in the current situation analysis is the identification of the resources available at the property. Such analysis is used to understand the client's current system and develop a mental picture of the client and his/her property, particularly if the grower is new to the consultants. This is useful as a basis for tailoring the template/standard IPM strategies.

In the farm management literature, goal formulation forms a separate phase, although may occur simultaneously with data collection (information gathering) in the planning process (Boehlje & Eidman, 1984; Wright, 1985). In this study, goal formulation becomes part of the information gathered from the client. By understanding the client's expectations from IPM strategies, the consultants can assess the feasibility of such expectations, in relation to the extent of IPM strategies which can be implemented in the client's situation, and explain them to the client. Such explanations can be used to screen the client's readiness to implement IPM strategies.

Instead of identifying possible strategies and analysing them to come up with the selected strategies tailored to the farm's goals and resources (Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 987), the consultants use a single template of IPM strategies, particularly regarding the use of *Encarsia* as the key component of IPM strategies for greenhouse tomatoes. This template is modified given the information on the client's greenhouse and cropping system, and by using decision rules, so that it is tailored to the client's site-specific conditions. This approach to modify a template plan, rather than generating possible plans, is considered reasonable since the options of IPM strategies which can be implemented in greenhouses are limited, and therefore creative modifications of the available existing strategies is required to meet the demand of various growers' situations.

During the planning process, information about pest history, neighbours' crop activity, and the location of the property is used by the consultants to predict possible pest scenarios for the development of contingency plans. Such provision of contingency plans has also been mentioned by Boehlje & Eidman (1984) and Wright (1985). The contingency plans provided by the consultants during the planning stage, although only in the simple form of lists of pesticides which may be used in various pest problem situations, provide a degree of preparation for the client if such pest problems occur. In addition, the consultants provided also a monitoring strategy to be used by the client during the control stage. The monitoring strategy lists the parameters to be monitored, the frequency, and when and how they should be monitored. Such development of monitoring strategies to monitor the progress of the plan has been mentioned also by Boehlje and Eidman (1984) and Downey and Erickson (1987).

Following the development of the preventative IPM strategies by the consultants, the client is responsible for making the decision regarding their implementation and undertaking the actual implementation of the strategies. Once implemented, the client is then responsible for monitoring the progress of the plan using the parameters and the monitoring strategy provided by the consultant (Figure 5.4). The traditional view of farm management (Boehlje & Eidman, 1984; Downey & Erickson, 1987) also considers decision making, implementation, and monitoring as the responsibility of the farm managers. Threshold levels can be used to identify potential problems, but because growers lack expertise in integrating the use of the common pest control method (e.g. use of chemicals) with *Encarsia*, the consultant may be contacted for advice on the solutions. The consultant then has to gather information to confirm that a problem exists (validation), followed by diagnosing the actual cause of the problem before designing the best way of overcoming the problem. During the control process, the consultant is also responsible for providing the clients with information so that they can understand the nature of the problem and the reasons for particular curative strategies. The effectiveness of the solutions designed is determined by the consultants' ability to make appropriate diagnosis and assessment of the problems (Peacock & Smart, 1995; Mellinger, 1996; Newton *et al.*, 1996). The presence of a design phase in the control process proved that Wright's (1985) broad definition about control function in management was accurate. Throughout the control process, continuous design of corrective actions may be needed as new and unpredictable circumstances unfold.

As suggested by Boehlje and Eidman (1984), the corrective actions may occur in the form of plan modifications or use of contingency plans. However, how these modifications can be conducted or how the contingency plans are used to solve the problems are not mentioned in detail by the authors. In this study, it was found that modifications to the preventative IPM strategies are conducted by the consultants using decision rules. Contingency plans are used normally after the consultants have provided additional details regarding the use of chemicals and their relation to other pest control methods which are being used by the grower at the same time. Decision rules are used also to determine the most appropriate strategy among the contingency plans.

As in the planning stage, growers are responsible also for making the decision about the implementation of the curative strategies designed by the consultants. However, at this stage, the consultants may take bigger role in making the decisions, compared to their role in the growers' decision making during the planning process. Such a role has been performed by Britain's consultants also, particularly in relation to decisions concerning sprays (Errington, 1984). Overall, the general control process is similar to that in the farm management literature (Boehlje & Eidman, 1984; Downey & Erickson, 1987), except for the shared responsibilities and the interactions in the validation and information provision phases, which are required for a client/consultant process such as this.

5.2.2 IPM STRATEGIES FOR GREENHOUSE TOMATOES

In this section, aspects and components of IPM strategies designed by the consultants are compared to those derived from the literature review and those included in the New Zealand official IPM manual for greenhouse tomatoes.

COMPARISON WITH IPM LITERATURE

The IPM strategies designed by the consultants for greenhouse tomato growers represent the basic three components of IPM strategies found in most IPM definitions (e.g. Stern *et al.*, 1959; Whitby *et al.*, 1988; Arntzen & Ritter, 1994), which are: integration of various pest control strategies, use of monitoring in pest control decision making, and ensuring favourable economic and ecological consequences.

As reported by Pedigo (1995), IPM strategies consist of preventative and intervention (curative) measures. Such measures were also found to make up the IPM strategies designed by the consultants. The consultant's preventative IPM strategies integrate the use of *Encarsia*, environmental strategies, cultural practices (e.g. use of bumblebees for pollination, deleafing, and layering), a sanitation programme, a spray programme, the use of resistant varieties (when applicable), a monitoring strategy, and contingency plans. These strategies are designed by the consultants during the planning process. The curative IPM strategies integrate the modifications of the preventative IPM strategies and use of contingency plans. This may result in the use of high *Encarsia* introduction rates, chemical applications, environmental strategies, and cultural practices, to solve the pest problems. These strategies are designed during the control process, as problems unfold.

In Section 2.8.1.1, derived from various IPM literature, four categories of information which a consultant will require from growers in order to design the IPM strategies, were proposed. The four categories are: facility (of the greenhouse), crop production practices, human resource, and financial resource. The consultant collects information in three categories: the greenhouse (or the facility), the cropping system (crop production practices), and the client (human resource). Only Case Study Two collects financial information about the client's budget allocation for pest control. However, this information is included as part of the client category. The consultants use little information about the client's financial situation because such information relates more to the client's overall business, and is not exclusively related to IPM. Although the total information collected by the consultants is similar to that advocated in Section 2.8.1.1, the way in which it is classified under the major category headings differed somewhat. For example, Bot (1992), Spriegel (1992), Clouaire *et al.* (1996) suggested that information about the client's spray programme should be allocated under the cropping system. The consultants however, include this information as part of the greenhouse category because of its effect on the cladding material quality and persistence period. In addition, the consultants also seek information about the client's expectations and discuss them with the client so that they are achievable given his/her circumstances.

It was proposed that IPM strategies for greenhouse tomatoes should consist of aspects of greenhouse environment (environmental control and sanitation), crop production strategies (selection of media and variety, crop duration, planting date, use of pest-free seeds, plant density, nutrition, irrigation, and training systems), pest and beneficial organisms (use of beneficial organisms and chemicals), and external environment (external hygiene, and preparation for external threat such as neighbours' crop activity and change in weather pattern). While aspects of greenhouse environment, pest and beneficial organisms, and external environment are included as part of the IPM strategies by the consultant, the crop production strategies are excluded by the consultants because they are designed as part of the crop management system, and are not exclusively designed for IPM. That is, these are aspects of good crop management practice and are the same whether a grower is using conventional pest control methods or IPM strategies.

COMPARISON WITH THE OFFICIAL IPM MANUAL FOR GREENHOUSE TOMATOES

Although IPM research in New Zealand commenced in 1981, and followed with the active promotion of IPM strategies for greenhouse tomatoes since 1991, the IPM manual for greenhouse tomatoes has been revised only once, in 1995. Since then, no updated version of the manual has been published to incorporate new research findings about IPM strategies for greenhouse tomatoes, despite the importance of the greenhouse tomato industry in New Zealand. This may be the reason for a large difference between the recommendations provided by the consultants and those suggested in the IPM manual. The official IPM manual for greenhouse tomatoes (Martin, 1995), covers only the use of *Encarsia*, environmental control, plant management, and spray pesticide application, whereas the strategies designed by the consultants integrate additional aspects and details of pest control management for greenhouse tomatoes.

The major difference between the consultants' IPM strategies and those in the IPM manual is that regarding the *Encarsia* introduction rate. In the manual, only one rate of *Encarsia* introduction, 1 per m^2, is recommended throughout the season. In contrast, the consultants use decision rules, incorporating 7 to 8 factors before coming up with appropriate introduction rates (Section 4.1.2.2 A and 4.2.2.2 A). The important factors used by the consultants are: type of crop, greenhouse age, crop age, whitefly population levels, the ability to heat, season, stud height, and persistence period. The decision rules developed by the consultants are based on experience, knowledge, discussions with other IPM experts, and reading IPM-related literature. The consultants recommend a different *Encarsia* introduction rate for different situations which are classified on the basis of the 7 to 8 factors mentioned above. In addition, the consultants also distinguish between the initial introduction rate and the maintenance rate. The *Encarsia* rates recommended to growers vary from $1/m^2$ to $8/m^2$. Rates as low as $1/m^2$ can be used only in modern greenhouses with high stud height and good heating systems, while the high *Encarsia* rate of $8/m^2$ is normally recommended for old, low stud height greenhouses with inadequate heating. An inundation rate may also be used to control whitefly populations if the grower is a risk taker, or if suggested by a consultant who has relatively high threshold levels.

The time duration over which *Encarsia* should be introduced is not influenced by the factors mentioned in the IPM manual (the ability to heat, season, crop duration, and cropping system). Instead, the consultants use the sustainable level of whitefly parasitism to determine when to stop introducing *Encarsia* or whether it is still necessary to keep introducing the beneficial organisms. In most cases, this is until four weeks prior to pulling out the crop. Despite the differences between the *Encarsia* strategies designed by the consultants and those suggested in the IPM manual, similar factors such as season and the persistence period, are used by the consultants to determine the start of *Encarsia* introduction. The presence of pests other than whitefly does not influence the start of *Encarsia* introduction, as long as they cause problems only in some hotspot areas in the greenhouse.

The other preventative IPM strategies are designed to ensure that the crop and beneficial organism growth are maintained and at the same time, reduce the risk of pest attacks/infestations. As in the manual, prevention of diseases is conducted through environmental control and preventative sprays. A list of pesticides, as included in the IPM manual, is given to clients as part of their contingency plans prior to the implementation of preventative IPM strategies. Because the IPM manual is out of date, information about newer IPM-friendly chemicals such as pymetrozine, fenbutatin-oxide, and *stobilurus tenacellus* fungicides, is not available through the manual. The use of such IPM-friendly chemicals is critical in IPM if the use of inundation rates is unacceptable for growers for whatever reasons. For the monitoring strategy, the consultants provide recommendations similar to that in the IPM manual, such as what and when to monitor, frequency of monitoring and some threshold levels. These parameters are selected to reflect the actual conditions of the crop-pest-natural enemy dynamics (Mellinger, 1996).

The curative IPM strategies are provided by the consultants to clients as a result of plan modifications or providing more details for the contingency plans. Plan modifications normally relate to the alteration of the *Encarsia* introduction rates or of the environmental set points to accommodate changes in the whitefly-*Encarsia* population balance or weather patterns. The curative IPM strategies designed by the consultants for whitefly problems may range from do nothing (if the whitefly population is still below the threshold levels), to the use of high *Encarsia* introduction rates (by doubling the previously low rates or using inundation rates) and spray applications. The appropriate curative strategies are determined using decision rules, and are affected by the client's risk perception of the problems. The IPM manual does not mention the use of high *Encarsia* introduction rates to control whitefly problems. Instead, the manual provides only recommendations regarding the use of pesticides when *Encarsia* is present in the greenhouse. Such gradual recommendations to solve whitefly problems are difficult to apply from the manual alone since they require on-going information transfer about the trend in the whitefly population, and hence can be best provided by a two-way communication such as a consultancy service, instead of a one-way communication as in the IPM manual.

Contingency plans are used if certain pest threshold levels are exceeded. Unlike in the IPM manual, where a list of pesticides is given for growers to choose as curative actions, the consultants use decision rules to determine the appropriate curative strategies for a given problem. The consultants tend to start with curative strategies which do not upset the beneficial organisms, and which target localised infected areas first. This concurs with Klassen's (1979) and Peacock and Smart's (1995) suggestions about intervention strategies. The effectiveness of the curative strategies is evaluated at the end of the season, normally during an informal discussion. Therefore, the final evaluation parameters are not planned formally, as suggested by Peacock and Smart (1995) to be included as part of the monitoring strategy. Such final evaluation parameters are not provided in the IPM manual either.

CHAPTER SIX

CONCLUSIONS

The main objective of the study was to investigate the processes consultants use to assist greenhouse tomato growers in the planning and control of IPM. Specifically, the study aims to: review the literature on the planning and control, consultancy, and IPM strategies for greenhouse tomatoes; develop an IPM consultancy processes model, comprised of the planning and control stages, used by the consultants in assisting their greenhouse tomato clients; identify factors considered important by consultants when developing IPM strategies for their greenhouse tomato grower clients; and to compare the IPM strategies designed by the consultants with those published in the IPM manual.

A multiple case study research design was selected as the method to achieve the research objective. This chapter outlines the conclusions from the study and is divided into three sections, a discussion of the main findings of the research, an assessment of the method used in the study, and finally, suggestions for future research.

6.1 MAIN FINDINGS

The main findings of the study can be separated into three sections. The first two sections discuss the IPM consultancy processes, which can be separated into the physical activities and the planning and/or control processes. Finally, the key findings about the IPM strategies which the consultants advocate for greenhouse tomato growers are presented.

PHYSICAL ACTIVITIES

Both greenhouse consultants studied for the thesis undertake similar physical activities. The physical interactions involve telephone conversations and field visits, each can be conducted for the planning or control purposes. Such differentiation in the visit purpose has not been reported in the previous farm management consultancy literature (McCosh, 1995; Rogers, 1995; Rogers *et al.*, 1996; Williams, 1997; Gray *et al.*, 1999). The phases within the physical process conducted by the consultants are similar to those reported in the literature for farm management consultants, although different terms have been used to describe the various activities in the process. Some differences in the physical activities however, were identified. Greenhouse consultants do not undertake observation of the district in their pre-visit stage because unlike farms, horticultural businesses are smaller and not visible from road. Both greenhouse consultants use additional communication tools during the control stage, Case Study One uses a newsletter, while Case Study Two uses Email. In contrast to farm management consultants' clients, greenhouse tomato growers do not normally make the decision regarding the implementation of IPM strategies while the consultants are still in the property. This may be because the decision to shift dependence from chemical to IPM is seen as quite daunting for some growers, and thus requires more time before a decision is made. Both greenhouse consultants left the property after providing the clients with the key changes which they had proposed during the visit, thus saving themselves considerable report preparation time, while most farm management consultants prefer to send their clients formal reports of the visit.

PLANNING AND CONTROL PROCESSES

The planning and control framework enables an understanding of the processes greenhouse consultants use to provide IPM strategies which are tailored to the client's situation to be developed. The consultants acknowledged the importance of rapport to build a trusting relationship which enables the exchange of information. The consultancy processes at both stages starts by gathering information from the clients. During the planning stage, information gathering is used by the consultant to provide an understanding of the client's systems for the purpose of designing IPM strategies him/her. However, during the control stage, this is used to identify, validate, and make appropriate diagnoses and assess the problems faced by the grower.

An important finding in this study is the acknowledgement of three phases during the planning and control processes which have not been reported in the previous farm management consultancy literature. The first of three is the presence of "provision of information" phase throughout the planning and control processes. This step is critical in IPM consultancy because of the complex nature of IPM, and since growers are often considered to lack the specific IPM knowledge which would enable them to undertake their own IPM planning and control. The second phase is the use of "screening" by the consultant during the planning process to ensure the development of favourable attitudes toward IPM before proceeding to designing the preventative IPM strategies. Third, the use of a "validation" phase during the control process to confirm the existence of the problems for further diagnosis and problem assessment. McCosh (1995), Rogers *et al.* (1996), and Gray *et al.* (1999) failed to identify the validation phase explicitly, although they implied that the farm management consultants postulated hypotheses about the problems and gathered information to confirm their existence.

As with farm management consultants, the strategies provided by the greenhouse consultants to the client are tailored to the client's situation. However, instead of narrowing down the possible solutions, each greenhouse consultant has a single template plan, which he modifies using decision rules to come up with the appropriate IPM strategies for the client. Unlike in farm management consultancy, where clients may take part in providing possible solutions, due to the complex nature of IPM this is not the case in IPM consultancy. A monitoring strategy and contingency plans are provided by the consultant as part of the preventative IPM strategies. There was no mention of either monitoring strategy or the use of contingency plans in the farm management consultancy literature (McCosh, 1995; *Roger et al.*, 1996; Gray *et al.*, 1999). Furthermore, the study also identified an additional role of clients, aside from making the decisions and implementing them, as reported in the previous farm management consultancy literature. The additional role of clients in IPM consultancy is to undertake the monitoring activities during the control stage. This activity is vital to IPM strategies as a basis for pest control decision making during the control stage.

Compared to the traditional view of planning and control processes in the farm management literature (e.g. Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987), significant differences were found in the planning and control stages in the consultancy processes. The traditional theory assumes the farm manager is the problem owner, who is responsible for planning, implementation, and control. Since the consultant is seen as an outsider by the client, who is the problem owner, the need for the inclusion of interactive phases throughout the planning and control processes arises. In this study, throughout the consultancy processes, these roles and responsibilities are shared between the consultant and the client. During the planning process, the consultant is responsible for understanding the client's system in order to provide IPM strategies tailored to the client's circumstances. In order to do this, the consultant needs to gather information from the clients, provide IPM-related information, and screen the clients, before designing the strategies. The client is responsible for providing the consultant with the information he needs, understanding the consultant's explanations in order to make decisions regarding IPM implementation, and implementing the strategies. Following the implementation, during the control stage, the client needs to undertake the monitoring role, and is responsible for informing the consultant about the results which are causing concern. At this stage, the consultant is responsible for providing information regarding the cause and effects of the problems, and designing the curative strategies to solve the problems. These responsibilities are carried out by gathering information from the clients, validating it, and making an appropriate diagnosis. The joint roles and responsibilities of consultants and their clients during planning and control have not been reported in the traditional farm management literature.

Unlike in the traditional planning process (Boehlje & Eidman, 1984; Wright, 1985; Downey & Erickson, 1987), where farm managers generate possible solutions, analyse them, and finally select the best option(s), the greenhouse consultants use decision rules to modify their IPM template to come up with the best possible preventative IPM strategies to be implemented in the client's property. A similar approach is used by the greenhouse consultants during the control stage to modify the preventative IPM strategies, or in selecting from among the contingency plans, while little was reported in the traditional farm management literature about how modification of the current plan was conducted.

IPM STRATEGIES FOR GREENHOUSE TOMATOES

The preventative IPM strategies designed by the consultants during the planning stage involve the use of *Encarsia*, environmental strategies, cultural practices, a sanitation programme, a spray programme, the use of resistant varieties, a monitoring strategy, and contingency plans. Since whitefly is the major pest for greenhouse tomatoes, the use of *Encarsia* becomes the key strategy of IPM for greenhouse tomatoes. Other strategies, which are used to provide a favourable environment for the crop and beneficial organisms, but which do not favour the development of pests are proposed. Major differences were found between the consultants' IPM strategies, particularly in relation to *Encarsia*, with those published in the IPM manual. The fact that the manual has been revised only once, in 1995, meant that newer research findings, which are important to growers, were not incorporated into the manual.

Various *Encarsia* introduction rates are recommended by the consultants, depending on the type of crop, greenhouse age, crop age, whitefly population levels, the ability to heat, season, stud height, and chemical persistence period. These factors are structured into a decision tree in order for the consultant to come up with the appropriate *Encarsia* introduction rates. The introduction rates can be classified as the initial rates and maintenance rates, which differ from the single *Encarsia* rate suggested in the IPM manual for use in all situations throughout the season. The lowest initial *Encarsia* rate ($1/m^2$) is suggested by Case Study One for tomatoes grown in modern greenhouses with high stud height and good heating systems, while the highest initial rate ($8/m^2$) is normally recommended by Case Study Two for old, low stud height greenhouses with inadequate heating. However, the consultants differ in their approach to using the *Encarsia* rates. Case Study One prefers to start with a low level of *Encarsia* for 2 to 4 weeks, and then increases the rate and maintain it until a sustainable level of parasitism is achieved. In contrast, Case Study Two starts with a high level of *Encarsia* for 6 to 10 weeks, and then decreases the rate and maintains it until a sustainable parasitism level is achieved. The time duration over which *Encarsia* needs to be introduced is determined by the achievement of a sustainable level of whitefly parasitism.

Most pest problems are dealt with by either modifying the preventative IPM strategies or by providing more detail to the contingency plans. Plan modifications are conducted by altering either the *Encarsia* introduction rates or the environmental set points to accommodate changes in the whitefly-*Encarsia* population balance or weather pattern. Contingency plans are used if certain pest threshold levels are exceeded. The curative IPM strategies for whitefly problems vary from doing nothing, to increasing the *Encarsia* rates, and the use of chemicals. The strategies used depend on the pest monitoring results. In contrast, the manual recommends only the use of chemicals to deal with increased trends in whitefly populations. The consultants tend to start with curative strategies which do not upset the beneficial organisms, and start in localised infected areas. If chemical application is unavoidable, then preference is given to the use of IPM-friendly products. The effectiveness of both the preventative and curative strategies is evaluated at the end of the season.

The results highlight the inadequacies of the IPM manual for practical implementation by greenhouse tomato growers. Such general recommendations in the IPM manual for greenhouse tomato growers may lead to failure if growers depend solely on its content. A more detailed IPM manual, which allows for the specific circumstances in greenhouse tomato growers' properties, is required to assist growers in the adoption of IPM strategies.

In conclusion, the overall objective of the study was achieved through the achievements of the four specific objectives targeted in the beginning of the study. The literature on the planning and control, consultancy, and IPM for greenhouse tomatoes was reviewed in Chapter Two. However, because of the shift in the focus of the study due to the emergence of several important aspects of the planning and control and consultancy processes, literature from these domains was added toward the end of the study. As a result, a less detailed review was conducted for the planning and control and consultancy processes. The study was able to develop general consultancy processes models at the planning and control stages of IPM. In addition, the study also identified the important factors used by the consultants when tailoring their template IPM strategies, which is useful in providing comparisons with the strategies suggested in the IPM manual.

6.2 ASSESMENT OF THE METHOD

The method used to achieve the objectives of this study was a multiple case study, involving two expert greenhouse consultants. The case study approach suggested by Yin (1994) was followed. The literature on the consultancy, planning and control, and IPM domain was reviewed. Cases were then selected, and an interview protocol was developed using the literature. Data for the thesis was collected using semi-structured interviews (six interviews for each consultant), field observations (two with Case Study One and one with Case Study Two), and documentation of related materials. The verbatim transcripts of the recorded interviews and field notes were qualitatively analysed using the NUD-IST software. Similarities and differences between the two case studies were compared and contrasted, and a general model for each of the planning and control processes was synthesised. Finally, a comparison of the results of the study with the literature was conducted.

The case study method was found to be the appropriate method to obtain the in-depth information about the planning and control processes used by the consultants. Such detailed information could not have been obtained through other research methods such as a survey or archival analysis. Limited literature was available on how consultants assist greenhouse tomato growers in the planning and control of IPM. As such, the literature provided limited guidance in relation to sample size, and the researcher underestimated the complexity of the problem domain. As a result, two case studies were selected rather than one. In hindsight, and given the complexity of the problem domain, the researcher now believes that a single case study design should have been adopted because there was insufficient time to conduct a full investigation of the control process. Alternatively, a multiple case study design could have been adopted, but to investigate the planning process only.

In addition, there was a problem of focus in relation to the literature review. Initially, emphasis was given to IPM, and therefore, considerable time was spent on this area. However, as more interesting information on consultancy and planning and control emerged from the interviews, the need to expand the relevant literature on planning and control and consultancy arose towards the end of the study. The limited time available at this stage meant, however, that it was not possible for finer revisions to the literature review to accommodate unexpected findings arising from the study to be conducted. In hindsight, a less detailed literature review should have been undertaken prior to data collection and then further literature should have been identified and reviewed as relevant areas emerged from the study. This problem is one identified in exploratory qualitative research areas where often areas of interest which were not predicted at the start of the data collection process, emerge throughout the interview process (Gummeson, 1991; Dey, 1993). Thus, the nature of the qualitative research which occurred in this study created a problem in balancing the IPM and management domains, as the latter domain tended to be overshadowed by the IPM strategies themselves, which were initially the centre of attention in the study.

The combination of interviews, field observations, and documentation provided an excellent source of information regarding the topic being studied. Having the transcripts ready and summarised prior to the subsequent interviews provided a useful source of follow-up questions. Furthermore, issues which were covered with one consultant, but were overlooked during an interview with the other consultant, could be covered in the following interview. Although most data were collected during the interviews, field observations were particularly useful to confirm some of the interview findings and provide information about the physical process conducted by the consultants during a field visit. In addition, documentation provided useful records of the documents used by the consultants in the planning and control processes. The documents also showed the formalised and personalised form of the IPM strategies submitted to the clients.

The use of NUD-IST was found to be very useful in categorising and classifying the large amount of data in the transcripts. However, a considerable amount of time was required to undertake the process. The cyclical process of description, classification, and connection (Dey, 1993) was found to occur in tandem. When describing or summarising the transcripts, categories and linkages were identified. The classification process identified further linkages and this improved the description. However, failure to conduct detailed and in-depth analysis using NUD-IST after each interview, meant that some information, which could have been gathered during the following interview, was not covered. Problems occurred due to the time constraint, which prevented the formal connection process between the categories (Dey, 1993) using the intersect index search facility in NUD-IST. This problem can be attributed to sample size and, in hindsight, the selection of a single case study as opposed to a multiple case study design would have overcome this problem.

Despite the constraints and shortcomings in conducting this multiple case study, this method was considered appropriate for achieving the objectives of the study, although to a certain extent, depth was sacrificed at the expense of breadth (Patton, 1990).

6.3 SUGGESTIONS FOR FUTURE RESEARCH

As mentioned earlier, due to the exploratory nature of the study, the researcher was not able to predict accurately the time required to conduct a multiple case study of the processes consultants use to assist greenhouse tomato growers in IPM planning and control. Therefore, a further investigation of the planning and control processes used by greenhouse consultants could be carried out. If time had permitted, several areas identified in this study could have been investigated in more depth, particularly in the control area. An area in the planning stage which may require further investigation is the use of decision rules (other than the ones used for determining the *Encarsia* strategy) in other preventative IPM strategies such as environmental control and preventative spraying. In addition, four areas in the control process could be further investigated. These include: the types of information which the consultants collected during information gathering, the validation process, the use of decision rules in making the diagnoses and assessments of the problems, and the role of decision rules in modifying preventative IPM strategies.

Similar research could also be conducted by comparing the planning and control processes used by expert and novice private consultants to assist greenhouse tomato growers in IPM issues. Comparing experts and novices will provide insights into the role of knowledge (Cooke, 1992) and experience (Winkles, 1992) in dealing with IPM issues. In addition, it may also be worth studying the differences in the IPM strategies, particularly in relation to use of beneficial organisms, between private consultants and beneficial organism representatives. Such a study may identify the extent of the adviser's independence in providing IPM-related recommendations.

The study also identified large differences between the IPM strategies provided by the consultants and those in the IPM manual, particularly regarding the use of *Encarsia* as the key strategy of IPM for greenhouse tomatoes. More detailed recommendations, which might play an important role in determining the success or failure of IPM strategy implementation in greenhouse tomatoes, were not provided in the manual. This might lead to the failure of IPM if growers depended solely on the manual. More in-depth research into the technical IPM-related recommendations may lead to the development of an applicable and more useful IPM manual for greenhouse growers. In addition, such an in-depth research may also lead to the development of a computerised decision support system, which could be developed to incorporate the various factors affecting *Encarsia* introduction rates.

Another area for further research is to conduct a similar study on other greenhouse crops such as cucumbers or capsicums. The official IPM manuals for these crops were published in 1993 and 1994. However, as for tomatoes, these manuals may need to be tailored to a grower's circumstances. Because these two popular greenhouse crops have different major pests from tomatoes, it is likely that consultants may use different decision rules to determine the appropriate strategies for pest control.

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Appendix 1 Summary of IPM manual for greenhouse tomatoes
Source: Martin, N. 1995. Integrated pest management for greenhouse tomatoes.

Whitefly

Greenhouse whitefly is a major pest in greenhouse tomatoes in New Zealand, and is currently controlled by *Encarsia formosa*. Before introducing *Encarsia*, whitefly must be kept undetectable during propagation and after planting out by:

- controlling weeds outside the greenhouse 3-4 weeks before pulling out old crops;
- when pulling out old crops, prevent as many whitefly as possible from escaping;
- removing all whitefly from the empty greenhouse;
- preventing whitefly from getting onto the seedlings;
- covering the door and vents with fine mesh netting after planting out;
- spraying the plants if whitefly are seen.

It is important to monitor the crop throughout the whole season, however the most important time to monitor adult whitefly is during winter and early spring. They can be monitored by counting and recording the number of adult whitefly seen in each row when growers are working the top of the crop. The appearance of many adult whitefly can be predicted 4-6 weeks before they are seen.

It important to always start with very low numbers of whitefly. The target number of whitefly before introducing *Encarsia* is as follows:

- If planning to introduce *Encarsia* during propagating or soon after planting: adult whitefly < 1 per 20 plants.
    * In districts where tomato stemborer is absent and thrips control to prevent bronze top is not required, *Encarsia* can be introduced as soon as possible with the rate of 1 *Encarsia*/m^2/week.
        ⇒ If the crops are heated and layered, *Encarsia* is released until plants are stopped or tipped (about 25 introductions), or wait until spring and start about 1 August if greenhouse is unsuitable during winter.
        ⇒ For summer planting and short crop. *Encarsia* is released for 12 weeks.
        ⇒ For winter and spring planting, and short crop, *Encarsia* is released for 9 weeks.
- If planning to introduce *Encarsia* after plants reach the 5th flowering, then:
    * During propagation, keep adult whitefly < 1 / 100 plants,
    * Until 2nd truss flowering, keep adult whitefly < 1 / 50 plants,
    * Between 2nd and 5th truss flowering, keep adult whitefly < 1 / 20 plants

- * In districts where tomato stemborer is present or thrips control is required.
  - ⇒ Introduction during propagation until the 2nd truss is flowering, whitefly numbers must be very low. If whitefly are seen in the crops, spray straight away with the spray used for control of onion thrips and tomato stemborer.
  - ⇒ Introduction during the next three weeks, if adult whitefly > 1 /20 plants, spot spray with *Methomyl* four times 3-4 days apart.
  - ⇒ Introduction when the 5th flowering: 1 *Encarsia*/m^2/week. The period of introduction is the same as in the district without tomato stemborer.
- If planting a 10-12 months crop in late summer or autumn, try for even lower numbers of whitefly.

After *Encarsia* introduction, it is still possible to use pesticides to reduce high numbers of adult whitefly by spraying the area causing concern. However, care should be taken because most pesticides are harmful to *Encarsia*. Repeated frequent pesticide application is harmful to *Encarsia*, therefore fewer applications are recommended if whitefly numbers are low and percent parasitism is high. Details of the active ingredients can be found in Table 2.2.

Two-spotted mite

Two-spotted mite is controlled with *Phytoseiulus persimilis*. The predators should be introduced at the rate of 4/m^2 once the symptoms appear. The bean leaves bearing predators from the package should be spread evenly through the crop by placing the bean leaves onto the tomato leaves.

Other pests

Aphid is controlled either by pesticides or by expecting natural immigration of parasites. Caterpillar can be controlled with biologically-based pesticides which contain *Bacillus thuringiensis*. Application is usually needed from January to April, every 2-3 weeks. The frequency should be increased to once every 2 weeks in the presence of tomato fruit worm. Fungus gnats (sciarid flies) are more likely to infect the roots during propagation. Drenching soil with diazinon is needed if there are 5 larvae per young plant. Spiders can cause problems for bumble bees because of their webbing. However, since all pesticides for spider control are harmful to *Encarsia* and *P. persimilis*, spraying should be conducted before the introduction of natural enemies, if a spider problem is anticipated.

Thrip control action with insecticides should be applied regularly during propagation and until the 2nd truss flowering. Pesticides effective on western flower thrip will likely to control onion thrip as well, because the former is resistant to many pesticides while the latter is not. If growers plan to start *Encarsia* between 2nd and 5th truss flowers, only Methomyl can be used to control onion thrip. Tomato stemborer is controlled with regular application of pesticides until 2nd truss flowering, because little is currently known about them. It may be possible to delay spraying until the 1st truss flowering. As in onion thrips control, only Methomyl can be used between 2nd and 5th truss flowers.

Diseases

Fungicide resistance management strategy should be applied to ensure effective disease control. Growers are suggested to use mainly protectant fungicides and save the at-risk fungicides for critical occasions.

Botrytis, the major disease in greenhouse tomatoes, may be sprayed locally on the infected part with concentrated dichlofluanid without harming *Encarsia*. Environment control by keeping the plants dry at night, which has been discussed in the Diseases Section in the literature review, is recommended to reduce the risk of Botrytis infection. Pesticide resistance management strategy for *Botrytis* includes:

- the use of environment control as a priority;
- training of plants to allow good air movement and, easy and effective pesticide application;
- the use of protectant fungicides regularly before *Botrytis* appear;
- the use dicarboximides fungicides only early in crop development or very early in *Botrytis* outbreak. A maximum of 3 applications of these fungicides per crop is recommended;
- the use of benzimidazoles once only because of widespread resistance problem to this group, and their harmfulness to *P. persimilis*;
- preventing the use of fruit-setting sprays. If unavoidable, the spray must not contain a dicarboximide or benzimidazole fungicides.

Didymella stem canker, which has symptoms similar to *Botrytis*, and early and late blight are controlled with fungicides. To avoid resistance of late blight on metalaxyl, it must not be used more than 3 times per crop, and during the period of crop growth only. Leaf mould can be controlled by managing the greenhouse environment such as keeping the plants dry at night, and preventing long periods of high humidity, or with fungicides.

Bacterial diseases should be prevented by keeping humidity low, avoiding overhead irrigation, stopping water leaks and drips, and snapping laterals and leaves rather than pinching or cutting. All infected plants (except by stem bacteriosis and tomato pith necrosis) should be removed. Internal stem rot can be prevented only by growing strong plants. In tomato canker, it takes several weeks for the disease to show up. Therefore, finding one infected plant will mean that others will have been infected too, particularly along the row. In this case, it is recommended that the row is quarantined and managed by one person only with separate cutting tool and gloves. Infected plants should be destroyed. That person then, should wash down thoroughly before moving to uninfected plants.

Bumblebees

Once bumblebees are used to assist in the pollination of greenhouse tomatoes, care should be taken in controlling tomato stemborer, thrip, and whitefly. Insecticides used to control thrip and tomato stemborer are harmful to bumblebees, and therefore the introduction should be delayed until the danger from the pests has passed. Growers are recommended to discuss their whitefly control with their supplier before introducing bumblebees.

Appendix 2 Interview questions sent to the consultants.

First interview

A. The consultant
1. Could you please provide a brief overview of your background since you left high school?
2. What is your speciality area?
3. How many clients do you have?
4. What are the ranges of your clients in terms of property size, crops, technology, etc.?
5. From what regions do they come from?
6. What type of work/service do you provide for your clients, and time as a percentage of the year spent on each of these?
7. What percentage of your work is related to IPM?
8. What crops do you cover?
9. What percentage of your clients uses IPM systems?
10. What is the percentage of your greenhouse tomato grower clients that use IPM?
11. How did you start getting involved in IPM?
12. What kind of services do you offer in IPM area?
13. What are your sources of knowledge about IPM?

B. IPM and consultancy - general
1. How do you yourself define IPM?
2. Why do you think IPM was introduced into New Zealand?
3. How has it been promoted to growers?
4. What horticultural industries are currently adopting IPM?
5. Do you think there is adequate support for IPM?
6. How specialised are the consultants in New Zealand?
7. How many of them (%) have expertise in IPM? And for greenhouse crops?

C. The greenhouse tomato industry and IPM
1. How big is the greenhouse tomato industry in New Zealand, in terms of the number of growers?
2. Where are the major areas of tomato growing in New Zealand?
3. What are the typical/range of greenhouses used to grow tomatoes in New Zealand?
4. What do you think about the progress in the rate of IPM adoption among greenhouse tomato growers since it was first introduced?
5. Why do you think that some greenhouse tomato growers are interested in IPM, while others are not? What do you think are limiting them to adopt it in their greenhouses?

D. The consultant and IPM for greenhouse tomatoes
1. What type of greenhouse tomato growers usually needs your assistance in IPM?
2. At what stage of plant growth do you think that you are most needed by these growers?
3. At what stage of IPM adoption do you think that you are most needed by these growers?
4. What area of IPM is the most difficult for greenhouse tomato grower clients? Why?

Second interview
1. Let's say that a client came to you and said that he wanted to grow tomatoes using IPM strategies for the next season. What would be your first step to do?
2. Is there any attribute of your client that you think is important for you to know before starting designing specific IPM strategies for him? Could you please list them and tell me why they are important?
3. Is there any attribute of yourself as consultant that was taken into account?

4. How would you determine (what factors do you consider to determine) that IPM strategies are suitable or unsuitable for his particular circumstances or should he use IPM just for half of the season?
5. To what extent do you design the IPM strategies for your clients (strategic, tactical, or operational level)?
6. How detail is your IPM strategies design for a particular grower (incl. daily, weekly, monthly activities)?
7. What are the main factors do you consider when designing IPM strategies for your clients?
8. Could you please provide some more details on each of these factors?
9. Once you have designed the strategies for this particular client, is there any possibility that you would change or modify the strategies at some stage later on during the season?
10. If yes, what circumstances could lead to these modifications?
11. What is the role of your client when you design IPM strategies for him (to what extent does your client is involved in the design process)?
12. After finishing the design, to what extend do you involve in the implementation of the design?
13. How do you monitor whether the strategies are running well or not? What parameters do you use and when to use them?
14. How do you deal with unexpected event (e.g. extreme outside temperature)? How do you determine which control measures should be taken to overcome the problem? What parameters do you use to make that decision?
15. Do you give your client scenarios of possible situations that might occur?
16. At the end of the season, how do you determine whether the IPM strategies had performed well or not? What parameters do you evaluate?

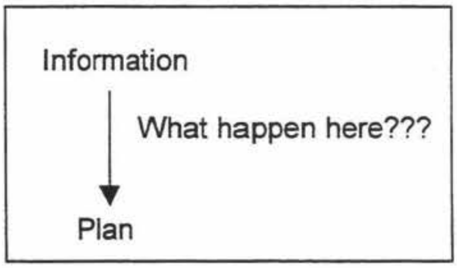
Third interview

📠: Please see the attachment (hierarchy of information gathered from the client) sent through fax.

1. What do you think about this outline of your consultancy process with client? Would you like to make any comment on it?
2. Do you think it really represents what actually happens in practice?
3. Is there any variation in the order of the stages in the process?
4. Based on our last interview, it seems that there is some sort of screening process happen on the phone to identify whether they are just curious, interested, or really serious before you put more effort on them and visit them on the field. Could you please explore more about this stage?
5. How long does this first phone call last usually?
6. How often do you receive phone calls from growers who are just curious about IPM?
7. Do your clients usually make up their minds about adopting or rejecting IPM on their first phone call with you? If not, who usually makes the initiative to find out the decisions (next phone call)?
8. How long is the average time gap between the first phone call and the first visit?
9. What is the role of information you provide for the grower on the telephone (for decision making or a bit of persuasion)? Could you please give some examples of which one is used for which?
10. Based on our last interview, you mentioned that for new clients, you still gather some more information in the field. Is there any difference between the information you gather through telephone and field visit?

   📠 What is the nature of the difference? Could you please point in this hierarchy which one is gathered on the phone and which one is collected in the visit?

11. Among the hierarchy that I have written (see the fax document) based on our previous interview:
    - Is there any other factor that you would like to add, that has not been mentioned before?
    - What do you think about the hierarchy? Can you suggest another way to arrange this information hierarchically?
12. What is this information used for? Which ones are really affecting your IPM strategies design and which ones are just put as mental notes?
13. When you design the IPM strategies for the grower, do you based in on a some sort of template plan that you just personalise for each grower (give the grower plan for the whole season in the beginning) or do you plan the strategies in accordance with the learning process of the client (plan gradually)?
14. What are the components of your? Is there any order & priority among the components? What about the range of time of when each component must be conducted?
15. Template: Is there any variation in your plans (sets of template plans) that is ready to be modified according to the client's attributes? How many template plans do you have?
    Learning: What levels of grower's learning stage are there? What indicators do you use before you proceed to the next stage of the plan?
16. Based on the information you gathered before, how do you use it to come up with a plan for a client? How do you work through the factors in the information hierarchy (decision rules)?



Fourth interview

[Please refer to the decision making tree sent through fax to your office]

1. Could you please comment on the decision making tree developed based on our last interview? Do think it represents your decision making rules?
2. How old are these 'new' and 'old' plastic greenhouses?
3. How long is the withholding/persistence period of chemical before you can start IPM?
4. Does the source of seedlings matter for you? Does it affect the decision making tree?
5. What if the previous or current crop is heavily attacked by whitefly? Is that going to make any difference to your decision making tree?
6. Do you only distinguish two seasons, winter and summer, for IPM?
7. What is the standard of your *Encarsia* introduction rate under normal circumstances?
   1.5/m2 for ... weeks ⇒ at the first truss
   then...
8. Is the standard rate the same regardless of the crop stage when IPM starts?
9. What happen after the 'Start IPM' boxes in the decision making tree?
10. How are the disease and other pest pressures going to affect this decision tree?
11. The second decision tree based on our last interview is for the growers to make up their mind about implementing IPM or not. Could you please comment on this?
12. What are your standards of performance for IPM-grown greenhouse tomatoes?
13. Is there any control measures included in your plan? If there are, what are they?
14. When does the grower need to measure them?

Fifth interview

1. What would you do if after the *Encarsia* has established, then suddenly there's an increase in whitefly population?
2. To what extend is your involvement in the control stage after IPM has been implemented? What is your role in this stage?
3. Could you please describe the process you go through during this control stage with your client?
4. What are the criteria of performance that you require growers to measure, so that they can receive signals about how their IPM strategies are progressing? Discuss the monitoring table.
5. When and how often do they need to measure these parameters?
6. What tools do you suggest them to use?

Sixth interview

1. What are the parameters related to IPM in your check list that you control/inspect when visiting IPM growers? How do you do it?
2. How and when do you decide to recommend the growers to carry on or give up IPM?
3. What factors are important in making the monitoring process useful?
4. What is the difference between monitoring in summer and winter?
5. Do you think your control strategies are more of preventive or curative?
6. What parameters do you evaluate at the end of IPM growing season?

Appendix 3. Hierarchy of categories developed during data classification of Case Study One using NUD-IST.

Index Tree
- (1)Consultancy
  - (1 1)Subject
    - (1 1 1)IPM
      - (1 1 1 1)Interaction
        - (1 1 1 1 1)Telephone
          - (1 1 1 1 1 1)Initial calls
            - (1 1 1 1 1 1 1)Activities
              - (1 1 1 1 1 1 1 1)Initial information gathering
              - (1 1 1 1 1 1 1 2)Initial information provision
              - (1 1 1 1 1 1 1 3)Screening
              - (1 1 1 1 1 1 1 4)Appointment
              - (1 1 1 1 1 1 1 5)Initial IPM design
            - (1 1 1 1 1 1 2)Duration
            - (1 1 1 1 1 1 3)Frequency
          - (1 1 1 1 1 2)Regular calls
            - (1 1 1 1 1 2 1)Confirmation
            - (1 1 1 1 1 2 2)Problem solving
            - (1 1 1 1 1 2 3)Appointment
            - (1 1 1 1 1 2 4)Suggestion
        - (1 1 1 1 2)Field visit
          - (1 1 1 1 2 1)Activities
            - (1 1 1 1 2 1 1)Arrival
            - (1 1 1 1 2 1 2)Preparation
            - (1 1 1 1 2 1 3)Ice breaking
            - (1 1 1 1 2 1 4)Review
            - (1 1 1 1 2 1 5)Control
              - (1 1 1 1 2 1 5 1)Crop walk
              - (1 1 1 1 2 1 5 2)Suggestion
              - (1 1 1 1 2 1 5 3)Check problem
              - (1 1 1 1 2 1 5 4)Check-list
              - (1 1 1 1 2 1 5 5)Grower's opinion
              - (1 1 1 1 2 1 5 6)Problem solving
              - (1 1 1 1 2 1 5 7)Answer
              - (1 1 1 1 2 1 5 8)Neighbour
            - (1 1 1 1 2 1 6)Follow-up information gathering
            - (1 1 1 1 2 1 7)Follow-up info provision
              - (1 1 1 1 2 1 7 1)Tools
                - (1 1 1 1 2 1 7 1 1)Verbal
                - (1 1 1 1 2 1 7 1 2)Physical tools
            - (1 1 1 1 2 1 8)Screening
            - (1 1 1 1 2 1 9)Summarize
            - (1 1 1 1 2 1 10)Leaving
          - (1 1 1 1 2 2)Frequency
        - (1 1 1 1 3)Tech topic

      - (1 1 1 2)Management consultancy
        - (1 1 1 2 1)Planning
          - (1 1 1 2 1 1)Activity
            - (1 1 1 2 1 1 1)Information gathering
              - (1 1 1 2 1 1 1 1)Greenhouse
                - (1 1 1 2 1 1 1 1 1)Structure
                  - (1 1 1 2 1 1 1 1 1 1)Low stud height
                  - (1 1 1 2 1 1 1 1 1 2)High stud height
                - (1 1 1 2 1 1 1 1 2)Environmental control
                  - (1 1 1 2 1 1 1 1 2 1)Temperature
                    - (1 1 1 2 1 1 1 1 2 1 1)Heated
                      - (1 1 1 2 1 1 1 1 2 1 1 1)Adequate
                      - (1 1 1 2 1 1 1 1 2 1 1 2)Inadequate

(1 1 1 2 1 1 1 1 2 1 2)Non-heated

(1 1 1 2 1 1 1 1 2 2)Controller

(1 1 1 2 1 1 1 1 2 2 1)Computer

(1 1 1 2 1 1 1 1 2 2 2)Electronic

(1 1 1 2 1 1 1 1 2 2 3)Manual

(1 1 1 2 1 1 1 1 2 3)Venting

(1 1 1 2 1 1 1 1 2 4)Humidity

(1 1 1 2 1 1 1 1 3)Location

(1 1 1 2 1 1 1 1 3 1)Garden

(1 1 1 2 1 1 1 1 3 2)Neighbour

(1 1 1 2 1 1 1 1 3 2 1)Crop

(1 1 1 2 1 1 1 1 3 2 1 1)Onion

(1 1 1 2 1 1 1 1 3 2 1 2)Greenhouse tomatoes

(1 1 1 2 1 1 1 1 3 2 2)Schedule

(1 1 1 2 1 1 1 1 4)History

(1 1 1 2 1 1 1 1 4 1)IPM

(1 1 1 2 1 1 1 1 4 1 1)Success

(1 1 1 2 1 1 1 1 4 1 2)Failure

(1 1 1 2 1 1 1 1 4 2)Pest & Disease

(1 1 1 2 1 1 1 1 4 3)Spray

(1 1 1 2 1 1 1 1 4 3 1)What?

(1 1 1 2 1 1 1 1 4 3 2)When?

(1 1 1 2 1 1 1 1 5)Cladding material

(1 1 1 2 1 1 1 1 5 1)Plastic

(1 1 1 2 1 1 1 1 5 2)Glass

(1 1 1 2 1 1 1 1 6)Links

(1 1 1 2 1 1 1 2)Cropping system

(1 1 1 2 1 1 1 2 1)Crop age

(1 1 1 2 1 1 1 2 1 1)Young plant

(1 1 1 2 1 1 1 2 1 2)Mature plant

(1 1 1 2 1 1 1 2 2)Variety

(1 1 1 2 1 1 1 2 2 1)Type of plant

(1 1 1 2 1 1 1 2 2 1 1)Vegetative

(1 1 1 2 1 1 1 2 2 1 2)Generative

(1 1 1 2 1 1 1 2 2 2)Crop duration

(1 1 1 2 1 1 1 2 2 2 1)Short

(1 1 1 2 1 1 1 2 2 2 2)Long

(1 1 1 2 1 1 1 2 2 2 3)Semi

(1 1 1 2 1 1 1 2 3)Media

(1 1 1 2 1 1 1 2 3 1)NFT

(1 1 1 2 1 1 1 2 3 2)Bag

(1 1 1 2 1 1 1 2 4)Links

(1 1 1 2 1 1 1 3)Grower

(1 1 1 2 1 1 1 3 1)Expectation of IPM

(1 1 1 2 1 1 1 3 1 1)Family health

(1 1 1 2 1 1 1 3 1 2)Market

(1 1 1 2 1 1 1 3 1 3)Chemical dislike

(1 1 1 2 1 1 1 3 2)Experience

(1 1 1 2 1 1 1 3 2 1)New

(1 1 1 2 1 1 1 3 2 2)Experienced

(1 1 1 2 1 1 1 3 3)Attitude toward IPM

(1 1 1 2 1 1 1 3 4)Policy on chemical control

(1 1 1 2 1 1 1 3 4 1)Routine spray

(1 1 1 2 1 1 1 3 4 2)Use thresholds

(1 1 1 2 1 1 1 3 5)Goal

(1 1 1 2 1 1 1 3 6)Marketing policy

(1 1 1 2 1 1 1 3 6 1)Where?

(1 1 1 2 1 1 1 3 6 2)Market requirements

(1 1 1 2 1 1 1 3 7)Innovativeness

(1 1 1 2 1 1 1 3 7 1)Source of information

(1 1 1 2 1 1 1 3 7 2)Interest on new things

(1 1 1 2 1 1 1 3 7 3)Risk perception

- (1 1 1 2 1 1 1 3 8)Links
- (1 1 1 2 1 1 2)Provision of information
  - (1 1 1 2 1 1 2 1)Encarsia
    - (1 1 1 2 1 1 2 1 1)Topic
    - (1 1 1 2 1 1 2 1 2)Method
  - (1 1 1 2 1 1 2 2)Spray
  - (1 1 1 2 1 1 2 3)Whitefly
  - (1 1 1 2 1 1 2 4)Cost
  - (1 1 1 2 1 1 2 5)Support
  - (1 1 1 2 1 1 2 6)Bumblebees
- (1 1 1 2 1 1 3)Validation
- (1 1 1 2 1 1 4)Design
  - (1 1 1 2 1 1 4 1)Pollination
  - (1 1 1 2 1 1 4 2)Monitoring strategies
    - (1 1 1 2 1 1 4 2 1)Encarsia
    - (1 1 1 2 1 1 4 2 2)Insects
      - (1 1 1 2 1 1 4 2 2 1)Whitefly
      - (1 1 1 2 1 1 4 2 2 2)Russet mite
      - (1 1 1 2 1 1 4 2 2 3)Caterpillar
      - (1 1 1 2 1 1 4 2 2 4)Stemborer
      - (1 1 1 2 1 1 4 2 2 5)Thrip
      - (1 1 1 2 1 1 4 2 2 6)Aphid
      - (1 1 1 2 1 1 4 2 2 7)Spider mite
      - (1 1 1 2 1 1 4 2 2 8)Sciarid fly
    - (1 1 1 2 1 1 4 2 3)Diseases
      - (1 1 1 2 1 1 4 2 3 1)Botrytis
      - (1 1 1 2 1 1 4 2 3 2)Leaf mould
      - (1 1 1 2 1 1 4 2 3 3)Dydimella
      - (1 1 1 2 1 1 4 2 3 4)Blight
        - (1 1 1 2 1 1 4 2 3 4 1)Early blight
        - (1 1 1 2 1 1 4 2 3 4 2)Late blight
    - (1 1 1 2 1 1 4 2 4)Crop management
      - (1 1 1 2 1 1 4 2 4 1)Direct
        - (1 1 1 2 1 1 4 2 4 1 1)Deleafing
        - (1 1 1 2 1 1 4 2 4 1 2)Layering
      - (1 1 1 2 1 1 4 2 4 2)Indirect
        - (1 1 1 2 1 1 4 2 4 2 1)Nutrition
          - (1 1 1 2 1 1 4 2 4 2 1 1)Self monitoring
          - (1 1 1 2 1 1 4 2 4 2 1 2)Lab test
        - (1 1 1 2 1 1 4 2 4 2 2)Pollination
        - (1 1 1 2 1 1 4 2 4 2 3)Root health and vigour
        - (1 1 1 2 1 1 4 2 4 2 4)Irrigation
    - (1 1 1 2 1 1 4 2 5)Tools
    - (1 1 1 2 1 1 4 2 6)Environment
      - (1 1 1 2 1 1 4 2 6 1)Temperature
      - (1 1 1 2 1 1 4 2 6 2)Humidity
      - (1 1 1 2 1 1 4 2 6 3)CO2
    - (1 1 1 2 1 1 4 2 7)Threshold levels
      - (1 1 1 2 1 1 4 2 7 1)Pests
        - (1 1 1 2 1 1 4 2 7 1 1)Whitefly
        - (1 1 1 2 1 1 4 2 7 1 2)Caterpillar
        - (1 1 1 2 1 1 4 2 7 1 3)Stemborer
        - (1 1 1 2 1 1 4 2 7 1 4)Thrip
      - (1 1 1 2 1 1 4 2 7 2)Diseases
      - (1 1 1 2 1 1 4 2 7 3)Factors
        - (1 1 1 2 1 1 4 2 7 3 1)Grower
          - (1 1 1 2 1 1 4 2 7 3 1 1)Grower's risk perception
          - (1 1 1 2 1 1 4 2 7 3 1 2)Grower's comfortability
          - (1 1 1 2 1 1 4 2 7 3 1 3)Grower's experience
        - (1 1 1 2 1 1 4 2 7 3 2)Parasitism
        - (1 1 1 2 1 1 4 2 7 3 3)Crop age
          - (1 1 1 2 1 1 4 2 7 3 3 1)Young

(1 1 1 2 1 1 4 2 7 3 3 2)Mature
(1 1 1 2 1 1 4 2 7 3 4)Whitefly trend
(1 1 1 2 1 1 4 2 7 3 5)Greenhouse
(1 1 1 2 1 1 4 2 7 3 5 1)Greenhouse structure
(1 1 1 2 1 1 4 2 7 3 5 2)Greenhouse location
(1 1 1 2 1 1 4 2 7 3 6)Temperature
(1 1 1 2 1 1 4 2 7 3 7)Other pests
(1 1 1 2 1 1 4 3)Crop management
(1 1 1 2 1 1 4 3 1)Deleafing
(1 1 1 2 1 1 4 3 2)Layering
(1 1 1 2 1 1 4 3 3)Truss pruning
(1 1 1 2 1 1 4 3 4)Truss arches supporting
(1 1 1 2 1 1 4 3 5)Harvesting
(1 1 1 2 1 1 4 3 6)Spacing
(1 1 1 2 1 1 4 3 7)Nutrition
(1 1 1 2 1 1 4 3 8)Propagation
(1 1 1 2 1 1 4 3 9)Irrigation
(1 1 1 2 1 1 4 4)Encarsia
(1 1 1 2 1 1 4 4 1)Greenhouse
(1 1 1 2 1 1 4 4 1 1)Age of the greenhouse
(1 1 1 2 1 1 4 4 1 2)Stud height
(1 1 1 2 1 1 4 4 1 2 1)Low stud height
(1 1 1 2 1 1 4 4 1 2 2)High stud height
(1 1 1 2 1 1 4 4 1 3)Cladding material
(1 1 1 2 1 1 4 4 2)Crop age
(1 1 1 2 1 1 4 4 2 1)<2nd truss
(1 1 1 2 1 1 4 4 2 1 1)Source
(1 1 1 2 1 1 4 4 2 2)>2nd truss
(1 1 1 2 1 1 4 4 3)Whitefly population
(1 1 1 2 1 1 4 4 3 1)Low whitefly population
(1 1 1 2 1 1 4 4 3 2)High whitefly population
(1 1 1 2 1 1 4 4 3 2 1)IPM clean-up
(1 1 1 2 1 1 4 4 4)Temperature control
(1 1 1 2 1 1 4 4 4 1)Adequate temperature
(1 1 1 2 1 1 4 4 4 2)Inadequate temperature
(1 1 1 2 1 1 4 4 4 3)Over-heated
(1 1 1 2 1 1 4 4 5)Season
(1 1 1 2 1 1 4 4 5 1)Winter
(1 1 1 2 1 1 4 4 5 2)Summer
(1 1 1 2 1 1 4 4 5 3)Spring & Autumn
(1 1 1 2 1 1 4 4 6)Spray history
(1 1 1 2 1 1 4 4 6 1)Persistence
(1 1 1 2 1 1 4 4 6 1 1)Within persistence
(1 1 1 2 1 1 4 4 6 1 2)Over persistence
(1 1 1 2 1 1 4 4 6 2)What?
(1 1 1 2 1 1 4 4 7)Rate
(1 1 1 2 1 1 4 4 7 1)Initial
(1 1 1 2 1 1 4 4 7 2)Maintenance
(1 1 1 2 1 1 4 4 7 3)Inundation
(1 1 1 2 1 1 4 4 7 4)Hot spots
(1 1 1 2 1 1 4 4 8)Crop
(1 1 1 2 1 1 4 4 9)Others
(1 1 1 2 1 1 4 5)Environmental control
(1 1 1 2 1 1 4 5 1)Temperature
(1 1 1 2 1 1 4 5 2)Ventilation
(1 1 1 2 1 1 4 5 3)Humidity
(1 1 1 2 1 1 4 5 4)CO2
(1 1 1 2 1 1 4 5 5)Solar radiation
(1 1 1 2 1 1 5)Decision making
(1 1 1 2 1 1 6)Provision of contingency plan
(1 1 1 2 1 1 6 1)Bumblebees
(1 1 1 2 1 1 6 2)Whitefly

(1 1 1 2 1 1 6 3)Other insects
(1 1 1 2 1 1 6 4)Other diseases

(1 1 1 2 1 2)Type of plan
(1 1 1 2 1 2 1)Form of design
(1 1 1 2 1 2 1 1)Grower summary letter
(1 1 1 2 1 2 1 2)Original plan or Crop time table
(1 1 1 2 1 2 1 2 1)For new growers
(1 1 1 2 1 2 1 2 2)For experienced growers
(1 1 1 2 1 2 1 2 3)Components
(1 1 1 2 1 2 1 3)Contingency plans
(1 1 1 2 1 2 1 4)Visit report
(1 1 1 2 1 2 1 5)Verbal
(1 1 1 2 1 2 2)Level of plan
(1 1 1 2 1 2 2 1)Strategic
(1 1 1 2 1 2 2 2)Tactical
(1 1 1 2 1 2 2 3)Operational

(1 1 1 2 2)Control
(1 1 1 2 2 1)Monitoring activities
(1 1 1 2 2 1 1)Grower
(1 1 1 2 2 1 1 1)Dislike
(1 1 1 2 2 1 1 2)Time
(1 1 1 2 2 1 1 3)Reactiveness
(1 1 1 2 2 1 2)Greenhouse
(1 1 1 2 2 1 2 1)Environment
(1 1 1 2 2 2)Plan modification
(1 1 1 2 2 3)Curative action
(1 1 1 2 2 3 1)Insects
(1 1 1 2 2 3 1 1)Whitefly
(1 1 1 2 2 3 1 1 1)>10 whitefly
(1 1 1 2 2 3 1 1 2)Closer to 10 whitefly
(1 1 1 2 2 3 1 1 3)5-7 whitefly
(1 1 1 2 2 3 1 1 4)<5 whitefly
(1 1 1 2 2 3 1 1 5)Number of spray
(1 1 1 2 2 3 1 2)Russet mite
(1 1 1 2 2 3 1 3)Caterpillar
(1 1 1 2 2 3 1 4)Stemborer
(1 1 1 2 2 3 1 5)Thrip
(1 1 1 2 2 3 1 6)Aphid
(1 1 1 2 2 3 2)Diseases
(1 1 1 2 2 3 2 1)Botrytis
(1 1 1 2 2 3 2 2)Leaf mould
(1 1 1 2 2 3 2 3)Dydimella
(1 1 1 2 2 3 2 4)Blight
(1 1 1 2 2 3 2 5)Root zone diseases
(1 1 1 2 2 4)Final evaluation
(1 1 1 2 2 4 1)Cost
(1 1 1 2 2 4 2)Strategies
(1 1 1 2 2 4 3)Fruit quality & quantity
(1 1 1 2 2 5)Give-up IPM

(1 1 1 2 3)Implementation
(1 1 1 2 3 1)Expectation
(1 1 1 2 3 2)Comfortability
(1 1 1 2 3 3)Cost effectiveness
(1 1 1 2 3 4)Labour
(1 1 1 2 3 5)Experience & Support
(1 1 2)Other

(1 2)Type of service
- (1 2 1)Preferential Customer Program
- (1 2 2)One-off
  - (1 2 2 3)Fire fighting

(1 3)Consultant
- (1 3 1)Source of expertise
  - (1 3 1 1)Knowledge
  - (1 3 1 2)Experience
  - (1 3 1 3)Literature
  - (1 3 1 4)Discussion
  - (1 3 1 5)Research
- (1 3 2)Role
  - (1 3 2 1)Education
  - (1 3 2 2)Encouragement
  - (1 3 2 3)Leading
  - (1 3 2 4)Assistance
  - (1 3 2 5)Recommendation
  - (1 3 2 6)Information provider
  - (1 3 2 7)Give options
  - (1 3 2 8)Fire fighting
- (1 3 3)Skills
  - (1 3 3 1)Rapport building

(1 4)Grower
- (1 4 1)Role
  - (1 4 1 1)Make decisions
  - (1 4 1 2)Monitoring
  - (1 4 1 3)Implementation
  - (1 4 1 4)Be communicative

Appendix 4. Hierarchy of categories developed during data classification of Case Study Two using NUS-IST.

Index Tree
(1)Consultancy
(1 1)Subject
(1 1 1)IPM
(1 1 1 1)Interaction
(1 1 1 1 1)Telephone
(1 1 1 1 1 1)Initial calls
(1 1 1 1 1 1 1)Activities
(1 1 1 1 1 1 1 1)Screening
(1 1 1 1 1 1 1 2)Initial information gathering
(1 1 1 1 1 1 1 3)Initial info provision
(1 1 1 1 1 1 1 4)Appointment
(1 1 1 1 1 1 1 5)Initial IPM design
(1 1 1 1 1 1 2)Duration
(1 1 1 1 1 1 3)Frequency
(1 1 1 1 1 2)Regular call
(1 1 1 1 2)Field visit
(1 1 1 1 2 1)Activity
(1 1 1 1 2 1 1)Arrival
(1 1 1 1 2 1 2)Ice breaking
(1 1 1 1 2 1 3)Information gathering
(1 1 1 1 2 1 4)Information provision
(1 1 1 1 2 1 5)Screening
(1 1 1 1 2 1 6)Summarize
(1 1 1 1 2 1 7)Leaving
(1 1 1 1 2 1 8)Self preparation
(1 1 1 1 2 1 9)Design
(1 1 1 1 2 1 10)Validation
(1 1 1 1 2 1 11)Review
(1 1 1 1 2 1 12)Evaluation
(1 1 1 1 2 2)Frequency
(1 1 1 1 3)Email
(1 1 1 2)Management consultancy
(1 1 1 2 1)Planning
(1 1 1 2 1 1)Activity
(1 1 1 2 1 1 1)Information gathering
(1 1 1 2 1 1 1 1)Greenhouse
(1 1 1 2 1 1 1 1 1)Cladding material
(1 1 1 2 1 1 1 1 1 1)Plastic
(1 1 1 2 1 1 1 1 1 2)Glass
(1 1 1 2 1 1 1 1 2)Technology
(1 1 1 2 1 1 1 1 2 1)Controller
(1 1 1 2 1 1 1 1 2 1 1)Computer
(1 1 1 2 1 1 1 1 2 1 2)Manual
(1 1 1 2 1 1 1 1 2 2)Height
(1 1 1 2 1 1 1 1 2 2 1)< 2m
(1 1 1 2 1 1 1 1 2 2 2)> 2m
(1 1 1 2 1 1 1 1 2 3)Environmental control
(1 1 1 2 1 1 1 1 2 3 1)Humidity
(1 1 1 2 1 1 1 1 2 3 2)Heating capacity
(1 1 1 2 1 1 1 1 2 3 2 1)Degree
(1 1 1 2 1 1 1 1 2 3 2 2)Supply
(1 1 1 2 1 1 1 1 2 3 2 2 1)Limited
(1 1 1 2 1 1 1 1 2 3 2 2 2)Extra
(1 1 1 2 1 1 1 1 3)Age
(1 1 1 2 1 1 1 1 4)Location
(1 1 1 2 1 1 1 1 4 1)Address
(1 1 1 2 1 1 1 1 4 2)Area
(1 1 1 2 1 1 1 1 4 3)Neighbour

(1 1 1 2 1 1 1 1 5)History
(1 1 1 2 1 1 1 1 5 1)Property
(1 1 1 2 1 1 1 1 5 2)Spray
(1 1 1 2 1 1 1 1 5 2 1)What?
(1 1 1 2 1 1 1 1 5 2 2)When?
(1 1 1 2 1 1 1 1 5 2 3)Period
(1 1 1 2 1 1 1 2)Cropping system
(1 1 1 2 1 1 1 2 1)Previous crop
(1 1 1 2 1 1 1 2 2)Current crop
(1 1 1 2 1 1 1 2 2 1)Crop health
(1 1 1 2 1 1 1 2 2 2)What crop
(1 1 1 2 1 1 1 2 2 3)Growth stage
(1 1 1 2 1 1 1 2 2 4)Time
(1 1 1 2 1 1 1 2 3)Next crop
(1 1 1 2 1 1 1 2 3 1)What crop
(1 1 1 2 1 1 1 2 3 2)When to plant
(1 1 1 2 1 1 1 2 3 2 1)Winter
(1 1 1 2 1 1 1 2 3 2 2)Post X'mas
(1 1 1 2 1 1 1 2 4)Media
(1 1 1 2 1 1 1 2 4 1)Soil
(1 1 1 2 1 1 1 2 4 2)Hydroponic
(1 1 1 2 1 1 1 3)Grower
(1 1 1 2 1 1 1 3 1)Source of info
(1 1 1 2 1 1 1 3 2)Budget
(1 1 1 2 1 1 1 3 3)Attitudes
(1 1 1 2 1 1 1 3 3 1)Risk perception
(1 1 1 2 1 1 1 3 3 1 1)Age
(1 1 1 2 1 1 1 3 3 1 2)Understanding
(1 1 1 2 1 1 1 3 3 1 3)Experience
(1 1 1 2 1 1 1 3 3 1 4)Innovativeness
(1 1 1 2 1 1 1 3 3 1 5)Info availability
(1 1 1 2 1 1 1 3 3 2)Patience
(1 1 1 2 1 1 1 3 3 3)Try
(1 1 1 2 1 1 1 3 3 4)Detail
(1 1 1 2 1 1 1 3 3 5)Interest
(1 1 1 2 1 1 1 3 4)Reason
(1 1 1 2 1 1 1 3 5)IPM knowledge
(1 1 1 2 1 1 1 3 6)Problem solving skills
(1 1 1 2 1 1 1 3 7)Management ability
(1 1 1 2 1 1 2)Information provision
(1 1 1 2 1 1 2 1)Encarsia
(1 1 1 2 1 1 2 2)Whitefly
(1 1 1 2 1 1 2 3)Spray
(1 1 1 2 1 1 2 4)Cost
(1 1 1 2 1 1 2 5)Monitoring
(1 1 1 2 1 1 2 6)Support
(1 1 1 2 1 1 2 7)External environment
(1 1 1 2 1 1 2 8)Crop management
(1 1 1 2 1 1 2 9)Tools
(1 1 1 2 1 1 3)Screening
(1 1 1 2 1 1 4)Design
(1 1 1 2 1 1 4 1)Pollination
(1 1 1 2 1 1 4 2)Encarsia
(1 1 1 2 1 1 4 2 1)Greenhouse
(1 1 1 2 1 1 4 2 1 1)Stud height
(1 1 1 2 1 1 4 2 1 1 1)High stud height
(1 1 1 2 1 1 4 2 1 1 2)Low stud height
(1 1 1 2 1 1 4 2 1 2)Age
(1 1 1 2 1 1 4 2 1 2 1)Old
(1 1 1 2 1 1 4 2 1 2 2)Modern
(1 1 1 2 1 1 4 2 2)Rate
(1 1 1 2 1 1 4 2 2 1)Hotspot

(1 1 1 2 1 1 4 2 2 2)Initial
(1 1 1 2 1 1 4 2 2 2 1)Standard
(1 1 1 2 1 1 4 2 2 2 2)High
(1 1 1 2 1 1 4 2 2 2 3)Initial + treatment
(1 1 1 2 1 1 4 2 2 3)Factors
(1 1 1 2 1 1 4 2 2 4)Maintenance
(1 1 1 2 1 1 4 2 3)Spray history
(1 1 1 2 1 1 4 2 4)Whitefly
(1 1 1 2 1 1 4 2 4 1)High population
(1 1 1 2 1 1 4 2 4 2)Low population
(1 1 1 2 1 1 4 2 5)Season
(1 1 1 2 1 1 4 2 5 1)Summer
(1 1 1 2 1 1 4 2 5 2)Winter
(1 1 1 2 1 1 4 2 6)Heating
(1 1 1 2 1 1 4 2 6 1)Adequate temperature
(1 1 1 2 1 1 4 2 6 2)Inadequate heating
(1 1 1 2 1 1 4 2 7)Crop type
(1 1 1 2 1 1 4 2 8)Crop age
(1 1 1 2 1 1 4 2 8 1)In or near harvest
(1 1 1 2 1 1 4 2 8 2)Seedlings
(1 1 1 2 1 1 4 3)Environmental control
(1 1 1 2 1 1 4 3 1)Heating
(1 1 1 2 1 1 4 3 2)Humidity
(1 1 1 2 1 1 4 3 3)Ventilation
(1 1 1 2 1 1 4 3 4)CO2
(1 1 1 2 1 1 4 3 5)Light
(1 1 1 2 1 1 4 4)Spray program
(1 1 1 2 1 1 4 4 1)What
(1 1 1 2 1 1 4 4 2)Persistence
(1 1 1 2 1 1 4 4 3)Resistence
(1 1 1 2 1 1 4 5)Cultural practices
(1 1 1 2 1 1 4 5 1)Deleaf
(1 1 1 2 1 1 4 5 2)Irrigation
(1 1 1 2 1 1 4 5 3)Nutrition
(1 1 1 2 1 1 4 5 4)Harvesting
(1 1 1 2 1 1 4 5 5)Layering
(1 1 1 2 1 1 4 5 6)Spacing
(1 1 1 2 1 1 4 5 6 1)Winter
(1 1 1 2 1 1 4 5 6 2)Summer
(1 1 1 2 1 1 4 5 7)Screen
(1 1 1 2 1 1 4 6)Monitoring strategies
(1 1 1 2 1 1 4 6 1)Tools
(1 1 1 2 1 1 4 6 2)Encarsia
(1 1 1 2 1 1 4 6 3)Insects
(1 1 1 2 1 1 4 6 3 1)Whitefly
(1 1 1 2 1 1 4 6 3 2)Russet mite
(1 1 1 2 1 1 4 6 3 3)Caterpillar
(1 1 1 2 1 1 4 6 3 4)Stemborer
(1 1 1 2 1 1 4 6 3 5)Thrip
(1 1 1 2 1 1 4 6 3 6)Aphids
(1 1 1 2 1 1 4 6 3 7)Two-spotted mite
(1 1 1 2 1 1 4 6 3 8)Sciarid fly
(1 1 1 2 1 1 4 6 3 9)Spider mites
(1 1 1 2 1 1 4 6 4)Diseases
(1 1 1 2 1 1 4 6 4 1)Botrytis
(1 1 1 2 1 1 4 6 4 2)Leaf mould
(1 1 1 2 1 1 4 6 4 3)Didymella
(1 1 1 2 1 1 4 6 4 4)Blight
(1 1 1 2 1 1 4 6 5)Crop management
(1 1 1 2 1 1 4 6 5 1)Nutrition
(1 1 1 2 1 1 4 6 5 1 1)Lab test
(1 1 1 2 1 1 4 6 5 1 2)Self monitoring

(1 1 1 2 1 1 4 6 5 2)Irrigation
(1 1 1 2 1 1 4 6 5 3)pH
(1 1 1 2 1 1 4 6 5 3 1)Bag system
(1 1 1 2 1 1 4 6 5 3 2)NFT system
(1 1 1 2 1 1 4 6 5 4)CF or EC
(1 1 1 2 1 1 4 6 5 5)Pollination
(1 1 1 2 1 1 4 6 5 6)Crop performances
(1 1 1 2 1 1 4 6 6)Environment
(1 1 1 2 1 1 4 6 6 1)Temperature
(1 1 1 2 1 1 4 6 6 2)Humidity
(1 1 1 2 1 1 4 6 6 3)CO2
(1 1 1 2 1 1 4 6 6 4)Ventilation
(1 1 1 2 1 1 4 6 7)Root zone
(1 1 1 2 1 1 4 6 8)Threshold level
(1 1 1 2 1 1 4 6 8 1)Insects
(1 1 1 2 1 1 4 6 8 1 1)Whitefly
(1 1 1 2 1 1 4 6 8 1 2)Russet mite
(1 1 1 2 1 1 4 6 8 1 3)Caterpillar
(1 1 1 2 1 1 4 6 8 2)Diseases
(1 1 1 2 1 1 4 6 8 3)Factors
(1 1 1 2 1 1 4 6 8 3 1)Greenhouse stud height
(1 1 1 2 1 1 4 6 8 3 2)Season
(1 1 1 2 1 1 4 7)Quality system
(1 1 1 2 1 1 4 7 1)NFT or bag systems
(1 1 1 2 1 1 4 7 2)Production
(1 1 1 2 1 1 4 7 3)Crop performance
(1 1 1 2 1 1 4 8)Sanitation
(1 1 1 2 1 1 4 8 1)Clean-up
(1 1 1 2 1 1 4 8 1 1)Crop removal
(1 1 1 2 1 1 4 8 1 2)Between crop
(1 1 1 2 1 1 4 8 1 2 1)Thorough
(1 1 1 2 1 1 4 8 1 2 2)Small
(1 1 1 2 1 1 4 8 1 3)Irrigation
(1 1 1 2 1 1 4 8 2)Internal hygiene
(1 1 1 2 1 1 4 8 2 1)Foot bath
(1 1 1 2 1 1 4 8 3)External environment
(1 1 1 2 1 1 4 9)Resistant variety
(1 1 1 2 1 1 4 10)Provision of contingency plans
(1 1 1 2 1 1 6)Decision making
(1 1 1 2 1 2)Type of plans
(1 1 1 2 1 2 1)Form of plan
(1 1 1 2 1 2 1 1)Verbal
(1 1 1 2 1 2 1 2)Written
(1 1 1 2 1 2 1 2 1)Tomato blue print
(1 1 1 2 1 2 1 2 2)Spray program
(1 1 1 2 1 2 1 2 3)Nutrition
(1 1 1 2 1 2 1 2 4)Greenhouse management
(1 1 1 2 1 2 1 2 5)Koppert book
(1 1 1 2 1 2 1 3)Components
(1 1 1 2 1 2 2)Level
(1 1 1 2 1 2 2 1)Strategic
(1 1 1 2 1 2 2 2)Tactical
(1 1 1 2 1 2 2 3)Operational
(1 1 1 2 1 3)Means
(1 1 1 2 1 3 1)For experienced growers
(1 1 1 2 1 3 2)For new growers

(1 1 1 2 2)Control
(1 1 1 2 2 3)Curative actions
(1 1 1 2 2 3 1)Insects
(1 1 1 2 2 3 1 1)Whitefly
(1 1 1 2 2 3 1 2)Russet mite

(1 1 1 2 2 3 1 3)Caterpillar
(1 1 1 2 2 3 1 4)Stemborer
(1 1 1 2 2 3 1 5)Thrip
(1 1 1 2 2 3 1 6)Aphid
(1 1 1 2 2 3 1 7)Spider
(1 1 1 2 2 3 1 8)Two-spotted mites
(1 1 1 2 2 3 1 9)Sciarid fly
(1 1 1 2 2 3 2)Diseases
(1 1 1 2 2 3 2 1)Botrytis
(1 1 1 2 2 3 2 2)Leaf mould
(1 1 1 2 2 3 2 3)Didymella
(1 1 1 2 2 3 2 4)Blight
(1 1 1 2 2 5)Plan modification
(1 1 1 2 2 5 1)Cause
(1 1 1 2 2 5 2)Solutions
(1 1 1 2 2 6)Final evaluation
(1 1 1 2 2 6 1)Cost
(1 1 1 2 2 6 2)Whitefly
(1 1 1 2 2 6 3)Intervention
(1 1 1 2 2 6 4)Plan validity
(1 1 1 2 2 6 5)Grower
(1 1 1 2 2 6 5 1)Grower's improvement
(1 1 1 2 2 6 5 2)Expectation
(1 1 1 2 2 6 5 3)Health benefit
(1 1 1 2 2 7)Give-up IPM

(1 1 1 2 3)Implementation
(1 1 1 2 3 1)Budget
(1 1 1 2 3 2)Managerial ability
(1 1 1 2 3 3)Mental attitude
(1 1 1 2 3 5)Risk
(1 1 2)Others

(1 2)Consultant
(1 2 1)Source of expertise
(1 2 1 1)Knowledge
(1 2 1 2)Experience
(1 2 1 3)Literature
(1 2 1 4)Discussion
(1 2 1 5)Internet
(1 2 1 6)Research
(1 2 2)Roles
(1 2 2 1)Educate
(1 2 2 2)Encourage
(1 2 2 3)Recommend
(1 2 2 4)Information provision
(1 2 2 5)Give options
(1 2 2 6)Problem solving
(1 2 2 7)Assistance
(1 2 2 8)Decision making
(1 2 2 9)Suggestion
(1 2 3)Skills & attributes
(1 2 3 1)Rapport building
(1 2 3 2)Simplicity
(1 2 3 3)Understanding
(1 2 4)Approach
(1 3)Growers
(1 3 1)Roles
(1 3 1 1)Make decisions
(1 3 1 2)Implement
(1 3 1 3)Monitoring
(1 3 1 4)Be communicative

Appendix 5 Grower Summary Letter.

Substratus New Zealand Ltd

Specialist Horticultural Advisers

I.P.M Design for Tomato Crop

11 November, 1998

Dear Mr

Here are the key points relating to the establishment of IPM (integrated pest management) in your tomato crop. These notes should be used in conjunction with the Bio-Force/Crop & Food IPM manuals. In addition the information regarding spray compatibility is now updated and you can contact either myself or John Thompson for these.

It is recommended that you start to implement IPM in House 5 as an experiment. The crop (Red Roy) is now in their 3rd truss and is starting to stretch. Considerable leaf area will be present in 2 to 3 weeks' time potentially carrying significant levels of whitefly eggs. If introduction of Encarsia (predator wasp) is to be started then we will need to be prepared for this situation. If the introduction is delayed for any longer it would be advisable to wait until replanting in March or May 1999.

Recommendations – House 5

1. In order to provide a good environment for the predators the environment needs to be managed so that Relative Humidity is between 70-85% and temperatures between 18°C-26°C. These conditions encourage rapid multiplication of the wasp and help reduce disease risk. Excessively high temperatures (>30°C) slows wasp growth rate and can kill wasps.

2. Introduce *Encarsia* at the following programme:

Start	0 –2 weeks	3rd truss	**3.0/m²/week**
	2- 4 weeks	4th –7th truss	**4.0/m²/week**
	4 weeks +	7th truss +	to be decided

3. *Encarsia* eat the whitefly egg and crawler stages and lay their own eggs (parasitise) in the pupa (white scale) of Whitefly. As the Encarsia wasp develops it turns the white scale black. The adult Encarsia wasp emerges from the scale and flies up toward the top of the plant feeding on young whitely stages and looks to parasitise another cycle of whitefly pupa (scale). In the peak of summer when pest lifecycles are completed very rapidly it is often necessary to introduce extra predators and spray to get some knockdown of adult whitefly numbers. Be ready to increase numbers to **as high as 10/m²/week** for short periods to regain control of outbreaks.

4. To ensure that beneficial insects are not being harmed use only biologically friendly sprays. These are; Chess @ 60g /1000m² + Cittowet sticker as Whitefly (adult) control or Applaud for Whitefly pupa (scale) control. Torque or Agrimec can be used in spray bottles for spot application for Russet Mite. Pirimor @ 25g/100l for aphids, Apollo @ 40ml/100l for Two-Spotted Mite. Always conduct target/spot applications rather than broad (whole house) applications of chemical where possible.

5. The cost for Encarsia is likely to be as follows:

   - **Encarsia** @ $10/1000 for the first 4000 in a month thereafter
     $8.75/1000 for the next 4000 " " thereafter
     $6.83/1000

Note, these prices exclude postage and G.S.T. charges. I hope that this provides a good background, if you have any questions regarding the pricing contact John Thompson or Michael Surrey at BioForce (09) 294 8973.

Yours sincerely

Bryan Hart

Substratus New Zealand Ltd (025) 284 0047

wwl- Nov 98-Tomato–IPM notes 11/11

Appendix 6 Crop Time Table.

SECTION B CROP TIMETABLE

The crop timetable for "**Example**" is outlined below. Key target dates are identified for future reference and benchmarking.

MAY 98	JUNE	JULY	AUGUST	SEPTEMBER
Plant 13th	First flower open 2/6 & Bees in	Set 4th-7th truss	Set 7th-10th truss	Set 10th-11th truss
			Pick 1st truss	Pick 3rd truss
Prevacure @ planting	Fongarid old pots 3/6		Probable Apron in old pots	
Control water & CF 45/ 50 100ml/feed, 2-3/day	Control water & CF 45, raise to 110-120 ml/feed, 4-5/day	Generative regime Feed change	Less Generative regime	Balanced regime, some vegetative.
Balanced 17°/17° day/night temp.	Balanced 17°/17° day/ night temp.	Incr. Diff. 18°/16° day/night temp.	Incr. Diff. 18°/16° day/night temp.	Balanced 17°/17° day/ night temp.
String up plants end May	Twist plants	De-leaf at setting of 6th truss		
Monitor leaf mould	Monitor leaf mould	Monitor botrytis	Monitor botrytis	Monitor botrytis
Monitor Stem Borer	Encarsia in at 1 adult/ 20 plants	Encarsia at 1.5/m²/ week	Encarsia at 1.5-2.0 /m²/week	Encarsia at 1.5-2.0 /m²/week

OCTOBER 98	NOVEMBER	DECEMBER	JANUARY 99
Pick 5th-8th truss	Pick 8th-11th truss	Strip Pick first week December	HOLIDAY
		Re-plant pre-Christmas	
Probable Apron & follow-up Octave in old pots		Full hygiene programme & new media for next crop.	
Balanced water regime 150-160 ml/feed	Balanced water regime		
Some Generative 19°/16° day/ night temp.	Some Generative 20°/16° day/night temp.		
Heads out last week October			
Monitor late blight	Mmonitor late blight		
Monitor Stem Borer & looper caterpillar. Encarsia at 1.5/m²/week.	Good clean-up before final pick.		

Appendix 7 Case Study One's clean-up program.

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Clean Up Programme

At the end of a crop follow this clean up programme to reduce the risk of pest and disease transfer into the subsequent crop.

- **4-5 days before** pulling out cut plant stems
- **3 days before** pulling out spray for residual pests eg Russet mite or Whitefly
- Remove old crop and either burn or bury plant material
- Fog the greenhouse with **Formalin** at 3l /1000m^2 & close for 24hours (only if it is a single planting ie not in a mixed age house) **or** wash down with **Perocetic acid.**
- If Formalin is applied ventilate well for 48 hours before working in the house. If Perocetic acid is used work can recommence in 4 hours post application.
- If Formalin is used follow up by washing the walls, roof, floors, footpaths & pandafilm in the gullies with Virkon or Chlorine and then ventilate well.
- Steam the bags if re-using them. Less desirable is to drench with **either**; Fongarid @ 80g/ 1000m^2 **or** Benlate @ 50g plus Thiram @ 100g per 1000m^2 **or** Apron 35SD @ 110g/1000m^2.
- Flush irrigation and micro tubes with **nitric acid** @ 3l acid + 7l water. Then turn dilution pumps to maximum setting and flush drip lines. Note, don't do this if you have a mixed age planting. Plants don't grow well with pH 1.0 nutrient solution.
- **Prior to transplanting** run starter nutrient feed through irrigation at target CF to ensure bag is wet.
- **Prior to transplanting** dip all plants in the tray with **Prevacure** @ 15g/ 10l stock solution for 1 minute, then stand to drain. Note the dip should be warm (20° C) to avoid cold shock.
- Once planted feed at target CF and follow recommended watering and temperature profiles.

Substratus New Zealand Ltd - September 1998

Appendix 8 Pest Monitoring Sheet.

SECTION E PEST MONITORING SHEET

The Pest Monitoring Sheet is used to track pest populations over time and to assist in making decisions on chemical application.

DATE	ROW 1	2	3	4	5	6	TOTAL	Encarsia Rate/m^2	Truss # Position of tag	Tag from ? trusses from top of plant	% parasitism

Appendix 9 TechTopic.

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Summary of Effect of night humidity on the vegetative growth and mineral composition of tomato and strawberry plants

These notes are made from the research paper by; J.H. Choi and others, College of Agriculture, Chonnam National University, South Korea, Scientia Horticulture 70(1997) pages 293-299.

Key Points:

- **A short period (30days) of high night humidity (90-95%) for tomato resulted in increased shoot dry weight and leaf area.**
- **The concentration of five major nutrients (N, P, K, Ca & Mg), were all reduced under high night humidity conditions. The calcium content in the younger leaves was the most severely affected.**
- **The strawberry plants increased concentration of major nutrients under high night humidity, including calcium in younger leaves.**
- **Transpiration and root pressure influence calcium uptake.**
- **Plants react differently to high day humidity versus high night humidity.**

Discussion:

High humidity conditions are common when exposed to periods of warm wet weather or when inadequate heat and poor ventilation combine together. This can release excess moisture as the air reaches its Dew Point and condensation occurs (as the air cools). High humidity environments often result in Blossom End Rot occurring, however it also has a significant impact on the whole plant biology. J.C. Bakker showed that high humidity negatively affected yield and quality of cucumbers (1987) & tomato (1990).

Transpiration (water sucked up through the roots and stem as leaves dry), is the main driving force for calcium transport to many plant organs. However root pressure which develops under conditions of high air humidity also supplies calcium to some plant organs, especially in strawberry. Guttation (water exuding out of tips of leaves) as a result of root pressure can be seen in tomato and cucumber when night humidity is high, but it is considered that the mechanism is not sufficient to supply the plants needs. In addition root restriction (smaller pot sizes) reduces root uptake ability.

Plants (cucumber – Bakker 1987) respond differently to high day humidity than to high night humidity. During the day, water status influences stomatal conductance (leaf pore opening) and hence CO_2 uptake. Changes under high day humidity take considerable time to occur compared to very short time frames with high night humidity. This means that different plant mechanisms are involved.

In summary, unless a vegetative growth habit is sought, high night humidity should be avoided. Addition of heat (energy) inputs and regular (controlled) venting can reduce the risk of loss of yield or fruit quality of tomato and cucumber.

Summarised by: Substratus New Zealand Ltd – Tech Topic #2- Night humidity & growth of tomato