DIAGNOSIS OF THE CONVENTIONAL KIWIFRUIT PRODUCTION SYSTEM AND PRELIMINARY DESIGN OF INTEGRATED KIWIFRUIT PRODUCTION IN GREECE

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Abstract

The kiwifruit sector in Greece has been well established and disseminated as a promising alternative option to the traditionally grown crops since the mid 80s. However, it faces agronomic, ecological and socio-economic problems which to a large extent are due to unequal emphasis given on maximizing gross yields while little attention is thrown to exportable fruit quality and size, agroecosystemic functions and processes and the regional environment.

The main objective of the study is to carry out an extended diagnosis of the current kiwifruit production situation in Greece in order to reveal the magnitude of the problems and shortcomings and form the basis of a preliminary design of an integrated kiwifruit production system. The diagnosis is focuses on three problematic areas which are seen as threats to the industry. These are:

- Inefficient nutrient utilisation
- Botrytis rot incidence during cool storage
- Frost damage on Greek kiwifruit vines

The Buwalda-Smith model, developed in New Zealand, estimates nutrient uptake based on target fruit yield and is used in this study to estimate NUE in order to illustrate the inefficiency or not of the applied nutrients. Besides, the QUEFTS system is proposed as a way of eliminating the drawbacks of the Buwalda-Smith model. Botrytis rot incidence is currently seen as the most important disease in Greek kiwifruit orchards and potential control methods are proposed in addition to the chemical control. Moreover, frost damage in orchards of C. Macedonia is diagnosed and the etiology and applied control methods are presented and evaluated. Finally, a preliminary design based on the concept of the prototyping methodology is illustrated.

In general, the diagnosis emphasises the over-supply of phosphorus due to the wrong type of fertiliser used by the farmers and is shown by its low NuE. Botrytis rot incidence is a postharvest disease and great efforts are given in Greece on experimenting on the post-harvest physiology of the fruit while little attention is thrown on the development of the fungus during the growing season. Finally, frost damage is a product of wrong design of kiwifruit producing areas and inadequate development of effective control methods.

Two visits were contacted to Greece (June and November 1997) where several contacts with academic experts and fruit industry specialists were made in the hope of getting a closer approach on the current problems. Further, correspondence with academics in New Zealand helped to gain better insight on techniques applied in other countries.
Acknowledgements

I would like to thank my supervisor Dr. W.A.H. Rossing for his active personal support and guidance but also for the many fruitful discussions we had during all the stages of the thesis. Besides, thanks are due to Dr. M. van Ittersum for supervising my work at the last phase.

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Chapter 1

Introduction

1.1 Kiwifruit production in Greece

Greece is a mountainous country and agricultural land represents only 30% of the total area. Fruit orchards cover 25% of the cultivated land and fruit industry is very important for the country and the European Union (Kukuryannis and Vasilakakis, 1995).

The kiwifruit was introduced in Greece in 1971 and very quickly its cultivation spread in many areas over the whole country because of the very high prices in the European market. However, the kiwifruit well-adapted mainly in Pieria area, central Macedonia, N. Greece and in a few other regions of the country providing favourable soil and climatic conditions (Fig. 1.1). In recent years, the cultivation area covers approximately 4,000 ha, a figure which has not been increased since 1990 (fig. 1.2) due to the low prices and the difficulty the farmers face in selling the produce. After 1980 Greece started producing considerable quantities of kiwifruit (fig. 1.3) and more recently the kiwifruit production varies between 35,000 and 50,000 tons from year to year. Although domestic kiwifruit consumption is increasing the primary marketing concern is exportation mainly to EU (Kukuryannis and Vasilakakis, 1995; E. Sfakiotakis, 1997, pers. comm.).

Prices of the kiwifruit have experienced great changes over the last 13 years, fluctuating at as high as 200 drachmas/kg in 1986 to the very low 30-50 drachmas/kg in 1992, a year considered as the worst year in the history of the kiwifruit industry (Fig. 1.4). Similarly to other main producing countries, the area has been stabilized to nearly 4,000 hectares since 1990 (Fig. 1.2). This reduction in acreage has been produced in areas where lower yields were obtained and whose main competitive advantage was an early harvest in the season compared with New Zealand, particularly relevant in the first phase of kiwifruit exporting from Greece.

The massive production of 1992/93 (fig. 1.3) together with a world over-supply of all fruits put Greek growers under great stress. Since then it is widely recognized by all stakeholders that the price crisis is due to unequal emphasis given on maximizing gross yields while little attention is thrown to exportable fruit quality and size, agroecosystemic functions and processes, and the regional environment. The question, whether or not the kiwifruit sector faces agronomic, ecological and socio-economic problems, and if so to what extent, remains unclear. As the Hellenic kiwifruit industry is heading for increased exportable yields, current conventional practices should be diagnosed and converted to reconcile with issues such cost effective production, integrated nutrient, water and chemical inputs management.
Introduction

Figure 1.1. Contribution as % of the main regions of Greece to the total kiwifruit production of the country.
(Kukuryannis and Vasilakakis, 1995)
Introduction

1.2 Motivation and thesis outline

The kiwifruit plant was chosen for this thesis because the author's family runs a kiwifruit enterprise at Nestos valley, Greece. The main objective of the study is to carry out a diagnosis of the current kiwifruit production situation in Greece in order to reveal the magnitude of the problems and shortcomings and form the basis of the design of an integrated kiwifruit production system (chapter 5). Two visits to the main kiwifruit producing areas in Greece were held during the development of the thesis, in order to gain a better insight on which problematic areas are currently seen as threats to the industry (append. I and II). Thus, the diagnosis is focused on three problematic areas and these are:

⇒ Inefficient nutrient utilization (chapter 2)
⇒ Botrytis rot incidence during cool storage (chapter 3)
⇒ Frost damage on Greek kiwifruit vines (chapter 4)

In chapter 2, a static model which estimates nutrient uptake by the mature vines, named the Buwalda-Smith model, is used to construct nutrient balances at the regional level. Further, postharvest grey mould decay of kiwifruit has become a serious disease in Greece in recent years, mainly due to the extension of the trade period by extending the storage life of the fruit. Moreover, the spreading of kiwifruit cultivation was not accompanied by planning or consideration of the actual environmental needs of the plant, resulting in establishment of orchards in cooler areas of northern Greece with frequent frosts, like Imathia and Pella.

Figure 1.2 Cultivated area in ha with kiwifruit in Greece during the last 15 years (Hellenic Ministry of Agriculture, 1997)
Figure 1.3  Kiwifruit production and exportation during the last years in Greece (1994 exportation data not available).  
Kukuryiannis and Vasilakakis, 1995)

Figure 1.4  Kiwifruit prices achieved over the last 13 years (1995-1997 prices derived from the visits).  
(Manolopoulos, 1995; Author’s data based on growers’ interviews)
Figure 1.5 and 1.6 illustrate two problem trees as a way of visualizing the causes and effects of *Botrytis* rot incidence and frost damage on kiwifruit vines, respectively. The problem trees help to show the nature of the respective problem more systematically. At each level the problems shown can be turned into objectives and at each level going down the tree the problems and objectives become more specific. This provides a checklist for identifying options to meet the objectives, and can be used to help establish priorities for different options (Norton and Mumford, 1993). At the most specific levels in Fig. 1.5 some options become clear immediately: remove the necrotic tissues during growing season; look for effective biological suppression on *B. cinerea* populations; provide a disease monitoring system; avoid the use of MBC fungicides. Looking at the other branches of the problem at the same level shows the wider dimensions of the problem which must also be solved. For instance, the relative importance of postharvest handling difficulties and bulk cool storage of kiwifruit must be determined, and they may need to be solved to achieve a significant decrease in incidence of *Botrytis*. In chapter 3, the problem of increased incidence of *Botrytis* is investigated according to the structure of the corresponding problem tree and integration of control methods is proposed according to current knowledge and available techniques. Similarly, in chapter 4, the etiology and implications of frost damage on kiwifruit production is investigated and a visualization of the causes and effects is given in fig. 1.6.

Within the course of diagnosis several design elements can be revealed, therefore, in chapter 5 a preliminary design of an integrated kiwifruit production system is presented where prefatory objectives in areas of environment, public health and nature are explicitly addressed in addition to economic objectives.
Figure 1.5 A problem tree for the Botrytis rot incidence in Greek kiwifruit orchards. At each level the problems can be turned into objectives and at each level going down the problems and objectives become more specific (after Norton & Mumford, 1993).

**Effects**

- Cost of applications exceeds loss from rot
- Image of fruit on local and distant markets is damaged
- Increased price of final, marketable product
- Direct loss of the product

**Causes**

- Development of resistant strains
- Pesticide residues on fruits
- Shippers lack criteria on which fruit to sell first
- Additional costs for re-sorting and re-packing
- Loss of fruit qualitative characteristics

**Increased incidence of Botrytis**

- Ineffective pre-storage curing of the fruit
- Postharvest handling difficulties
- Fruits from orchards with history of high rot incidence are not stored separately
- High N:Ca ratio in the kiwifruits

**Increased preharvest fungicide applications**

- Outbreak of postharvest decay by gray mould
- Premature ripening of healthy fruit in CA
- Rotting and early softening of infected fruit

**Induced ethylene production by the fruit even at storage temperatures**

**High source of inoculum**

- Intensive preharvest fungicide applications
- Problems with refrigeration control
- Considerable fruit water loss in CA
- Rot incidence is unpredictable
- Nutrient management not adjusted for disease control

**Short delays between harvest and placement in CA**

- MBC resistant strains of B. cinerea
- Fruits stored in bulk bins in CA

**Senescence and necrotic tissues are not removed during the growing season**

- Ineffective (yet) biological suppression on B. cinerea populations in kiwi canopies
- Condensation on fruit surface
- Unstable humidity levels
- Rot incidence is highly variable both between years and orchards

**Defrost cycles result in short periods of increased temperature**

- Break downs of refrigeration units during storage

CA = controlled atmosphere
Effects

- Under-sized fruits
- Poor shoot and bud nutrition
  - Reduced bud growth
  - Reduced and non-uniform vine growth
  - Atrophied shoots
  - Undesirable growth
  - Shoots with reduced fruit numbers

Anomalies in vine performance

- Incomplete pollination
- Poor shoot and bud nutrition

Greek kiwifruit industry is shrinking

- Farmers’ risk of running out of business becomes high
- Economic return not enough to cover cost of cultivation

Very low yield attained

Cumulative effect on subsequent yields

Frost damage on kiwifruit vines

Causes

Expansion of kiwifruit cultivation without planning

- Higher market prices in the past
- Dissemination of kiwifruit culture in frost sensitive regions
- New growers weren’t alerted/advised in time

- Intensive agriculture has increased
- Hydroelectric power station in nearby river

More frequent frosts in recent years

- Changes in regional microclimate
- Late fertilisation
- Late irrigation

- Late arrival of frost control methods
- Still under experimentation

Extension of growing season

- High Sept-Oct temperatures
- Economic initiatives are inadequate
- Wind machines don’t justify their cost

Anti-frost protection is lacking

- Expensive
- Delayed and low compensation funds by the state

Inefficient anti-frost operations

- Market pressure
- The later harvest the better fruit quality achieved
References

Chapter 2

A target-oriented approach for the diagnosis of nutrient inputs in kiwifruit production systems in Greece

2.1 Introduction

In spite of the increasing importance of kiwifruit as a commercial crop in Greece, relatively little research has been conducted on the inputs and outputs in terms of energy, pesticides, organic/inorganic fertilisation and irrigation water which makes difficult to define the magnitude of current and potential shortcomings. Reported data show that many of the kiwifruit farmers in Northern Greece supply more nutrients than the quantities needed, which according to Sale (1985) are 170 kg N, 56 kg P and 150-200 kg K per ha. In particular, Jastas and Therios (1995) reported that about 40% of the kiwifruit growers in Pieria district apply 200-400 N kg/ha while the majority applies 100-400 N kg/ha. Concerning phosphorus more than 40% of the farmers apply 100-150 P kg/ha every year, while a small percentage does not apply P at all or applies a small quantity every 2-3 years. With respect to potassium fertilisation 40% of the growers apply 200-300 K kg/ha and the vast majority applies between 100-400 K kg/ha.

The variation in nutrient inputs leads to question whether fertilisers are applied effectively and the recommended levels of N,P,K are sufficient to replace the nutrients removed from the orchards each year. When imbalances exist between imports and exports of nutrients in kiwifruit systems, either the soil nutrient store is depleted or nutrients accumulate in the soil or are emitted to the environment. To express the degree of utilisation of nutrients in kiwifruit production systems the concept of 'efficiency' is used. In this section, an attempt is made to estimate the Nutrient Utilisation Efficiency\(^1\) using a model developed by Buwalda and Smith (1988) in New Zealand and the QUEFTS system (Quantitative Evaluation of the native Fertility of Tropical Soils) developed by Janssen et al. (1990).

2.2 Nutrient balances for Greek kiwifruit orchards

2.2.1 Buwalda-Smith model

The annual uptake of nutrients by a perennial plant depends on the nutrient accumulation in the current season’s growth and the redistribution of stored nutrients from transient and perennial parts (Smith et al., 1988). Buwalda and Smith (1988) developed a static model which consists of a set of simple equations with the aim to estimate uptake by the mature vines. Figure 2.1 shows the nutrient fluxes as it is

\(1\) Nutrient Utilisation Efficiency is defined as the ratio of yield to actual nutrient uptake (Janssen, 1997).
described in the model. Total vine dry weight, annual growth and nutrient uptake are estimated, based on target fruit yield and a standard distribution of dry matter amongst the various vine components (fig. 2.2). Nutrients taken up may be distributed to perennial, transient and deciduous components. Recycling occurs from transient components depending on vine management techniques whereas deciduous organs may be exported from the orchard (harvested fruit) or cycled as senesced plant material. The soil nutrient pool represents the balance of external inputs and subsequent losses and the annual growth cycle and nutrient uptake initiates after fruit harvest. In the model, the amount of fertiliser input required to meet crop demand is calculated assuming a fixed nutrient utilisation efficiency computed from historical data. In this study, only the uptake for each nutrient is estimated to construct the nutrient balances.

Figure 2.1. Schematical representation of directional flows of nutrients within the kiwifruit ecosystem (Based on Buwalda and Smith 1988)

sh = shoot, lt = laterals, le = leader, st = stem, rs = structural roots, ft = fruit, rf = fibrous roots, lf = leaves

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Diagnosis of nutrient inputs in kiwi orchards

Figure 2.2. Distribution of total vine dry weight for a mature kiwifruit vine producing 30 t/ha/yr (Smith et al., 1988).

Table 2.1. Proportion of the total quantity of nutrients remobilised from leaves by fruit harvest (Smith et al., 1987).

<table>
<thead>
<tr>
<th>NUTRIENTS</th>
<th>PERCENTAGE OF NUTRIENT REMOBILOISED FROM LEAVES BY FRUIT HARVEST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>leaf from fruiting shoot</td>
</tr>
<tr>
<td>Potassium</td>
<td>37</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>22</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>14</td>
</tr>
<tr>
<td>Sulphur</td>
<td>5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>5</td>
</tr>
<tr>
<td>Calcium</td>
<td>4</td>
</tr>
</tbody>
</table>

2.2.2 Model equations

Nutrient uptake is related to current season growth subtracting the nutrients resorbed from leaves during senescence and from shoots retained at winter pruning. The proportion of the total quantity of nutrients remobilised from leaves is illustrated in Table 2.1. For mature vines without nutrient disorders the annual nutrient uptake is estimated by:

\[ U = M(csg) + M(lt) - [f*M(sh) + R(lf)] \]  

(abbreviations are explained in Appendix A at the end of the chapter)

The nutrient quantities for each component organ, \(M(\cdot)\), are calculated by the nutrient concentration and dry weight in the various tissues at harvest. It is assumed that these concentrations (table 2.2) are not influenced by the age and productivity of the vine (Buwalda and Smith 1987) therefore nutrient quantities accumulated in various organs depend on biomass production only. According to Buwalda (1987) biomass production is correlated to fruit yield by,
Diagnosis of nutrient inputs in kiwi orchards

VDW = (FY*k) + TVDW  
(abbreviations are explained in Appendix A at the end of the chapter)

<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>ORGAN</th>
<th>ft</th>
<th>if</th>
<th>sh</th>
<th>lt</th>
<th>le</th>
<th>st</th>
<th>rf</th>
<th>rs</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>9.4</td>
<td>23.0</td>
<td>9.4</td>
<td>7.4</td>
<td>5.8</td>
<td>5.2</td>
<td>9.7</td>
<td>11.1</td>
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</tr>
<tr>
<td>P</td>
<td>1.7</td>
<td>1.6</td>
<td>1.3</td>
<td>1.0</td>
<td>0.8</td>
<td>0.7</td>
<td>1.4</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>19.2</td>
<td>15.5</td>
<td>5.8</td>
<td>4.7</td>
<td>4.5</td>
<td>4.7</td>
<td>6.1</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>2.4</td>
<td>34.1</td>
<td>5.0</td>
<td>5.7</td>
<td>5.5</td>
<td>6.5</td>
<td>8.8</td>
<td>9.2</td>
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</tr>
<tr>
<td>Mg</td>
<td>0.7</td>
<td>4.1</td>
<td>1.7</td>
<td>1.5</td>
<td>1.2</td>
<td>1.2</td>
<td>2.1</td>
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<td>S</td>
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<td>0.8</td>
<td>0.6</td>
<td>0.6</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

Buwalda and Smith (1988) measured the nutrient concentrations in table 2.2 from vines destructively harvested in the field. However, because the potassium status of the vines was low at the time of harvest (the leaves contained 15.5 g/Kg dry weight of potassium instead of the minimum recommended concentration of 20 g/Kg dry weight), the annual quantities of potassium taken up are likely to be underestimated by about 30%. As the model does not redress existing nutrient imbalances, the 20 g/kg DW leaf concentration was used in our calculations. It was found that calculated fertiliser inputs were underestimated by 4-6% (148 kg/ha instead of 140 kg/ha) and not by as much as 30% (180 kg/ha instead of 140 kg/ha) that Buwalda and Smith (1988) reported.

2.2.3 Model Results

The concept of a target-oriented approach is used (van Ittersum and Rabbinge, 1997), in which amounts of nutrients required are calculated to realise a particular yield level per hectare in the physical environment where kiwis are grown. This approach enables determination of the most efficient combination of nutrient inputs to realize a desirable fruit yield according to current level of knowledge and available techniques.

A range of fruit yields from 10 to 50 t/ha are used to generate an estimate of vine dry weight and hence nutrient uptake for each yield level. Once vine dry weight has been estimated, the model can calculate nutrient quantities in component organs using reference data shown in Table 1 for N, P, K, Ca, Mg, S and subsequently nutrient uptake is predicted.

The model equations and data from table 2.2 and figure 2.2 were transferred to a computer spreadsheet assuming that there are orchards producing the same yield every year, therefore recycling is the same each year. The results are summarised in Table 2.3 and relationships are shown in figures 2.3 and 2.4. The set of data in Table 2.3 are calculations from the spreadsheet software and are not included in the Buwalda and Smith’s paper apart from the 30 t/ha yield level. We found many discrepancies in the data shown in the paper and there is a small deviation between our calculations.
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(Table 2.4) and those in the Smith et al. (1988) paper (Table 2.5). However, the resulting uptake prediction for each nutrient is the same as Smith et al., (1988) have calculated except for potassium where the recommended leaf concentration (20 g/kg dw instead of 15.5 g/kg dw) was used. It was not possible to estimate an uptake quantity for Cl and Na because there were no data for the remobilisation proportion of these nutrients from leaves (Table 2.2).

![Figure 2.3. Relation between model estimated N, K, Mg uptakes and fresh fruit yield of mature kiwifruit orchards producing the same yield every year and being in a steady-state situation.]

![Figure 2.4. Relation between model estimated P, Ca, S uptakes and fresh fruit yield of mature kiwifruit orchards producing the same yield every year and being in a steady-state situation.]

Chapter 2
Table 2.3. Model estimates of nutrient uptake (kg/ha) at different yield levels (t/ha) for kiwifruit orchards being in a steady-state production situation. (The hatched cells represent the reference data from Smith et al. (1988))

<table>
<thead>
<tr>
<th>FRUIT</th>
<th>N UPTAKE</th>
<th>P UPTAKE</th>
<th>K UPTAKE</th>
<th>Ca UPTAKE</th>
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<td>270</td>
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</table>

Table 2.4. Model estimations of nutrient quantities (kg/ha) within component organs of mature kiwifruit vines with a fruit yield of 30 t/ha at harvest. (K cone. in leaves = 15.5 g/kg dw, value in brackets for K cone. in leaves = 20 g/kg dw).

<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>ORGAN</th>
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<th>lf</th>
<th>rf</th>
<th>sh</th>
<th>lt</th>
<th>le</th>
<th>st</th>
<th>rs</th>
<th>total</th>
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<tbody>
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<td>7.7</td>
<td>4.1</td>
<td>2.4</td>
<td>3.6</td>
<td>1.7</td>
<td>0.5</td>
<td>0.6</td>
<td>10.7</td>
<td>31.3</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>86.7</td>
<td>40(51.6)</td>
<td>10.5</td>
<td>16.2</td>
<td>8.1</td>
<td>2.9</td>
<td>4.0</td>
<td>46.0</td>
<td>214.4</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>10.8</td>
<td>88.0</td>
<td>15.1</td>
<td>14.0</td>
<td>9.8</td>
<td>3.5</td>
<td>5.6</td>
<td>61.3</td>
<td>208.2</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>3.2</td>
<td>10.6</td>
<td>3.6</td>
<td>4.8</td>
<td>2.6</td>
<td>0.8</td>
<td>1.0</td>
<td>16.7</td>
<td>43.2</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>4.1</td>
<td>10.3</td>
<td>5.0</td>
<td>2.8</td>
<td>1.4</td>
<td>0.4</td>
<td>0.5</td>
<td>18.7</td>
<td>43.1</td>
</tr>
<tr>
<td>Cl</td>
<td></td>
<td>13.5</td>
<td>34.3</td>
<td>5.5</td>
<td>3.4</td>
<td>1.4</td>
<td>0.5</td>
<td>0.5</td>
<td>15.3</td>
<td>74.4</td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.7</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>2.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Table 2.5. Typical nutrient quantities within component organs of kiwifruit vines with a fruit yield of 30 t/ha at harvest (Smith et al., 1988). The hatched cells indicate calculations errors found.

<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>ORGAN</th>
<th>ft</th>
<th>lf</th>
<th>rf</th>
<th>sh</th>
<th>lt</th>
<th>le</th>
<th>st</th>
<th>rs</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td>44.1</td>
<td>59.3</td>
<td>19.7</td>
<td>26.3</td>
<td>12.7</td>
<td>3.8</td>
<td>4.5</td>
<td>76.7</td>
<td>236.9</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>8.0</td>
<td>4.1</td>
<td>2.3</td>
<td>3.6</td>
<td>1.7</td>
<td>0.5</td>
<td>0.6</td>
<td>9.6</td>
<td>30.9</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>90.8</td>
<td>40.0</td>
<td>11.9</td>
<td>16.2</td>
<td>8.1</td>
<td>2.9</td>
<td>4.0</td>
<td>44.0</td>
<td>215.7</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>11.2</td>
<td>88.0</td>
<td>15.8</td>
<td>14.0</td>
<td>9.8</td>
<td>3.6</td>
<td>5.6</td>
<td>60.5</td>
<td>208.3</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>1.7</td>
<td>10.6</td>
<td>3.7</td>
<td>4.8</td>
<td>2.6</td>
<td>0.8</td>
<td>1.0</td>
<td>16.3</td>
<td>41.3</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>2.7</td>
<td>10.3</td>
<td>5.3</td>
<td>2.8</td>
<td>1.4</td>
<td>0.4</td>
<td>0.5</td>
<td>20.0</td>
<td>54.5</td>
</tr>
<tr>
<td>Cl</td>
<td></td>
<td>13.4</td>
<td>34.3</td>
<td>5.0</td>
<td>3.4</td>
<td>1.4</td>
<td>0.5</td>
<td>0.5</td>
<td>22.0</td>
<td>50.3</td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>2.8</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Chapter 2
From the data presented nutrient balances are constructed for kiwifruit orchards in New Zealand (table 2.5). Furthermore, a recent study for kiwifruit production in Greece (Kukuryiannis and Vasilakakis, 1997) shows that farmers are satisfied with a yield of 25 t/ha. Therefore, based on current conditions nutrient balances for Greece can also be estimated (table 2.6). The fertiliser rates in table 2.6 are average rates according to Jastas and Therios (1995) and those in table 2.7 were derived from growers interviews during the second visit to Greece in November 1997. It is shown (Table 2.6 and 2.7) that an average orchard can produce the same yield with different nutrient inputs. It was revealed from the November visit that other cultivation techniques, such as pruning and training, are equally important on influencing yield and high fertilization should not be seen as the predominant yield increasing factor.

### Table 2.5. Nutrient inputs and NUE estimated for a mature kiwifruit orchard producing 30 t ha\(^{-1}\) of fruit every year in New Zealand (hatched rows represent model estimations).

<table>
<thead>
<tr>
<th>Nutrients (kg ha(^{-1}))</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertiliser(^1)</td>
<td>170</td>
<td>56</td>
<td>175</td>
</tr>
<tr>
<td>Cycling(^2)</td>
<td>87</td>
<td>9</td>
<td>51</td>
</tr>
<tr>
<td>Atmospheric(^3)</td>
<td>31</td>
<td>0.2</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>288</td>
<td>65</td>
<td>243</td>
</tr>
<tr>
<td>Uptake(^4)</td>
<td>130</td>
<td>17</td>
<td>128</td>
</tr>
<tr>
<td>NUE</td>
<td>0.45</td>
<td>0.26</td>
<td>0.61</td>
</tr>
</tbody>
</table>

\(^1\)Recommendation of Sale (1985).  
\(^2\)Model estimations (Table 2.4 and Fig. 2.1).  
\(^3\)Data for nitrogen fixation by clovers in kiwifruit orchards (28 kg/ha/yr) and data for quantities in rainwater for New Zealand.  
\(^4\)From Table 3.  
(Based on Smith et al., 1988)

### Table 2.6. Nutrient inputs and NUE estimated for a mature kiwifruit orchard producing 25 t ha\(^{-1}\) of fruit every year in Greece.

<table>
<thead>
<tr>
<th>Nutrients (kg ha(^{-1}))</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertiliser(^1)</td>
<td>300</td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td>Cycling(^2)</td>
<td>75</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>Atmospheric(^3)</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>375</td>
<td>132</td>
<td>303</td>
</tr>
<tr>
<td>Uptake(^2)</td>
<td>112</td>
<td>14</td>
<td>128</td>
</tr>
<tr>
<td>NUE</td>
<td>0.30</td>
<td>0.11</td>
<td>0.42</td>
</tr>
</tbody>
</table>

\(^1\)Average fertiliser rates as described by Jastas and Therios (1997).  
\(^2\)Estimated by the model (Table 2.4 and Fig. 2.1).  
\(^3\)Data not available.

*Chapter 2*
Table 2.7. Nutrient inputs and NUE estimated for a mature kiwifruit orchard producing 25 t ha\(^{-1}\) of fruit every year in Greece.

<table>
<thead>
<tr>
<th>Nutrients (kg ha(^{-1}))</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer 1</td>
<td>152</td>
<td>192</td>
<td>192</td>
</tr>
<tr>
<td>Cycling</td>
<td>75</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>Atmospheric</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>227</td>
<td>199</td>
<td>245</td>
</tr>
<tr>
<td>Uptake(^2)</td>
<td>112</td>
<td>14</td>
<td>128</td>
</tr>
<tr>
<td>NUE</td>
<td>0.49</td>
<td>0.07</td>
<td>0.52</td>
</tr>
</tbody>
</table>

\(^1\) Average fertilizer rates as derived by growers interviews during the November visit to Greece. 
\(^2\) Estimated by the model (Table 2.4 and Fig. 2.1). 
\(^3\) Data not available.

2.2.4 QUEFTS approach

An attempt was made to investigate whether other studies on estimating nutrient recovery by a soil could be applied to kiwifruit. Janssen et al. (1990) have developed a system for a Quantitative Evaluation of the native Fertility of Tropical Soils (QUEFTS) using calculated yields of unfertilised maize as a yardstick. In the system a distinction is made between the potential supply and the actual uptake of a nutrient. Potential supply is defined as the maximum quantity of the fertiliser nutrients that can be taken up by the crop when all other factors are at optimum (Janssen 1997). When the supply of a particular nutrient is small in relation those of other nutrients, the whole supply of that nutrient will be taken up by the crop. When the supply of a particular nutrient is large compared to those of other nutrients, crop growth is limited by the low availability of those other nutrients and the crop cannot make use of the whole supply of the particular nutrient. Thus, the potential supply of a nutrient is the maximum quantity that can be taken up, and the actual uptake of a nutrient equals the potential supply only if all other growth conditions are optimum.

The system comprises a number of successive steps: (1) assessment of the potential supply of N, P, K on the basis of data on soil fertility parameters; (2) calculation of actual uptakes of N, P, K as fractions of the potential supplies determined in step 1; (3) designation of yield ranges as functions of the actual uptakes of NPK determined in step 2; (4) calculation of the ultimate yield estimate by combining the three yield ranges established in step 3. For steps 1 and 3 empirical relations are used whereas in steps 2 and 4 equations used in the calculations have been derived from theoretical considerations.

Application of the QUEFTS approach requires estimation of (1) potential supply of various nutrients and (2) maximum and minimum nutrient concentrations within the crop. Potential supply by a soil depends on its physical and chemical properties, therefore experimental data are needed for soils where kiwifruit vines are grown in Greece. The Buwalda-Smith model shows the relation between yield and actual uptake by the vines for each nutrient (fig. 2.3 and 2.4) but not the border lines in which each

Chapter 2
nutrient is maximally accumulated or diluted in the vines and those lines (fig. 2.3 and 2.4) lay between the two extremes. When the required data are available then it will be possible to follow the conceptual framework of Janssen et al. (1990) and show diminishing returns for a fertiliser input instead of a linear relationship. Then more realistic estimates could be made for nutrient uptake quantities and subsequent nutrient utilisation efficiencies.

2.3 Model discussion

The main drawback of the Buwalda-Smith model is the absence of diminishing returns of a fertiliser input (fig. 2.3 and 2.4). It is a linear regression relationship where nutrient uptake by the vines is determined by this year’s predicted or target yield and constant nutrient concentrations. This linearity (fig. 2.3 and 2.4) is not realistic and it is caused by the single set of nutrient concentrations measured for each vine component and the absence of ranges of concentrations for shoots, laterals, leader, fibrous and structural roots, as they have been measured for leaves and fruits and can be found in the literature. However, some conclusions can be derived from such a relationship when applied to a limited range of target yields around 30 t/ha.

The model is static and does not take into account the nutrient dynamics of the vines in time. It calculates nutrient quantities in various organ components after harvest and it gives no information about the dynamics of a nutrient during the growing season.

2.4 Conclusion

The estimates given in table 2.6 and 2.7 show that the quantity of nutrient recovered by the roots (using actual fertiliser rates) by mature vines is comparatively low (<0.50) for all nutrients in Greek kiwifruit orchards. For potassium, nutrient utilisation efficiencies of between 0.50 and 0.70 are considered as normal (Smith et al., 1988). The low NuE of phosphorus may reflect the degree of immobilisation of phosphates in Greek soils in forms less available to the plant and the generous inputs relative to the requirements of kiwifruit vines for this element (table 2.6 and 2.7). For nitrogen, leaching may be the major cause of such a low NuE by the wrong timing of nitrogen application as most of the nitrogen is taken up the first 10 weeks after bud break (Smith et al., 1988).

The nutrient balances drawn in this chapter highlight the large demand by kiwifruit vines for nitrogen and potassium. Because over 60% of the total quantity of potassium in the vines accumulates in the deciduous components (fig. 2.2 and Table 2.4), a high proportion needs to be replaced each year from fertiliser or soil reserves.

The nutrient utilisation efficiencies estimated for Greek kiwifruit orchards indicate an over-supply of nutrients (table 2.6 and 2.7). This high input of fertiliser increases the cost of fertilisation without necessarily increasing yield and contributes to the environmental pollution. It is shown from the results of the Buwalda-Smith model

Chapter 2
Diagnosis of nutrient inputs in kiwi orchards

(Table 2.3) that kiwifruit is low demanding in phosphorus, however, growers apply a ten-fold rate more than is needed according to the model. Kiwifruit is grown in some maize dominant areas where 11-15-15 fertiliser type is commonly applied as base application. It was revealed from the November visit (Append. II) that many growers apply 11-15-15 to kiwifruit orchards because it is widely available and the low requirement of kiwifruit for phosphorus is not considered. Therefore, the nutrient balances show that nutrient management is seen as an important yield increasing factor and practiced extensively and in over-supply, while little attention is given on the negative effects of excess fertilisation on yield and quality. For example, it is common for many orchards to produce under-sized fruit despite of high fertilization rates because the grower does not take into account the increase in leaf canopy and subsequent competition for assimilates between kiwifruit and other vine components in addition with the extra shading to the leaves next to hanging kiwifruits which act primary assimilate sources for the fruit.
References


APPENDIX A

Plant components
ft fruit
lf leaf
sh shoot
lt lateral
le leader
st stem
rs structural root
rf fibrous root
csg current season growth; ft+lf+sh+rf

Crop dimensions
VDW vine dry weight (t/ha)
FY target fruit yield (fresh weight) (t/ha)

nutrient dimensions
U uptake (Kg/ha)
M nutrient quantity within plant or its component (Kg/ha)
R nutrient quantity reabsorbed from vine organ between fruit harvest and leaf senescence (Kg/ha)

Constants
f fraction of shoots retained as laterals at winter pruning (0.625)
k linear term in regression of vine dry weight against fruit yield (0.59)
TVDW Threshold vine dry weight below which no fruit production occurs (3.8 t/ha)
Chapter 3

Diagnosis of Botrytis rot incidence in Greek kiwifruits at cool storage

3.1 Introduction

Botrytis cinerea, the grey mould fungus, is a cosmopolitan invader of senescing and wounded plant tissue, and it persists as a saprophyte on dead tissue. Botrytis rot on kiwifruit develops while fruit is in cool storage and has been described from all the major kiwifruit producing countries. Brook (1991) distinguished four kinds of Botrytis rot, the most important one being Botrytis stem-end rot that begins at the stem end of the fruit and progresses to the distal end, affecting the whole fruit. Diseased flesh is glassy and watersoaked (Pennycook, 1985) and the rots are first obvious several weeks after fruit has entered the cool storage (Brook, 1990). Secondary Botrytis rots occur in the cool store when the fungus spreads from fruits with stem-end rot to adjacent fruits at points of contact. In the third category are rots that begin at points of injury but this type is not common in well graded fruit. In the fourth category are Botrytis rots that develop anywhere on fruits as they become senescent and these are ripe rots similar in nature to rots caused by several other fungi after fruit has been taken out of cool storage.

When a kiwifruit is harvested it is broken from its stalk, leaving a picking wound on the fruit. Botrytis stem-end rot results from contamination of the picking wound by spores and by pieces of infected tissue. Opportunities for contamination occur while fruits are being picked and when spores or infected debris are redistributed by fruits rubbing together during the harvesting operations and handling before storage. However, healthy tissues respond to wounding by developing defense barriers against invasion by pathogens, a process known as "curing". Such a curing period, a delay between harvest and cool storage placement of the fruits, has been found to reduce the incidence of Botrytis stem-end rot (Pennycook and Manning, 1992).

Botrytis rots of kiwifruit in cool storage have an indirect effect on fruit quality. Kiwifruit is a climacteric fruit very sensitive in the presence of ethylene during storage even at low concentrations. It has been reported that a concentration of 0.05 $\mu$L/L is enough to induce ripening (Arpaia et al., 1984). Fruit infected with B. cinerea produces significant amounts of ethylene enough to induce ripening even at -2 °C storage temperature (Niklis et al., 1992). Moreover, Pennycook and Manning (1992) found that presence of even one infected fruit in a tray accelerated the softening of healthy fruits and increased the amount of ripe rot caused by other fungi when the fruit was taken from cool storage.
3.2 The implications of Botrytis incidence in Greek kiwifruit orchards

More than 4,000 hectares of kiwifruit are presently grown in Greece producing 35,000 to 50,000 tons of fruit from year to year (Kukuryannis and Vasilakakis, 1995). Kiwifruit was regarded as a “disease free” crop in Greece, but as a result of increasing acreage and production during the last decade, the quantity of fruit in cold storage has increased, and post-harvest rotting due to Botrytis gray mould of kiwifruit has become a serious problem.

Grey mould storage decay caused by Botrytis cinerea is currently the most important disease of kiwifruit, even though B. cinerea does not develop in the field in Greece (prof. E. Sfakiotakis, 1997, pers. comm.). However, postharvest decay by grey mould is a direct result of B. cinerea infections that occur in the field but remain latent in the senescent floral parts (sepals and stamens), stem-end scars, or small wounds created during harvest (Sommer et al., 1983). Then, during long-term cold storage the pathogen invades the fruit tissues starting from the stem end.

Damages, estimated in yield percentages, have been observed during storage in Greece over the last five years but they are not accurately determined and not published yet (Niklis et al., 1995). Whenever losses during long term storage are high the economic implications to the industry are large due to the need for re-sorting and re-packaging in case of exportation. Cool-stored infected fruits destined for the local markets are sold at substantially reduced prices whenever possible, however, it is most common practice to damp the infected fruits. Consequently, the production costs are increasing and the final marketable product reaches the markets at uncompetitive prices. Moreover, the early softening of infected fruits creates marketing problems since the storage units accommodate harvests from many orchards with no history of rot incidence recorded. Therefore, a substantial part of the stored fruits become rejected for sale at the time of removal from cool storage leading to distrust and unreliability of the industry by the wholesale markets.

Since Botrytis rot became a problem in Greek kiwifruit orchards the growers start extensively using fungicides to control the disease. Unfortunately, the fungus was capable of becoming resistant to dicarboximides and MBC fungicides and as a consequence, the growers continue with postharvest treatments while the extension departments do not respond effectively to these measures. As a result, the cost of applications usually exceeds loss from rot and kiwifruits with pesticide residues are not preferred by the majority of the consumers who are greatly concerned about residues of chemicals on perishable products.

3.3 Description of current control methods

The predominant control method is chemical control with dicarboximides, iprodione and vinclozolin, traditionally applied at four times, two bloom and two preharvest sprays. Although such a spraying programme has the greatest effect by reducing the amount of Botrytis inoculum it also increases the risk of developing resistant strains of the pathogen (Michailides and Morgan, 1995). Therefore, the current recommendation is one bloom and one preharvest spray a week before
harvesting (prof. E. Sfakiotakis, 1997, pers. comm.). An application of dicarboximide at flowering substantially reduces the amount of petal infection but the greatest effect on stem-end rot is an application made one week before harvest (Brook 1991).

There is great diversity in the active ingredient rates applied in the majority of the orchards. Some growers apply post-harvest fungicides on fruits, bins and storage units in order to eliminate infection by the pathogen during long-term storage. There are also growers who carry out additional sprayings during the summer and others who do not follow the guidelines at all and spray all doses at the wrong time. Such practices have great impact on the Botrytis incidence and pesticide residues on kiwifruits amongst orchards.

Sale (1985) recommended the removal of senescent and necrotic tissues during the growing season as an effective control strategy, however, it is not considered as practical by the Greek growers because suitable machinery is lacking and labour cost is not justified for such an operation. Alternatively, biological control agents do not exist commercially in Greece although this alternative control method is under research (Elmer et al., 1995a, Thanassoulopoulos and Laidou, 1995).

3.4 Potential control methods

All the kiwifruit producing countries are greatly concerned about the losses caused by post-harvest grey mould decay and research is looking for alternative control methods which may be advantageous to conventional fungicide treatments. Experiments have shown that the application of fungicides to picking wounds immediately after harvest effectively prevents stem-end rot (Pennycook, 1985). Many countries will not accept fruit treated after harvest with chemicals and other methods for preventing the rots have to be used.

3.4.1 Potential preharvest chemical control methods

Two groups of chemicals, the benzimidazoles and dicarboximides, which are highly active against Botrytis spp. are currently available. Diethofencarb has been developed over the past decade to control B. cinerea strains resistant to benzimidazoles (Kato, 1988). Multisite fungicides such as chlorothalonil, dichlofluanid and thiram are also available, but their mode of action as protectants limit their use for prevention of post-harvest diseases. Some ergosterol biosynthesis inhibiting fungicides (EBIs) have also shown useful activity against Botrytis spp. (Reinecke et al., 1986) and recently developed fungicides with good anti-botrytis activity are expected to appear on the market in the next few years.

In the early 80s, fungicide trials in seven locations in California showed that bloom applications alone did not reduce Botrytis rot and preharvest spray alone were more effective than were the bloom sprays (Sommer et al., 1983). Recent studies in USA (Michailides and Morgan, 1995) also showed that fungicide application is effective when disease levels of the unsprayed controls were higher than 6% (Table 1 and 2). Under this disease pressure it was shown that only one spray (one week before harvest) was justified in significantly reducing disease, while when disease levels
Diagnosis of Botrytis rot incidence

Ranged from 0.5-3% such sprays were not necessary. This is a field-monitoring method which consists of sampling 60 fruits from orchards 4 months after fruit pollination and recording the incidence of botrytis colonization. The incidence of *B. cinerea* colonizing the sepal or stem ends collected 3 or 4 months after fruit pollination is a good predictor (r>0.95) of the levels of *Botrytis* decay after 3 and 5 months storage. It was found that a low (0-15%), medium (16-50%) and high (>50%) incidence of sepal or stem end colonization by *B. cinerea* was correlated for the majority of the vineyards to a low (<2%), moderate (2-6%), and high (>6%) incidence of postharvest grey mould decay after 5 months in storage, respectively (Table 3).

Table 1. Effect of one or two sprays with vinclozolin in the field to reduce *Botrytis* grey mould after 3 months cold storage at -0.5 °C and 8 ng/ml ethylene of kiwifruit in 1991-1993. (Michailides and Morgan, 1995).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Incidence of grey mould (%) in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsprayed control</td>
<td>8.2 a</td>
</tr>
<tr>
<td>Vinclozolin (bloom)</td>
<td>...</td>
</tr>
<tr>
<td>Vinclozolin (bloom + preharvest)</td>
<td>...</td>
</tr>
<tr>
<td>Vinclozolin (preharvest)</td>
<td>0.7 b</td>
</tr>
</tbody>
</table>

1. The rate of application was 1.2 g/L.
2. Two to six boxes each containing 33-39 fruits were harvested at commercial harvest time from each experimental vine. Means of disease incidence are the average of five to ten single-vine replications.
3. Numbers followed by the same letter are not significantly different according to Fisher’s Protected LSD test at P<0.05.

Table 2. Effect of vinclozolin sprays in reducing *Botrytis* grey mould decay caused by *Botrytis cinerea* in four vineyards with different levels of expected disease. (Michailides and Morgan, 1995)

<table>
<thead>
<tr>
<th>Orchard (date of harvest)</th>
<th>Treatment 2</th>
<th>Time of application (wks before harvest)</th>
<th>Total incidence of grey mould (%) after 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>1 (7 Nov)</td>
<td>Untreated</td>
<td>---</td>
<td>5.6a</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>2</td>
<td>4.4a</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>1</td>
<td>2.4b</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>2 and 1</td>
<td>1.2b</td>
</tr>
<tr>
<td>2, 3, 4 6</td>
<td>Untreated</td>
<td>---</td>
<td>0.8a</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>2</td>
<td>0.2a</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>1</td>
<td>0.1a</td>
</tr>
<tr>
<td></td>
<td>Vinclozolin</td>
<td>2 and 1</td>
<td>0.3a</td>
</tr>
</tbody>
</table>

1. Orchards were selected based on both previous history levels of *Botrytis* grey mould and on isolations of *B. cinerea* in 1993 and 1994.
2. Vinclozolin was applied at 1.2 g a.i./L of water.
3. Time of application was selected based on the time of commercial harvest.
4. Fruit was stored in a commercial CA cold storage (0.5 °C and 8 ng/ml ethylene).
5. Numbers followed by the same letter are not significantly different according to Fisher’s Protected LSD test at P<0.05.
6. Orchards 2 and 3 were harvested on 13 October and orchard 4 on 18 October 1994; disease incidences for these orchards are the average for each treatment of all three orchards.

Chapter 3
Table 3. Categories of sepal and receptacle colonization by Botrytis cinerea 4 months after fruit set and vineyards with fruit in low, moderate and high levels of postharvest grey mould decay after 5 months in storage (-0.5 °C and 8ng/ml ethylene) in 1993 and 1994 (Michailides and Morgan, 1995)

<table>
<thead>
<tr>
<th>Sampled plant part</th>
<th>Colonization level</th>
<th>Colonization (%)</th>
<th>Low (&lt;2%)</th>
<th>Moderate (2-6%)</th>
<th>High (&gt;6%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepals</td>
<td>Low 0 - 15</td>
<td>6, 2</td>
<td>0, 2</td>
<td>0, 0</td>
<td>0, 0</td>
</tr>
<tr>
<td></td>
<td>Medium 16 - 50</td>
<td>0, 0</td>
<td>3, 3</td>
<td>0, 0</td>
<td>0, 0</td>
</tr>
<tr>
<td></td>
<td>High &gt; 50</td>
<td>0, 0</td>
<td>0, 0</td>
<td>0, 1</td>
<td>0, 1</td>
</tr>
<tr>
<td>Receptacles</td>
<td>Low 0 - 15</td>
<td>4, 1</td>
<td>0, 1</td>
<td>0, 0</td>
<td>0, 0</td>
</tr>
<tr>
<td></td>
<td>Medium 16 - 50</td>
<td>2, 1</td>
<td>2, 3</td>
<td>0, 0</td>
<td>0, 0</td>
</tr>
<tr>
<td></td>
<td>High &gt; 50</td>
<td>0, 0</td>
<td>0, 1</td>
<td>1, 1</td>
<td>1, 1</td>
</tr>
</tbody>
</table>

1. Percentage of colonization was determined by plating 300 sepals and 60 receptacles per sampling in each orchard.
2. Paired numbers represent 9 orchards in 1993 and 8 orchards in 1994, respectively.

3.4.2 Potential cultural control methods

It was hypothesized that B. cinerea contamination of the fruit surface was a significant source of inoculum for fruit infection at harvest. Experiments with an MBC resistant isolate of B. cinerea artificially applied to fruit at harvest indicated that there were significant relationships between the number of viable propagules on the fruit surface at harvest, picking wound contamination and stem end rot incidence (Elmer et al., 1995b). In particular, smaller B. cinerea populations in the canopy resulted in fewer viable B. cinerea propagules on the fruit surface at harvest and less stem-end rot in cool storage, compared to the 'high' inoculum and untreated control plots (Table 4). Thus, estimation of the number of viable propagules on the fruit surface at, or near harvest maturity has potential as a method to predict stem-end rot incidence for decisions on disease control. However, these experiments were carried out with ‘uncured’ fruit and further investigation is needed on fruit samples which have been ‘cured’ prior to cool storage. Significant reductions in Botrytis inoculum on fruits hanging on the vines and stem-end rot incidence were achieved in field studies when all known sources of Botrytis inoculum were removed at 14 days intervals during the growing season (Elmer et al., 1995b).

Table 4. The effect of B. cinerea population size in the canopy on the number of viable B. cinerea propagules on the fruit surface at harvest and stem end incidence (Elmer et al., 1995b).

<table>
<thead>
<tr>
<th>Potential population size in the canopy</th>
<th>Harvest and postharvest measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPSP per m² canopy</td>
</tr>
<tr>
<td>Low</td>
<td>2.4x10⁵ a</td>
</tr>
<tr>
<td>High</td>
<td>4.4x10⁶ b</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>3.6x10⁵ b</td>
</tr>
</tbody>
</table>

TPSP = Total Potential Spore Production based on incubation tests.
* Visually assessed after 16 weeks cool storage at 0 °C.
(Means within a column with a common letter do not differ significantly).
Diagnosis of Botrytis rot incidence

Promising results are reported for curing, which increases fruit resistance to the postharvest pathogens by means of different mechanisms. In particular, when the cooling of kiwifruits is delayed by 1-2 days Botrytis storage rot is considerably reduced (Pennycook and Manning, 1992; Poole and Mcleod, 1994). In a storage experiment (Sharrock and Hallett, 1991), spore germination after 4 days in cured fruit was greatly reduced compared with that of control fruit, with the greatest effect being observed in fruit cured at ambient temperatures for 7 days (Table 5). It was evident that curing both reduced spore germination and germ tube development of spores inoculated onto the surface of the picking scar.

Ippolito et al. (1994) carried out specific trials and curing for 48 hours at 15 °C at high RH before storage at 0 °C proved to be the most effective treatment. The very low incidence of Botrytis rot in cured kiwifruits indicated an increase in fruit resistance due to curing conditions.

Moreover, B. cinerea was detected on the picking scars of at least 13% of fruit after grading and packing, but fewer than 1% of fruit of the same harvest developed aggressive stem-end rots. This supports the hypothesis that a large proportion of fruit that carry Botrytis spores on their picking scars do not develop stem-end rots. Microbial antagonists on the stem scars may limit the success of Botrytis in becoming established (Sharrock and Hallett, 1991).

In investigations on a possible connection between vine nutrition and susceptibility of the crop to Botrytis rot, it was emphasized that excessive use of NPK fertiliser contributed to severe Botrytis rot (dr. D. Velemis, 1997, pers. comm.). Prasad et al., (1990) found a correlation between high N:Ca ratio in fruit and high rot incidence, however, in practice nutrient management is not considered as a control measure yet.

Table 5. Germination of Botrytis spores on picking scars of kiwifruit at 4 days after inoculation onto cured and uncured fruits (Sharrock and Hallett, 1991).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit no.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>Uncured</td>
<td>+++ +++ ++ ++ +++ +++ ++ +++ +++</td>
</tr>
<tr>
<td>Cured 2 days at ambient</td>
<td>+ + ++ + + + + ++ +</td>
</tr>
<tr>
<td>Cured 7 days at 0 °C</td>
<td>+ + - + - + + + + -</td>
</tr>
<tr>
<td>Cured 7 days at ambient</td>
<td>++ + - + - - - - -</td>
</tr>
<tr>
<td>+++</td>
<td>high germination (all areas observed)</td>
</tr>
<tr>
<td>++</td>
<td>moderate germination (5 or more spores in most areas)</td>
</tr>
<tr>
<td>+</td>
<td>low germination (1-5 spores in one/two areas)</td>
</tr>
<tr>
<td>+</td>
<td>no germination</td>
</tr>
</tbody>
</table>

Chapter 3
Experience in New Zealand revealed a consistent difference in the fungal disorders between storage units. A survey of fungal diseases of kiwifruit stored in controlled atmosphere indicated the inefficiency of refrigeration systems to withstand stable cooling conditions during the storage periods (Manning and Lallu, 1995). It was found that some systems employ defrost cycles which result in short periods of increased temperature resulting in condensation on the fruit surface. Besides, fruit stored in bulk in controlled atmosphere - the most common storage method in Greece - loses more weight due to loss of water than fruit stored in trays in normal atmosphere, which may have an effect on the development of storage rots. Results from the trials of Manning and Lallu (1995) suggest that the following factors are important in minimizing storage rots of kiwifruit:

- A stable high humidity without condensation on the fruit surface.
- Effective pre-storage curing of the fruit. This is proving to be important for normal atmosphere storage, and is even more vital for controlled atmosphere storage.
- Fruit from orchards with a previous history of high rot incidence after storage should not be stored in controlled atmosphere.

### 3.4.2 Potential biological control methods

It is well known from the literature (Dubas, 1992; Malathrakis and Kritsotaki, 1992) that *Botrytis* colonies in PDA were completely destroyed by *Trichoderma koningii* in double cultures of the two fungi. Postharvest treatments of kiwifruit by dipping or spraying with antagonists during storage (*Trichoderma* spp., *Gliocladium* spp., *Paecilomyces* spp.) or metabolites produced by these antagonistic microorganisms have been tested for biocontrol of *B. cinerea* on kiwifruit (Dubos, 1992).

In a recent study (Thanassoulopoulos and Laidou, 1995), *T. koningii* gave good *in vitro* results but the *in vivo* tests were unsuccessful. Fruits inoculated with both fungi showed higher rotting caused by *Botrytis* (Table 6). *Trichoderma* showed an ability to penetrate into fruit flesh resulting in severe adverse effects on the fruit quality without any visual rot. Furthermore, in the same experiment origanum, basil and thymus oils were used to reduce the fungus growth, however, only origanum oil at 500 ppm was toxic to *Botrytis* but destroyed the qualitative characteristics of the fruits making them inappropriate for the market.

<table>
<thead>
<tr>
<th>Treatments of kiwifruits</th>
<th>Rot extent in mm</th>
<th>Rot extent in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control - kiwifruit not inoculated</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Control - kiwifruit dipped in <em>T. koningii</em> spore solution (low)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Control - kiwifruit inoculated with <em>B. cinerea</em></td>
<td>40.6</td>
<td>49.2</td>
</tr>
<tr>
<td><em>T. koningii</em> spores suspension (low) then <em>B. cinerea</em> inoculation</td>
<td>37.6</td>
<td>54.4</td>
</tr>
<tr>
<td><em>T. koningii</em> spores suspension (high) then <em>B. cinerea</em> inoculation</td>
<td>42.4</td>
<td>53.6</td>
</tr>
<tr>
<td><em>B. cinerea</em> inoculation then <em>T. koningii</em> spore suspension (low)</td>
<td>48.1</td>
<td>53.8</td>
</tr>
</tbody>
</table>

1. Average of 25 kiwifruits.
2. Low or high dose.
Diagnosis of Botrytis rot incidence

An alternative strategy may be the biological suppression of B. cinerea on necrotic tissues. B. cinerea sporulates primarily on dead tissue of the host plants. A field experiment with onions showed that necrotic tissue is a much more attractive substrate for saprophytic antagonists than the surface of an intact leaf (Kohl et al., 1992). Consequently, control of diseases caused by Botrytis spp. by suppression of sporulation seems to be more feasible than the use of antagonists to prevent infections on the green leaf or fruit surface. Successful suppression of B. cinerea sporulation on necrotic kiwifruit leaf disks exposed to field conditions was recently reported (Elmer et al., 1995a) and further experimentation to determine the effect of biological suppression on B. cinerea populations in kiwifruit canopies is in progress.

3.5 Integration of control methods according to current knowledge and available techniques

Kiwifruits in Greece are placed in bulk bins and stored in controlled atmosphere units from harvest (late October-early November) until May at maximum. The main aim is to sell all kiwifruits before the new harvest in New Zealand arrives on the international and domestic markets. Thereafter the competition becomes too severe and Greek kiwifruits cannot be sold at profitable prices. The current concern of the growers is to withstand quality and minimize losses during storage. The potential control methods of Botrytis storage rots illustrated in this chapter are integrated to constitute new possible management practices which could smooth production lines and stabilize fruit trade.

Integration starts from the current chemical control measures incorporating the objective of minimizing preharvest sprays. The current recommendation of one bloom and one preharvest spray with a dicarboximide could be restricted to a single preharvest spray since research revealed that such a practice is the most effective for an acceptable reduction of Botrytis rots during storage. Besides, the field-monitoring system developed in California could be easily adapted to Greek conditions. This decision tool is simple, inexpensive and quick (only 60 fruits per orchard), providing to the grower useful, practical criteria for deciding on preharvest spray(s), and to packing house operators and shippers for making marketing and transport decisions of fruit to be sold first or fruit to be kept in storage longer. Furthermore, this approach can help reduce unnecessary preharvest dicarboximide applications currently done routinely regardless of the changes of Botrytis postharvest decay. Obviously, field diagnostic tests that result in reducing Botrytis sprays reduce pesticides in the environment and avoid rapid build-up of resistant strains of the pathogen.

The practice of ‘curing’ fruits by holding them at ambient temperatures for several days after harvest is currently in use in New Zealand, however, it is not known and not practiced by Greek kiwifruit growers. It is a purely cultural method which could fit easily to the harvesting operations since the immediate placement of kiwifruits in storage units - the current practice - stresses the growers in the belief that the longer the fruits are kept at ambient temperatures after harvest the shorter the storage life of the kiwifruits. It has also been tested in Italy and results were promising, therefore such
a practice should be incorporated in Greek kiwifruit culture as an environmental-friendly prevention method.

The removal of all known sources of Botrytis inoculum at orderly time intervals during the growing season has the potential to be an effective control strategy, however, it is not feasible by the growers with the available farm machinery. Either vacuum removers or extra labourers are needed throughout the growing season for such an operation. Such a type of machinery is lacking and individual growers are neither able to bare the cost of a purchase nor the payment of extra labourers since most of the kiwifruit enterprises run on a family basis. Besides, most of the management practices are concentrated in the summer months at the same time when necrotic tissues need to be removed. Alternatively, growers in a same region could agree on commonly buying an appropriate machinery and employ an operator to remove the senescent tissues from all orchards in the area at pre-agreed time intervals.

Refrigeration units in Greece do not resemble the storage units described for New Zealand in the literature. Greek storage units range from small and individual cooling rooms with no mechanism for ethylene removal to large, fully-equipped units. Different storage management techniques are practiced according to the level of equipment, however, only the avoidance of condensation on the fruit surface and removal of ethylene is considered. The practice of preharvest curing of the fruit and the recording of the previous history of high rot incidence among orchards, in the case of storing multiple harvests in large units, should become common practice.

The role of vine nutrition on the postharvest Botrytis rot incidence becomes an issue under investigation in Greece and trials are necessary to derive any specific relationships. The nutrient balances described in another chapter indicate the overuse of nitrogenous fertilizers which have to be reduced in order to head for a sustainable kiwifruit production system. A reduction in the N:Ca ratio in fruit through the nutrient management techniques could possibly have positive implications on the Botrytis rot incidence.

The biological suppression of B. cinerea on necrotic tissues instead of using antagonists to prevent infections on the fruit surface is a promising biocontrol method but still in progress. Growers should be kept alert on any futural release of an effective bio-product suitable for kiwifruit. However, the above mentioned integrated suggestions could be conveniently applied by the majority of the Greek kiwifruit growers. These main and/or supplement measures to the conventional chemical applications could reduce production costs, emissions to the environment and pesticide residues on the final, marketable product.
References


Diagnosis of Botrytis rot incidence


Chapter 4

Diagnosis of frost damage on Greek kiwifruit vines

4.1. Introduction

Kiwifruit culture in Greece was introduced in the area of central Macedonia, mainly in Pieria district, 22 years ago. During the first harvests the pioneer growers enjoyed very high market prices (Fig. 1) and that has created widespread interest among Greek orchardists in other traditionally fruit grown regions of Northern Greece. However, the spreading of kiwifruit cultivation was not accompanied by planning or consideration of the actual environmental needs of the plant, resulting in establishment of orchards in cooler areas of Northern Greece with frequent frosts, like Imathia and Pella districts. Consequently, these orchards suffer from frosts almost every year and the recent seasons' yield losses, along with decreasing productivity of the vines in subsequent years, alerted the growers and extension officers as kiwifruit enterprises in these areas became uneconomical to run (Fig. 2).

According to a 1995 survey by the state branch of Greek Agricultural Insurance (ELGA) (Argyriou, 1995), there are 2,625 ha of cultivated kiwifruit in central Macedonia. A subtotal of 260 ha are located in regions where frosts are very frequent and in half of these orchards frost damage has occurred in three out of four seasons resulting in a yearly yield reduction of over 70%. 330 ha show frost damage once every four years with a yearly yield reduction of 30%, and 1,500 ha are damaged by frost once in nine years with consequences on yield depending on frost intensity mainly in the stages of bud emergence.

In recent years the market prices of kiwifruit in Greece were very low and it is estimated that the minimum yield should be at least 25 tons/ha in order to cover the cost of cultivation (Fig. 2). It is also estimated that the industry ran into loss even for orchards in frost-free areas since the early 90s (Table 1), and it is apparent that a mean yearly production of 3.5 t/ha in frequent frost areas cannot guarantee a sustainable income for the farmer and the continuity of kiwifruit farming (Fig. 2). The yield gap between frost-free orchards and frost-sensitive ones is very large as shown in Figure 3, and the productivity of those vines reaches an unacceptable plateau far below the current attainable yield level for Greece.

| Table 1. Economic performance of kiwifruit enterprises in Macedonia (Manolopoulos, 1995) |
|-----------------------------------------------|------------------|------------------|
| 1987                                         | 1994             |
| **Gross income (mean yield x Average selling price)** |
| 21 t/ha x 186,000 Drs/ton = 3,906,000 Drachmas/ha |
| 23 t/ha x 86,000 Drs/ton = 1,978,000 Drachmas/ha |
| **Total costs**                               |
| 1,576,450 Drachmas/ha                         |
| 2,722,930 Drachmas/ha                         |
| **Profit or loss**                            |
| 2,329,550 Drachmas/ha                         |
| -744,930 Drachmas/ha                          |
| **General Productivity Index**                |
| 1.67                                          |
| 0.72                                          |
Figure 1  Kiwifruit prices achieved over the last 13 years (1995-1997 prices derived from the visits).
(Manolopoulos, 1995; Author’s data based on growers’ interviews)

Figure 2. Mean yield levels of orchards established over 10 years ago (drs = Drachmas)
Frost damage on Greek kiwifruit orchards

Yield gap between current attainable yield level and yield from fields with frequent frost damage. The yield reduction is substantial even with the aid of anti-frost equipment (Argyriou, 1995).

Figure 3.

4.2. Etiology of frost damage in Greek kiwifruit orchards

The kinds of frosts that occur in frost sensitive areas are radiation frosts, advective frosts and combination of both, each affecting kiwifruit vines in a different way (Pyke et al., 1986). Radiation frosts, which appear on clear nights when high pressure systems dominate and extent in south Balkan peninsula, cause greater damages in the lower levels of the vines than in the upper ones. The advective frosts appear when a combination of high pressure system in south Balkans with a low pressure system in eastern Mediterranean exist. This kind of frost causes damages during and just after the dormancy phase when air temperatures are lower than approximately -7 °C (Argyriou, 1995). When frost results from combination of radiation and cold airstreams the damages are the same or greater in the upper than in the lower parts of the canopy.

An attempt was made in New Zealand to determine the critical temperatures at which freeze damage occurs for buds on dormant vines in winter and for flower buds at different development stages in spring (Hewett and Young, 1981). It was revealed that dormant shoots withstood temperatures of -10 °C before bud damage occurred (Table 2) while flower buds of kiwifruit could be damaged in spring frosts with minimum temperatures of -1.5 °C to -2 °C (Fig. 4). It was emphasized that there is only a small temperature difference between no damage and total damage to flower buds at critical temperatures during freeze conditions and there is therefore little margin for error in the use of any system to prevent frost damage.

The growth stages in which frost damage is most frequent in Greek kiwi vines is a) during dormancy, b) during the first activity of the buds, and c) during and just after bud emergence. The most serious implications on subsequent plant growth is noticed Chapter 4
on the asynchronisation of flowering between partially damaged and healthy flower buds and anomalies of vine growth due to reduced leaf number on atrophied shoots, appearance of undesirable shoot growth and delayed/reduced bud emergence and growth. Further, undersized fruits are increasing proportionally within orchards due to inadequate nutrition by the damaged shoots and incomplete pollination due to delayed bud emergence (Argyriou, 1995).

Table 2. Number of new shoots growing from dormant kiwifruit (cv. Hayward) cuttings exposed to different temperatures, then placed in a greenhouse at 20 °C for 5 weeks. (Mean of 2 expts, 28 July and 4 August 1977, 10 cuttings per treatment) (Hewett and Young, 1981)

<table>
<thead>
<tr>
<th>Minimum temperatures of freezing test (°C)</th>
<th>No. of shoots</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>11</td>
</tr>
<tr>
<td>-4</td>
<td>11</td>
</tr>
<tr>
<td>-6</td>
<td>9.5</td>
</tr>
<tr>
<td>-8</td>
<td>10</td>
</tr>
<tr>
<td>-10</td>
<td>9.5</td>
</tr>
<tr>
<td>-12</td>
<td>4</td>
</tr>
<tr>
<td>-14</td>
<td>1.5</td>
</tr>
<tr>
<td>-16</td>
<td>0.5</td>
</tr>
<tr>
<td>-18</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4. Flower bud damage on current season’s kiwifruit shoots (cv. Abbott) exposed to -1 °C, -1.5 °C or -2 °C for different periods. Temperature reduced at 1 °C per h after 1 hour equilibration at 0 °C. Duration is elapsed time after freezer reached holding temperature. Shoot length, 12-15 cm. (Hewett and Young, 1981).
Several cultivation practices followed by the majority of the growers also contribute to the susceptibility of the orchards to frost. Based on my own observations, kiwi growers continue fertigation until September and as a consequence, the vines extent their growth and delay dormancy initiation until freezing temperatures start to occur in late autumn. If the former is combined with high September-October temperatures then kiwi vines become extremely vulnerable to early winter frosts. Such observations are justified by comparison with abandoned kiwi fields in which there is no frost damage when damage occurs in late fertigated orchards.

The kiwifruit orchards in central Macedonia are concentrated in the valleys surrounding the Aliakmon river with more frequent frosts observed in recent years. There is a change in the microclimate of the area due to the hydroelectric power station which came recently into operation and the water supply by the river has been reduced since then.

4.3. Frost protection of kiwifruit vines

Since kiwiculture became popular among Greek orchadists the first attempts and advises to protect vines from frost was to save the whole vine from complete destruction in cases of severe freezing temperatures. The common practice was to cover the trunk with hay up to the height of the training system. Although all the upper components were lost whenever there was frost incidence the vine was not lost and it could come into production again one or two years later. However, such a practice was abandoned with years and there is recently a strong interest on active frost control methods. Two methods are currently practiced, mixing cold and warm air with wind machines or using the irrigation system as a water spraying system for frost control.

Wind machines were experimentally installed by Greek Agricultural Insurance state branch in three frost sensitive areas. The results as presented in the literature (Argyriou, 1995) are not very promising (Fig. 3) and these observations agree with the conclusion of Hewett and Young (1981) that there is little margin for error in any frost preventive method used. Yield reductions were high in the frost damage of 1995 in three locations where wind machines were installed (Table 3).

<table>
<thead>
<tr>
<th>Location of orchard</th>
<th>Yield reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vergina, Pella district</td>
<td>95</td>
</tr>
<tr>
<td>Meliki</td>
<td>75</td>
</tr>
<tr>
<td>Kato Ag. Ioannis</td>
<td>85</td>
</tr>
</tbody>
</table>

The water spraying system offers better results when air temperature reaches marginal levels for bud and young shoot damage in early spring, however, very critical
for the determination of the following season’s yield. This system is more approachable to the grower and many farmers have already made their own experiments and trials into adjusting the existing irrigation system for frost protection. The automation controls required for such an operation already exist in the majority of the kiwifruit orchards and several trials on commercial orchards were effective in preventing spring frost damage of newly emerging buds (Katerinis, 1997). Current research is promoting farmers initiatives and further trials are needed on the better performance of this system. However, such an operation requires a reliable irrigation pump which can supply water at any time and at no interrupted intervals because ice formation on the vines is not a good insulation for frost prevention. Further, the system is most efficient in well drained soils as low temperatures should not come along with waterlogged fields and the irrigation network should have pressure release valves at each end to prevent damage of the pipes at freezing temperatures.

Supplementarily, water spraying could be practiced during the warmest hours of the day during the first signs of bud activity to delay flowering for some days. A 5 to 7 days delay on flowering could be very beneficial as most of the frost damages usually occur in early flowering crops.

4.4. Conclusion

There is undoubtedly a serious problem as far as the adaptability of kiwifruit in areas where frosts are frequent. In recent years there is a speculation on the active protection of kiwi vines by wind machines as the first preventive method under trial. Although other methods are available and can contribute to a list of options to the farmer on which suits better under such conditions, cultural methods and careful planning of kiwifruit expansion could eliminate most of the problems. Crop nutrition, irrigation and pruning play an important role on the degree of vulnerability of the vines to spring and winter frosts and growers should always be aware that the crop management practices they follow also have a strong impact on next season’s frost damage levels. However, the most important components are the re-organization and systematic observation of all kiwi orchards located in areas where frosts are frequent and confrontation of the damages with appropriate pruning.
4.5 References


Chapter 5

Perspectives of designing an integrated production system for kiwifruit

5.1 Introduction

Considering preceding chapters it is obvious that the study is in its initial phase towards an envisaged kiwifruit production system in Greece. In the diagnostic phase the problems caused by the current system design were identified and the objectives of kiwifruit production were revealed in accordance to various sectors of the Hellenic kiwifruit industry. The diagnostic approach of this study consists of a target-oriented approach for nutrient inputs in kiwi orchards and empirical/experimental research elements for disease incidence and frost occurrence. Besides, information derived from interaction and interviews with growers, academics and extensionists during the two visits to Greece, emphasised the importance of socio-economic factors in production.

Within the course of diagnosis several design elements were realised which could form the basis of alternative production ways. Moreover, people involved in kiwifruit trade and farming are becoming aware of the drawbacks of the single-objective production method and envisage a sustainable kiwifruit production system. Thus, in order to incorporate the issue of sustainability in kiwifruit systems, it is essential to explicitly address objectives in areas of environment, public health and nature in addition to economic objectives.

5.2 Preliminary design of an integrated kiwifruit production system

Preliminary indicators of improved sustainability in kiwifruit crop management are: reductions in the use of fertilisers and broad-spectrum pesticides, increases in the numbers of mortality factors impacting on pest populations, improved frost protection, increase in fruit size and weight at harvest. Agricultural research is challenged to develop methodologies to achieve target values of those indicators while they are quantified.

5.2.1 Objectives of IKPS

Vereijken (1997) presented a methodical way of prototyping integrated and ecological arable farming systems in interaction with pilot farms. It concerns a comprehensive and consistent approach of 5 steps with the first two steps being: step 1: establishing a hierarchy of objectives considering the shortcomings of current farming system in the region, step 2: transforming the objectives in a set of multi-objective parameters to quantify them and establishing a set of multi-objective farming methods to achieve them. Based on diagnosis of the conventional design system and on
discussions with growers and advisors during the two visits in Greece, the objectives of the integrated kiwifruit production system were hierarchically selected and ordered according to the prototyping methodology (Table 5.1).

Table 5.1 Hierarchy of the general and specific objectives in preliminary prototyping of integrated kiwifruit production systems (adapted from Vereijken, 1994)

<table>
<thead>
<tr>
<th>general</th>
<th>specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic income/profit</td>
<td>1.1 farm level</td>
</tr>
<tr>
<td></td>
<td>1.2 regional level</td>
</tr>
<tr>
<td></td>
<td>1.3 national level</td>
</tr>
<tr>
<td>2. Food supply</td>
<td>2.1 quality</td>
</tr>
<tr>
<td></td>
<td>2.2 stability</td>
</tr>
<tr>
<td></td>
<td>2.3 quantity</td>
</tr>
<tr>
<td>3. Abiotic environment</td>
<td>3.1 soil</td>
</tr>
<tr>
<td></td>
<td>3.2 water</td>
</tr>
<tr>
<td></td>
<td>3.3 air</td>
</tr>
<tr>
<td>4. Health / well-being</td>
<td>4.1 urban people</td>
</tr>
<tr>
<td></td>
<td>4.2 rural people</td>
</tr>
<tr>
<td></td>
<td>4.3 farm animals</td>
</tr>
<tr>
<td>5. Employment</td>
<td>5.1 farm level</td>
</tr>
<tr>
<td></td>
<td>5.2 regional level</td>
</tr>
<tr>
<td></td>
<td>5.3 national level</td>
</tr>
<tr>
<td></td>
<td>6.2 fauna</td>
</tr>
<tr>
<td></td>
<td>6.3 landscape</td>
</tr>
</tbody>
</table>

Kiwifruit is the most recently introduced crop in Greece and cultivation practices followed by the growers do not differ between regions and the “Hayward” variety predominates throughout the orchards. The minor place of the fruit in local markets and increasing international trade competition indicate that the profitability of the crop at all levels is a crucial factor for any kind of improvement. Besides, the quality component in terms of exportable fruit size and level of pesticide residues on marketable fruit greatly concerns all sectors of the industry, and stability in production coincides with the degree of frost damage due to the existence of many orchards in pockets of frequent frost incidence.

Abiotic environment in terms of the soil and water components relates to the dissemination of the sustainability concept amongst Greek orchardists followed by the increasing demand of urban people for residue-free fruit. Soil water is ranked below as sprinkler irrigation system is used at the vast majority of the orchards in Greece, in which irrigation water is efficiently used. Besides, employment in terms of required working hours in the orchard throughout the growing season competes with other occupations the farmers have at the same period. Nature and landscape is considered less important because the cultivation area is relatively small in comparison with other crops at any level.

The transformation of the hierarchy of objectives into a suitable set of multi-objective criteria was not followed by quantification (Table 5.2). Since this chapter is a
preliminary design of IKPS

preliminary stage of the design phase, quantified multi-objective criteria necessitate more specific interaction with the stakeholders and continuation of the prototyping methodology which is beyond the scope of the thesis.

Table 5.2 Ranking specific objectives and expressing into multi-objective criteria in integrated kiwifruit production system prototyping in Greece (adapted by Vereijken, 1994).

<table>
<thead>
<tr>
<th>Major objectives ranked</th>
<th>Major objectives expressed in multi-objective criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic Income - farm level</td>
<td>1.1 fruit growth curve</td>
</tr>
<tr>
<td>2. Food supply - quality</td>
<td>2.1 fruit growth curve</td>
</tr>
<tr>
<td>3. Abiotic environment - soil</td>
<td>3.1 NuE</td>
</tr>
<tr>
<td>4. Basic income/profit - regional level</td>
<td>4.1 fruit growth curve</td>
</tr>
<tr>
<td>5. Food supply - stability</td>
<td>5.1 FPI</td>
</tr>
<tr>
<td>6. Health/well-being - urban people</td>
<td>6.1 TPSP</td>
</tr>
<tr>
<td>7. Abiotic environment - water</td>
<td>see 3.1</td>
</tr>
<tr>
<td>8. Employment - farm level</td>
<td>8.1 FE</td>
</tr>
<tr>
<td>9. Health/well-being - rural people</td>
<td>9.1 TPSP</td>
</tr>
<tr>
<td>10. Basic income/profit - national level</td>
<td>10.1 fruit growth curve</td>
</tr>
</tbody>
</table>

NuE - nutrient utilisation efficiency (Buwalda & Smith model), fruit growth curve (Lescurret et al. Model), FE - farm employment (labour hours ha\(^{-1}\)), TPSP - total potential spore production (Elmer et al, 1995b), FPI - frost protection index\(^1\)

\(^1\) (for explanation see below)

5.2.2 Model-based explorations in kiwifruit

According to Rossing et al. (1997), the prototyping methodology restricts to a limited number of tests, due to limitations in time and funding, resulting in ignorance of potentially relevant farming designs. In addition, prototyping relies on expertize summarized in simple rules which overlooks potential options and impedes understanding of systems behaviour.

Simulation models are useful tools for investigating the effect of cultural practices on orchard performance, since they are able to predict outcomes of alternative strategies and act as optimising models in either physical or economic terms (Bawden et al, 1984). In the near past, advisory services have traditionally based on experiments repeated in time and space which allows only slow processes. The problem is especially enhanced in perennial crops such as fruit tree crops, where results get a full sense over the productive life of trees. However, kiwifruit suits the purpose of orchard simulation since it is simpler than other fruit crops. The effects of crop
variety and training system could be neglected in a first attempt since the 'Hayward' variety and the Tbar system predominate throughout the world. Moreover, disease control does not need to be considered in most cases (e.g. Kiwifruit vines in Corsica are disease-free), therefore, research efforts are weighed on practices that are prominent to orchards i.e. pruning and thinning, which represent heavy cost of production, and planting scheme (Agostini and Habib, 1996).

Lescurret et al., (1998a,b) developed pollination and fruit growth models for adult kiwifruit orchards without limitations of water and nutrients. It was restricted to fruit size, individual growth curves (fresh weight) of the fruits of an orchard, which determine the size of fruit at a given harvest date. Fruit size is especially important for determining orchard profitability and it has been proven to be highly variable particularly within vines (Smith et al., 1994).

The pollination model simulates the fertilisation of pistillate flowers that open in an orchard, by considering first the mean amount of pollen grains deposited on the stigmas of a flower during its effective pollination period. This amount is provided by pollen vectors from the staminate flowers releasing pollen during the same period. Rain is supposed to stop temporarily the deposition process while plant arrangement is taken into account in this computation since the pollen flow from a male vine to a female vine is assumed to decrease according to distance between vines. Then, the model uses the computed amount together with information on pollen and ovule fertility, and on ovule numbers, to simulate the number of ovules that develop into mature seeds in fruit. Fruit set is viewed as a probabilistic process based on the number of seeds in fruits. The fruit growth model describes changes in individual fresh weights using the reference relative growth rate (RGR) (of a fruit with maximal cumulative growth described by Compertz equation) to which multiplicative effects of seed number and of crop load are applied. It is assumed the other growing conditions are optimal and the model accounts for crop load changes at any time of growth due to thinning. The model outputs and inputs are summarized in Table 5.3.

<table>
<thead>
<tr>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollination model</td>
<td>for every flower in the orchard</td>
</tr>
<tr>
<td>Geometric features of the orchard</td>
<td>number of seeds</td>
</tr>
<tr>
<td>number of rows</td>
<td>fruit set (success or failure)</td>
</tr>
<tr>
<td>number of plants per row</td>
<td></td>
</tr>
<tr>
<td>within-row distance (m)</td>
<td></td>
</tr>
<tr>
<td>between-row distance (m)</td>
<td></td>
</tr>
<tr>
<td>male:female ratio</td>
<td></td>
</tr>
<tr>
<td>male:female arrangement</td>
<td></td>
</tr>
<tr>
<td>Flowering distribution for every vine</td>
<td>number of flowers open per day</td>
</tr>
<tr>
<td>number of flowers open per day</td>
<td></td>
</tr>
<tr>
<td>Climatic conditions</td>
<td>number of repartition of rainy days</td>
</tr>
<tr>
<td>number of repartition of rainy days during the flowering period</td>
<td></td>
</tr>
<tr>
<td>Fruit growth model</td>
<td>growth curve until harvest</td>
</tr>
<tr>
<td>number of seeds in the fruit</td>
<td></td>
</tr>
<tr>
<td>crop load of the vine bearing the fruit</td>
<td></td>
</tr>
</tbody>
</table>

Chapter 5
Furthermore, the Frost Protection Index (FPI) is defined as:

\[ FPI = \frac{\text{no. orchards in frost-sensitive pockets}}{\text{total no. orchards in the area}} \]

or

\[ FPI = \frac{\text{no. of orchards with active protection}}{\text{total no. of orchards in the area}} \]

5.2.3 Reasons for choosing the multi-objective criteria

Lescurret et al. (1998a, b) emphasized in their model that growth of fruits in best conditions with respect to crop load decreased with increasing seed numbers. In the same way, growth of fruits in best conditions with respect to seed number decreased with increasing crop load. The output of the model which is the fruit growth curve at harvest, could be used as a criterion with the potential to be quantified after adaptation of model parameters to Greek conditions. Farm income and quality is interpreted into a threshold fruit size below which marketing of the fruit is undesirable. Lescurret et al model uses several cultivation practices such as fruit thinning rate and timing, as parameters and inputs to yield the fruit growth curve at harvest. By setting a target fruit size as a quantified criterion, current cultivation techniques are adjusted to meet the major objectives of IKPS (Table 5.2).

Similarly, the nutrient balances calculated by the Buwalda-Smith model illustrate the unsustainability of kiwifruit production systems. It is now clear that kiwifruit orchards produce the same yield at different fertilizer rates and a preliminary integrated nutrient management system could include NuE values for each nutrient as quantified criteria to meet the abiotic environment objectives. Besides, Total Potential Spore Production (TPSP) is the \textit{B. cinerea} population size in the canopy and is correlated with stem-end rot incidence at harvest, therefore being a predicting value. TPSP as a quantified criterion could serve to decrease fungicide use by incorporating a \textit{Botrytis} monitoring system into the design.

5.3 Conclusion

Although in prototyping the parameters are defined according to methodology, in this case the procedure was followed up to step 2 without quantifying the criteria. Instead, the outputs of the Buwalda-Smith model and Lascourret model were used and quantification depends on the models inputs. The Buwald-Smith model already takes into account the leaf nutrient reserves as well as nutrient uptake by the vines and subsequent NuE, therefore, this parameter can be easily quantified based on fertiliser inputs. However, the absence of diminishing returns of a fertiliser input in Buwalda-Smith model increases inaccuracy of NuE estimation whereas an extended work on ways of incorporating QUEFTS approach into the model could give a reliable estimate for NuE.

Total Potential Spore Production (TPSP) was derived from Elmer et al., (1995b) since it is the only experimental component found in the literature that has a potential
of being a quantified criterion. Although the findings of Elmer et al. (1995b) have the potential to predict stem-end rot incidence for decisions on disease control, there is no reliable range or value for TPSP to be used in the design phase. Furthermore, Farm Employment (FE) is a good indicator for labour intensity and is included in the provisional list of the I/EPFS parameters (Vereijken, 1994).

Prototyping offers a methodic way to weigh values on objectives and find ways to quantify them into parameters. Biotechnical models (Lascurret et al., 1998a) are also contributing to the design phase and form valuable parameters in other cases being impossible or too time consuming to quantify. Kiwifruit as a crop is suitable for modeling, for reasons of unique management practices and a single widespread variety, and the time constraint due to lack of data or “what if” explanations may be eliminated in the near future.
5.3 References


Appendix I

Report on the visit held between 8-15 June in Thessaloniki, Greece

Introduction

Within the frame of development of the study on integrated kiwifruit production in Greece a visit was held between 8-15 June 1997 at the Aristotle University in Thessaloniki where a closer approach to the current situation was elaborated with discussions and meetings with academic experts on Greek fruit production. The report is a detailed summary of the visit’s events and also includes the conclusions drawn during and after the contacts.

The aim of the visit was to establish further links with persons concerned in kiwifruit production and seek for possible ways of cooperation and contribution to the project.

Summary of events

The events consisted of discussions and interactions with academic experts at the University and the National Agricultural Research Foundation in Thessaloniki. Three persons were contacted:

♦ Prof. E. Sfakiotakis, Professor in Pomology, Aristotle University, Thessaloniki.
♦ Dr. D. Velemis, National Agricultural Research Foundation, Soil Science Institute of Thessaloniki.
♦ Prof. E.W. Hewett, Postharvest Physiologist, Massey University, New Zealand.

Prof. E.W. Hewett was visiting the University during that period. Initially, during the pre-arranged appointment with Prof. Sfakiotakis an introduction to the objectives and aims of the project were discussed. Further, an exchange of information on the recent situation of kiwifruit production in New Zealand was discussed with Prof. Hewett as part of his presentation on New Zealand’s fruit industry as well as personal interaction. In addition, the ways of cooperation and contribution of Prof. Sfakiotakis to the study was more clearly set and a further meeting with Dr. Velemis was arranged. During that meeting the current problems of kiwifruit production were emphasised and an initial structure of the problems’ approach was established in order to meet the requirements of the project.
Conclusions

There is a positive attitude towards prototyping by a small group of farmers as a tool of developing an integrated fruit production system in kiwi orchards in Greece. In terms of diagnosing the current production situation the interest is concentrated on the increasing incidence of Botrytis on kiwi vines, the degree of orchard fertilisation and the cultivation factors influencing the post-harvest phase of the production. There is limited knowledge on the inputs and outputs in terms of energy, pesticides, organic/inorganic fertilisation and irrigation water which makes difficult to define the magnitude of current and potential shortcomings. The methodic approach of prototyping is seen as an elucidation of causes and determination of priorities given to each system component.

Great emphasis was given to the establishment of objectives and identification of problems caused by the current system design. To further increase the impact of the approach two main drawbacks require attention. Firstly, the time and money constraints allow the development of the diagnosis phase only. Secondly, prototyping relies on expertise summarised in simple rules and this empirical tool is expected to be frequently used during diagnosis. This is a shortcoming, however, as it is difficult to convince people involved in Greek kiwiculture with empirically-driven values attached to an integrated kiwifruit production system. Therefore, experimental data based on Greek circumstances should optimally be used, whenever possible. In addition, farm structure should be taken into account as an important diagnostic variable, due to the fact that farm types varietate based on the geographic and socio-economic differences between the kiwi grown areas in Greece.

The current research interest in Greece is concentrated on the post-harvest phase of the fruit, particularly on the factors influencing the storage properties. The durability of the kiwifruit in cold storage and the cultivation parameters which determine the quality status of the fruit on the retail shelf need more detailed investigation in order to improve the competitiveness of the Greek kiwifruit on the international market. Post-harvest diseases, such as Botrytis, is considered as a major cause of reduced quality as well as the nutritional content of the vines and fruit at various times before harvest. There are many assumptions on which factors influence quality and the proposal on the design of an integrated kiwifruit production system is seen as a good way of improving the current system and setting priorities for the future.

Prof. Sfakiotakis insisted on the closer investigation of the cultivation techniques which affect the nutritional status of the fruit. He suggested that leaf and fruit analysis on vines of the current growing period is needed as an indication of the severity of the problems. He believes that some data are necessary in order to support the argumentation of the diagnosis objectives and have a more realistic approach to the situation. An appointment with Dr. Velemis at the Soil Institute of Thessaloniki was arranged for this reason.

Dr. Velemis shares a similar assumption with Prof. Sfakiotakis and he agreed on contributing to the experimental phase of the thesis. He can help on carrying out the leaf and fruit analysis in Thessaloniki and also further contribute as an advisor on the later stages of the project. To start the procedure a protocol of activities must be set
concerning ‘how and when’. Leaf samples must be collected from at least 10 orchards in which there is a good knowledge of the vine management techniques and orchard condition, between 15 July - 15 August. Later, fruit samples have to be collected before harvest in October for the fruit analysis. Besides, recent research data from Greece indicate a great influence of calcium concentration in leaves and fruits on the post-harvest quality of the kiwifruit. Therefore, low-calcium and high-calcium orchards must be chosen as candidates for sampling to clearly see the effect of calcium.

The analyses data will eventually be used for attaching the thesis objectives to the real orchard condition. Although the opinions in Greece favour a more specialised study on the effect of Botrytis and calcium on fruit quality, I personally believe that an integrated approach, as set on the proposal, should not only be based on a few parameters but on a combination of parameters and objectives. The diagnostic phase should seek for problematic areas in relation to the future design of an integrated production system and not based on a single objective consideration which is maximising financial returns. Therefore, Botrytis and calcium will constitute the thesis objectives and diagnostic outputs but other parameters will also be found following the methodology of the prototyping approach. A multi-objective diagnosis will then be achieved.

Furthermore, Prof. Hewett referred to the current kiwifruit production situation in New Zealand. According to his view, the already applied ‘KiwiGreen’ IPM system has major limitations and there are difficulties in the applicability of the project. The pest and disease occurrence in New Zealand orchards is considerably higher than in Greece, and the growers often hesitate to limit the number of sprayings. This creates great marketing problems because the quality standards set by the industry are increasingly strict and tight. It is still rather uncertain if the programme will succeed in the future and there are fears that such an approach puts the kiwifruit industry at greater risk. A considerable portion of the New Zealand growers still follow a single objective production system but there is a pressure recently to shift to a more integrated system. However, the organised infrastructure of New Zealand’s kiwifruit industry favours the design and implementation of an integrated production system. Such an organised environment is lacking in Greece.

The main characteristic of the visit is that there are multiple points of view on the approach as stated on the research proposal. These opinions will be further evaluated to define the time limitations and set priorities for the activities in the near future. Nevertheless, the visit drew the attention of the people involved in kiwifruit production in Greece it was a good dissemination of the study in the region where the research is concerned.
Appendix II

Report on the visit held between 4-25 November 1997 in kiwifruit producing areas of Greece

Introduction

As a part of the diagnosis of the current kiwifruit production system in Greece, a visit was held between 4-25 November 1997 to the main kiwifruit producing areas. In addition to the first visit in June 1997, where only academic experts were contacted, kiwifruit orchardists and extensionists were interviewed in order to gain a multiple view on the production shortcomings revealed from the study up to this point.

The aim of the visit was to gain a better insight of the problems as described in the literature and collect information on the people's views involved in production.

Summary of events

The events consisted of interviews with extensionists, kiwifruit orchardists and academic experts. The people contacted are listed below:

♦ Prof. E. Sfakiotakis, professor in Pomology, Aristotle University of Thessaloniki.
♦ Dr. D. Velemis, National Agricultural Research Foundation, Soil Science Institute of Thessaloniki.
♦ Dr. N. Niklis, Plant Quarantine Station of Thessaloniki.
♦ Dr. C. Thanassoulopoulos, plant pathologist, Aristotle University of Thessaloniki.
♦ Mr. T. Papaioannou, agricultural extensionist, Agricultural cooperative of Meliki, Imathia.
♦ Several kiwifruit orchardists in the kiwifruit producing areas of Kavala, Imathia and Pella.

The interviews were open discussions where each person was asked to critically address the importance of the problems mentioned in the study and contribute more inputs and data which have been lacking and are crucial for a realistic approach towards the diagnosis of the current kiwifruit production system.
Appendix II

Conclusions

The interviews were focused on the three components of the thesis according to each person’s expertise. The outcome of the interviews are shown in the three sections below.

**Botrytis incidence**

Postharvest fruit losses due to *botrytis* incidence is not considered as important as it is in New Zealand because the climatic conditions in the Greek kiwifruit regions are not as humid and the production cycle not as intensive as in New Zealand. The current crop protection methods are based sorely on chemical control with Iprodione and Vichlozolin preferably one week before harvest. *Botrytis* is not seen as a threat to the kiwifruit farmer because it does not affect the fruit standing on the vine and there are no visual symptoms up to harvest and selling time of the crop. Many farmers avoid spraying to reduce costs and also because they think it’s unnecessary in some years. In years where the production is low all newly harvested kiwifruit are absorbed by the wholesale traders for the local markets and some exports and storage life of the fruit is very short. However, in years there is a boost in production *Botrytis* becomes a serious disease because kiwifruit are kept longer in storage units. Farmers often judge from their experience whether to spray or not based on their estimations of the amount of kiwifruit about to enter the market in the following October.

No systematic agrochemicals are used and kiwifruit has currently the reputation of the most pesticide-free fruit in the Greek market. Iprodione and Vichlozolin are contact fungicides and it is believed that they are less harmful to the consumer since the flesh of fruit is removed and only the inside is perishable. Moreover, the chemical is concentrated on the hair of the fruit which is removed through the packing and sorting process.

Although the most convenient option for farmers and agrochemical agents who act as advisers is thought to be chemical control, many orchardists recently started to pay attention on the harvesting operations which plays an important role in *Botrytis* control. Since it is a saprophytic fungus, it gains entrance through the scars and injuries on the fruit surface which happen to be many if harvesting is without precautions. Workers are often taught how to handle the fruit on the vine and deliver them to the bins at the minimum injury. Besides, harrowing, which is used for weed control, creates a favourable soil environment for the cycle of the fungus and it is gradually abandoned by the growers.

The removal of necrotic tissues from the orchard is not practiced by the majority of the growers and those who practice often dispose the debris nearby the orchard with no effect on *Botrytis* control. Limited knowledge exists amongst the farmers on the importance of the inoculum on potential disease outbreak.

Iprodione and Vichlozolin are not officially registered for kiwifruit in Greece and the timing and rates of applications are based on recommendations of the extension officers and agrochemical agents. There are no pesticide residue tests undertaken by
state organisations since no chemical officially refers to kiwifruit for testing. Many
farmers soak the fruit placed in the bins with the fungicide after harvest as a
precautionary measure. As the fruit enter the cool and dark environment of the storage
units its effectiveness is reduced and residues remain for a prolonged period.

The cultural control method of ‘curing’ is not practiced in Greece and is virtually
not known amongst the growers. Advisors and academics believe that during the
curing process where kiwifruit are kept in ambient temperatures for a short period
before cool storage, the autocatalytic process of the fruit already initiates. The storage
life of those fruit is less as they mature quicker than the non-cured fruit. Although it is
a promising alternative to conventional fungicide spraying, such a practice is not
followed because the market destination of the fruit in the storage unit is not known in
advance. Even if this method reduces the *Botrytis* rot in storage the advanced
autocatalytic stage of the ‘cured’ fruit may be equally detrimental to fruit softening
after many months in storage.

**Vine nutrition**

The main objective of interviews on the nutrient balance of the orchards was to
reveal the scientific methods followed to draw fertiliser recommendations. The
mechanistic approach of the thesis was not shared as a reliable way of making fertiliser
recommendations, however, there was interest paid on the estimation of vine uptake
because there is no method predicting nutrient uptake by the vines in Greece. All the
existing recommendations are based on experience and soil and leaf analysis. Several
interviews with growers in different regions, showed that the vast majority of the
growers follow the fertilization programme below.

- 11-15-15 at 1000 kg/ha (February)
- Complesal (6-12-6+MgO+micronutrients) at 500 kg/ha (March)
- Plantleaf (12-12-12 or 20-20-20 or 20-5-20 +2MgO+micronutrients) at 140
  kg/ha (May-July).

Complesal and Plantleaf are liquid fertilisers and can be applied through the
irrigation system. Plantleaf is applied in small quantities every second irrigation until
mid-July. Many farmers apply ammonium sulphate or potassium sulphate instead of
11-15-15 at similar rates. The recommended time interval for Complesal application
and any potassium and phosphorus based fertiliser is every 2-3 years but many farmers
apply them every year and these elements are accumulating in the kiwifruit grown soils
causing imbalances and inefficiencies of other nutrients. According to Mr Papaioannou
many kiwifruit orchards will face serious problems with excessive potassium in the
regions of Imathia and Pella if such a practice is not corrected.

Based on the estimations of the Buwalda-Smith model, there is an extreme
oversupply of phosphorus although kiwifruit is low demanding for this nutrient. This
happens because, for example, in the kiwifruit producing area of Kavala where maize
is the predominant crop and 11-15-15 is used for maize fertilisation. Since this type of
fertiliser is easily accessible to farmer in February many orchards receive this kind of
fertiliser. Most growers are not aware of the low phosphorus requirement of kiwifruit and pay more attention to nitrogen than any other nutrient requirement of the vines.

Fe deficiency is also observed in the majority of the orchards which is corrected by application of Sequestrene 138 (6% Fe) whenever is necessary. Moreover, Bo toxicity is an insisting problem which is caused from the high concentration of Bo in the irrigation water.

**Frost damage**

Frost damage on kiwifruit vines is extremely common in central Macedonia (Imathia and Pella districts) and millions of state funds are flown every year for compensations. The Greek Ministry of Agriculture initiated research on frost preventive methods and several experiments are conducted in frost-sensitive areas. The wind machine experiments were very unsuccessful because there was lack of cooperation among the people conducting the research and the growers who preferred to obtain the compensation fund instead of protecting their orchards. In many cases the wind machines did not operate because there were batteries missing from the equipment or the machine was not tuned properly for the efficient protection of the experimental orchard. Apart from the improper use of the wind machine, such an installation is considered as too expensive for the size of an average kiwifruit orchard in Greece and the economic position of the average grower.

The water spraying system is a better alternative but requires accessibility to electricity supply. Irrigation in summer months is done with pumps powered by tractors or petrol machines which do not remain permanently in the orchard. Sometimes it takes more than an hour until underground water reaches the surface due to installing and de-installing the pumping equipment, therefore, this interval may be crucial for frost damage in the few morning hours when frost occurs. Farmers feel it is an unreliable method if electricity is lacking from the orchard because they cannot meet the emergency circumstances of frost occurrence with the available machinery they have.

Although the water spraying system is an investment within the economic potential of the average kiwifruit grower there are little initiatives given by the state or the extension officers. Since the kiwifruit orchards in frost-sensitive areas have been extensively damaged throughout the years, the best solution to the problem is currently seen to be the avoidance of kiwifruit cultivation in those areas. After close monitoring of frost occurrence it was revealed that there are pockets of frosts in the valleys of central Macedonia where severe frosts occur nearly every year. The plan is to avoid any new plantings in those pockets and to gradually abandon the existing orchards. The redesign of the region will be based on those areas where frost was minimally recorded in the past, however, the installation of a water spraying system may be necessary in some orchards but not in all the orchards in the region.

The outcome of the interviews conducted during the visit is a good information material for the completion of the thesis. In general, there is a positive attitude towards diagnosing the current production situation and the development of an integrated fruit production system for kiwifruit in Greece. This diagnostic approach was seen as the
preliminary stage to the design phase and there is good agreement from all the people interviewed that there is room for improvement.
Appendix III

The kiwifruit of cultivation

The kiwifruit of cultivation are large-fruited selections of *Actinidia deliciosa* var. *deliciosa* (formerly called *Actinidia chinensis* var. *hispida*), and is a member of the family *Actinidiaceae*. It is a dioecious, deciduous, perennial climbing shrub, indigenous to China, where it grows as a vigorous vine on the margins of temperate forests of the mountains and hills of south-western China. There are more than 50 species and 100 taxa in the genus *Actinidia*, mostly of east Asian origin, although some species occur over a wide geographical range from Siberia to Indonesia; about seven species are grown in different parts of the world for their ornamental value, but only a few species, *Actinidia deliciosa, Actinidia chinensis, Actinidia arguta, Actinidia kolomikta, and Actinidia eriantha* produce edible fruit, best of these being *Actinidia deliciosa*, the Chinese gooseberry or kiwifruit (Ferguson, 1990).

It was first grown in New Zealand in the early 20th century from seed obtained in China and vines from these seeds first fruited in 1910 and all New Zealand kiwifruit varieties are thought to have descended from these vines. Recently seed introductions have been made from China and the progeny will be used in long term breeding programmes to produce improved varieties.

The potential of kiwifruit as a commercial fruit crop was first considered in the 1930’s and several more small plantings were made in the 1940’s. Since then there has been a steady development of plantings and production and nowhere in the world has the kiwifruit attained the commercial development and consumer acceptance that it has in New Zealand (Sale, 1985). Although kiwifruit plants were introduced into many countries in the 1970’s, it was only after 1980 that the area planted in any country, other than New Zealand, exceeded 1000 ha (Warrington, 1990). Californian kiwifruit plantations in the USA hold a leading place for kiwifruit production today and Europe’s kiwifruit industry has very rapidly expanded over the last 15 years mainly in Italy, France and Greece (Costa et al., 1991). Many other countries, such as Australia, Chile, Japan, South Africa (Warrington, 1990), and British Columbia in Canada (Warner, 1989), have also become interested during the last decade in the commercial cultivation of this crop.

The fruit is about the size of a hen’s egg with a brown hairy skin and the exterior of the fruit is not striking in appearance, but when cut it shows an attractive interior. The flesh is green and a cross section of the fruit shows a pattern of lighter coloured rays, interspersed with numerous small dark seeds, radiating from the centre. Ripe kiwifruit has a refreshing, delicate flavour and it can be eaten on its own as a fresh fruit or combined with other fruits in salads and desserts. It also has a variety of culinary uses and is high in vitamin C content. Fruit of the different cultivars differ slightly in shape (Fig. I), ‘Bruno’, for example, being considerably more elongated than other cultivars, however, in terms of production and adaptability, the most widely grown is the ‘Hayward’ which is superior in keeping qualities to all cultivars presently available.
Figure I  Typical fruit shape for several commercial selections of kiwifruit (natural size)

(No photo. Dimoulas, 1988)
Annual Growth Cycle

A typical annual growth cycle of the kiwifruit cv. 'Hayward' is shown in Fig. II. In the climatic conditions prevailing in the most of the commercial kiwifruit-growing areas in Greece and other Mediterranean countries, the first sign of growth after winter is bud swell in late February. Bud break subsequently occurs in late March-early April and at that time a burst of new root extension begins (Paloukis and Dinopoulos 1989, Davison 1990). The corresponding months for New Zealand are late August and late September-early October respectively (Davison 1990).

The various stages of bud break and early shoot development, as described by Brundell (1975), are shown in Fig. III. Further intermediate stages were used by Snowball (1985) to define early shoot development. Following bud break, shoots then extend rapidly and flower bud development and enlargement occur concurrently. The flower buds open in late November-early December (S. Hemisphere), some 2 months after bud break.

After pollination and fruit set, the young fruitlets expand very rapidly both in length and circumference; the rates of length and circumference growth are very high for the first two months but are much slower and almost constant subsequently. The curve of volume growth from anthesis appears to be double-sigmoid in form, but the curve form is not strongly developed (Fig. IV). In contrast, the increase in dry weight with time is approximately linear from soon after anthesis until a few days prior to harvest maturity (Davison 1990). Pratt and Reid (1974), studying cv. 'Bruno', similarly suggested a sigmoidal curve of growth, with two slight rests in the curve following the early rapid growth phase.
Figure III  Shoot bud development in kiwifruit cv 'Hayward'. bs, bud swell; abs, advanced bud swell; bb, bud break; abb, advanced bud break; oc, open cluster; aoc, advanced open cluster.

(After Brundell 1975)
Figure IV  The changes in kiwifruit cv. 'Hayward' fruit dimensions - volume, dry weight, length, circumference - from pollination until harvest. (Davison 1990).
The rate of main cane growth declines in about mid to late July (S. Hemisphere: January), particularly as the competition of shoots with a heavy load of fruit becomes more marked; the decreased cane growth coincides with high rates of fruit growth. By August (S. Hemisphere: February), much of the extension growth of the longer canes has ceased and any growth occurring after that time is usually the development of 'water shoots' from older wood. Male cultivars without any fruit load tend to show vigorous shoot extension throughout the growing season until cooler autumn temperatures occur.

Fruit matures to a satisfactory harvesting stage by early October (S. Hemisphere: May), approximately 150 days after flowering. This stage has been defined for practical purposes as the time when the concentration of soluble solids in the fruit reaches a minimum of 6.2% (Harman 1981). Later, leaf fall commences. In the absence of frosts, leaves may persist well into warm winters, but it is usually the arrival of autumn frosts which hastens the onset of dormancy.

In Greece, (Dimoulas 1988), the dormancy phase of the vine generally then lasts from leaf fall (October - November) through until late February, when swelling of buds indicates the commencement of the new season.

References


Appendix III


