THE PLANNING AND MARKET SCOPE FOR A HYDROPONIC TURNKEY OPERATION

by: Mr Julian S.Wright

M.Phil Degree Thesis
1980

The Interdisciplinary Higher Degree Scheme
University of Aston in Birmingham

Abstract.

The company, Dunlop Ltd were considering the market for possible turnkey hydroponic systems, and this thesis was initiated to assess that market potential. Examination of alternative hydroponic methods showed that the most commercially viable systems were the nutrient film technique (NFT) rockwool and possibly forms of aggregate culture. The controlled - environment horticulture (CEH) industry was surveyed indicating that the 'greenhouse parks' can be a target market for a company supplying turnkey-style NFT equipment and services.

Partly on the basis of this assessment, Dunlop Irrigation Services (DIS) acquired Soil-less Cultivation Systems (SCS) Ltd. in November 1978. Subsequently plans for expansion were formulated and suggestions for the internal organisation of SCS are made following work experience in the order processing function.

Finally, the market scope is considered for further product and service opportunities, including the incorporation of micro-electronics into the control units for NFT systems.

Key words:
Hydroponics
Soil-less cultivation
Nutrient film technique (NFT)
Market potential
Turnkey

Preface.

This project was founded on the co-operation between the Interdisciplinary Higher Degrees scheme at the University of Aston in Birmingham and industry; in this case Dunlop Ltd. In this way practical problems are tackled with a nomadic and multi-disciplinary approach. A feature of the scheme is the benefit derived from involving people with different backgrounds in the project so gaining useful knowledge and problem-solving experience.

I am most indebted to my industrial supervisor at Dunlop, Dr. G.D.T. Owen and manager at Soil-less Cultivation Systems, Mr. M.A. Anselm. For their appreciative guidance, I am also indebted to my I.H.D. tutor, Dr. D.J. van Rest and university supervisors Dr. W.A. Hayes and Mr. S.N. Woodward.

Thanks are given to the staff and friends at I.H.D. and Dunlop Irrigation Services, particularly to Mrs. J. Eames for typing. Special thanks are due to Mr. C.J. Long and all the staff at SCS Ltd.

This project was supported by Dunlop Ltd. and by a studentship from the Science Research Council.

CONTENTS

CHAPTER 1 Project Background and Organization

1.1 Description of the Industrial Base

1.2 Origin and Purpose of Project

1.3 Organization of the Project

CHAPTER 2 Literature Review

Page

CHAPTER 5 Market Entry By Dunlop Ltd

5.1 Options for market entry

5.2 Soil-less Cultivation Systems Ltd until 1978

5.3 Strategic discussion

CHAPTER 6 Service And Produce Developments

6.1 A service development

6.2 A product development

Page

CHAPTER 7 Comments And Conclusions

List of Tables

List of Tables cont.

List of Figures

List of Figures cont.

LIST OF APPENDICES

CHAPTER 1

PROJECT BACKGROUND AND ORGANIZATION

1.1 Description of the Industrial Base

1.1.1 Introduction

Hydroponics may be described simply as the growing of plants in the solution of nutrients necessary for plant growth, rather than directly in the soil.

It is important to point out initially therefore that the project area is not directly concerned with irrigated agriculture, the main activity of Dunlop Irrigation Services. For this reason DIS has been entitled 'the industrial base' rather than 'the company'.

DIS provided a background against which the project could take shape dependent on the discovered market scope for hydroponics. In turn, the market scope was dependent on the hydroponic techniques available.

This chapter serves to describe DIS and explain the original project brief and thereby place in perspective the subsequent development of the project.

1.1.2 Dunlop Holdings Limited

As a group of companies, Dunlop operates throughout the world and has an annual turnover in excess of £1,300 million. To many people the name is synonymous with tyres, mattresses or golf balls. Indeed, sixty percent of the turnover still comes from tyres.

Meanwhile, diversification into other products and markets is being pursued. In the Dunlop Annual Report for 1976, it was stated that 'we have moved from selective containment to selective expansion'.

Represented in Figure 1 are the major operations of Dunlop Holdings. This Holding company was created in 1971 following the union with Pirelli SpA and Société Internationale Pirelli S.A. The three parent companies are not part of the union and each continues to administer its own subsidiaries.

Figure 1 - Organogram of the Dunlop group of companies

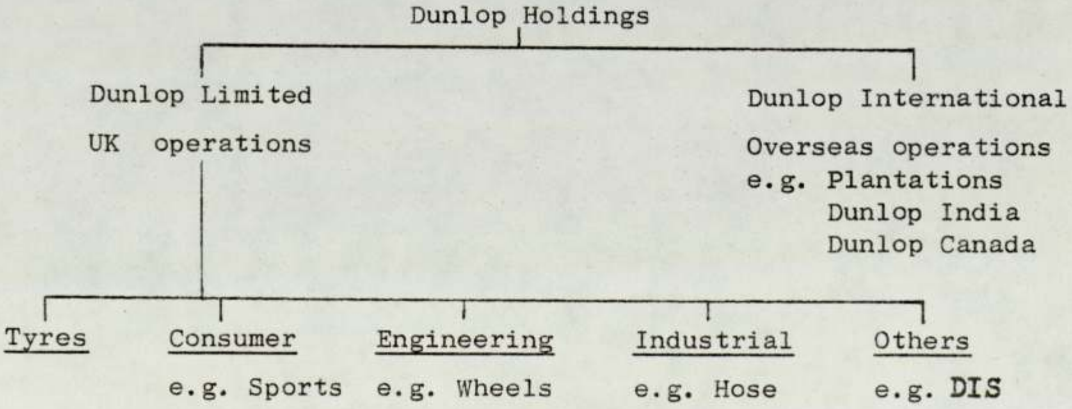


Figure 1 gives an indication of the present range of Dunlop's activities. Part of this is in the agricultural sector.

For sixty years, estates totalling 60,000 acres of palm oil, cocoa and rubber have been farmed and managed in Nigeria, Sri Lanka, Brazil and Malaysia.

Dunlop companies provide a range of products which are used in different facets of irrigation and water management. These include rubber membranes for canal and reservoir linings, specialised hoses for travelling irrigators, pumps and syphon tubes, collapsible water storage containers and elements for filtration equipment.

1.1.3 The irrigation market

With a projected world food demand in the year 2000, twice that of 1975 (2.1, 2.2), the need for improved agricultural output is being recognised. In the developing countries as a whole it is estimated that, in order to achieve an adequate nutritional standard, the increase in food supplies will have to exceed 250%.

It is imperative that the agricultural resources are managed in such a way that production is maximised without causing any deterioration of the prime physical resources of soil and water. In many parts of the globe, new land has been made available for agriculture through irrigation, but there are limitations (2.2).

Over-use of the scarce water resources is a frequent problem. The Food and Agriculture Organization (2.1) has commented that 'improved water management can do more towards increasing food supplies and agricultural income than any other agricultural practice'. Soils are often poor in minerals and do not respond to irrigation. To obtain an adequate return in yield, an appropriate amount of fertilizer must be applied.

In addition, evaporation in warm latitudes from open reservoirs and canals must be taken into account. These water courses are often short-lived since they become filled with silt or damaged by climatic conditions or maltreatment.

Erosion from stripped lands presents such a problem that agricultural methods such as cropping patterns, need to be carefully chosen.

Irrigation projects in the past have often not functioned effectively because each development stage was divorced from the others. Incorrect assessment of the environment and needs of the customer can result in the installation of poorly suited equipment and mismanagement.

Therefore, equipment supply, installation and management needs careful co-ordination. It is to this market need that the attention of Dunlop has been attracted.

Estimates of the size of such a market are necessarily tentative but there are indications of rapid growth in sales with a large potential. This view is based on enquiries received by Dunlop and projects known to be under investigation by other companies.

The size of the developing countries' market for sprinkler irrigation equipment (on-site above ground pipelines, pumps and sprinklers) was estimated at £100 million in 1977. The trickle irrigation market was perhaps half that figure. It is more difficult to estimate the market for underground pipelines, pumps and ancillary equipment used in irrigation but this may be measured in hundreds of millions of pounds.

The Middle East and North Africa together, probably account for about a third or a half of the developing countries' market.

As a result, the irrigation industry was chosen because it offered particularly good growth prospects and seemed more relevant to Dunlop than the alternatives of fertilizers, agricultural chemicals or equipment.

1.1.4 Dunlop Irrigation Services

1.1.4a The turnkey approach

Following an investigation into the irrigation market by the Corporate Planning Division in 1970-75 a small unit, Dunlop Irrigation Services was established at Thame, Oxfordshire in April 1976.

DIS is not simply a marketing outlet for Dunlop equipment. The intention is to provide a full range of capabilities to undertake every aspect of an irrigation project from its conception until it is handed over, as a complete running package. This 'turnkey' approach to projects is greatly favoured by Third World governments who recognise their own shortcomings in management and technology.

A turnkey operation can involve the following stages:-

- feasibility studies for selected sites
- planning for design, development and finance
- design, often via a pilot project
- preparation of tenders for irrigation development
- supervision of construction and installation
- commissioning of the project
- training of local operatives
- operation and management of part or all the farm
- servicing of equipment
- technical consultation service

However, it is not expected that most projects will include all these functions, since customers contract out only in those areas where they feel deficient.

At the largest organizational level in particular, there are mutual interactions between the staff. An example is the costing of engineering specifications. Several projects in progression at the same time also causes the overlap of any stated functions in the multi-disciplinary team that is DIS.

1.1.4b Competition

Economic entry barriers into irrigation equipment manufacture are low and therefore there are a large number of manufacturers, located mainly in the USA which has a large home market.

There are approximately seven manufacturers competent for international supply of centre pivot equipment, at least twice that number of solid-set/hand-move equipment manufacturers and a large number of trickle/drip irrigation equipment companies.

In the turnkey sector many companies and consortia are attacking the market.

Examples of British companies alone are:

Tate and Lyle Co. Ltd.	Farmkey Ltd.	
British Livestock Ltd.	Masstock Ltd.	Bookers McConnell Ltd.

From the USA there are several companies with turnkey irrigation capabilities such as Ball Agronomics Inc. In addition companies from Australia (Dalgety Ltd), from New Zealand, Holland, Ireland and Italy also contribute to a competitive market. Nearly all are better established than DIS which may mean a difficult market penetration period.

However, the market can be divided into rough segments. Companies such as Masstock and British Livestock for example, concentrate on livestock and associated fodder crops. Furthermore, by approaching the irrigation market firstly from a turnkey standpoint, and by including such facilities as finance identification, an almost unique service is sought.

1.1.4c Finance

The approximate composition of profit elements in a turnkey project, as represented in Table 1 can reflect the emphasis given the feasibility study and design/installation capability.

Table 1 Turnkey composition

Elements	% of total price	net contribution % of selling price
Feasibility study	1 - 2	high, $\leqslant 50$
Infrastructure	30 - 50	5
Farm equipment	20 - 30	10
Irrigation	20 - 30	20
Design and installation of equipment	5 - 10	high, $\leqslant 50$

For the establishment of a new business such as DIS, funds supplied via Head Office would be paid back over a three to six year period. This is especially necessary when the time scale for development of an irrigation project (in the region of two years) is considered.

There can however be a favourable cash flow within these periods since payment for projects may take place in stages, prior to the carrying out of contracted work. In 1978 however, there is still a negative gap, as expected, between sales turnover and operating cost. A breakeven phase may be reached in 1979.

The projected turnover in 1981 is £18 million. After overheads in the region of £1.38 million have been deducted, a profit of around £1.14 million is forecast.

1.1.4d Strengths and weaknesses

Implicit in the operation of DIS are certain strengths and weaknesses which may be identified.

Strengths:

- Dunlop name provides credibility/entrée
- the group has had a long experience in international operations with a range of technologies requiring an innovative awareness
- a co-operative company in Saudi Arabia has been established.
- tie up with a USA company gives some technological edge plus large market opportunity

Weaknesses:

- no Dunlop experience in this market
- some shortage of staff with relevant experience
- organizational problems comensurate with the establishment and development of a new business
- no home market
- established (strong) competition

1.1.4e Strategy

As a result of the preceeding considerations, DIS's strategy has five main objectives:

1) The pursuit of turnkey irrigated agricultural projects.
2) The sale of equipment relevant to the irrigated agricultural sector. (Some manufactured already by Dunlop, but mainly bought in products.)
3) To seek product manufacturing opportunities for Dunlop either through existing resources, own innovation, or acquisition of companies with relevant skills and strengths.

4) In conjunction with 3) to seek out special areas of growth and opportunity within the irrigated agricultural sector.

5) Geographically, to concentrate almost exclusively on the Middle East and North Africa.

1.2 Origin and Purpose of Project

1.2.1 An introduction to hydroponics and its history

Present day hydroponics is a more sophisticated revival of methods initiated over three hundred years ago.

The Hanging Gardens of Babylon may have utilized some form of hydroponic growing (3.1). Rice paddy fields may also be referred to as a half-way stage to true hydroponics.

In 1666, John Woodward (3.2) grew spearmint in water, with and without the addition of a small quantity of soil. He reported that the addition of the soil to the water increased plant growth. The technique was subsequently used quite frequently for research purposes and became known as 'water culture'. This situation illustrates that although agriculture and horticulture had attained a relatively high standard, there was little understanding of the manner in which crops obtained their nourishment.

By the middle of the 19th century, with improved scientific understanding, Jean Boussingault (3.1) had introduced controlled studies of the growth of plants in sand, quartz, and charcoal, to which solutions of known chemical composition were supplied.

During the period 1860 - 1920 a large number of formulae for standard solutions were published, notably by von Sachs, Knop, Pfeffer and Hoagland. It was the work of Julius von Sachs that really laid the foundation of modern hydroponics so that, Gericke (3.3) could first attempt to develop the commercial potential in 1929. He reported that the results he had obtained justified a serious consideration of the method for crop production.

Commercially, hydroponics only began to evolve during the last forty years, stimulated in part by the need to supply troops with fresh vegetables in arid areas (3.4).

Since then a vast amount of research has been carried out covering all facets of the subject from large-scale production of foodstuffs and ornamental plants, down to experimental and household units.

The revivival of interest in hydroponics is illustrated by the formation of the International Working Group on Soilless Culture (3.4) in the 1960's. With its fourth world congress in 1976, 166 active members from 41 countries were attracted.

The evolution of the subject has produced some possibly confusing terms, including that of 'soilless,' as in IWOSC; it is used synonymously with 'hydroponics'. The latter was in fact first coined by Setchell in the 1930's from the Greek for (hydro) water and (ponous) labour.

The main hydroponic methods considered in this project are the nutrient film technique, rockwool and aggregate culture. Their finer description follows in Chapter 2 but a central feature of hydroponics is the growing of plants in the solution of nutrients necessary for plant growth, rather than directly in the soil.

1.2.2 Relevance to the strategy of Dunlop Irrigation Services

DIS was set up in order to explore and exploit opportunities for Dunlop in irrigation and allied fields (see section 1.1.4e).

How therefore does hydroponics qualify both as an 'allied field' and as an 'opportunity'?

Where conventional agriculture or horticulture is not practicable, hydroponics may be. This tends to make it complementary to irrigation. Additionally, hydroponics may economically replace some conventional methods of horticulture.

It is in the semi-arid regions where DIS operates, that hydroponics most obviously may be applied to advantage. It was thought therefore, that an offering of an irrigation and hydroponic turnkey capability would give a competitive edge in the Middle Eastern and North African markets.

A preliminary study by DIS staff indicated that hydroponics was a rapidly growing business opportunity. Available literature promulgated a series of advantages implicit with hydroponic growth although an accurate cost-benefit analysis was not apparent; partly because the literary sources were often 'hydroponic enthusiasts' rather than commercial practitioners.

It was recognised by DIS that to evaluate 'the market scope' for hydroponics entailed a relatively objective investigation. At this point the project was initiated.

1.2.3 Initiation of project

In mid-1977 a project to start in October was initiated in collaboration with the Interdisciplinary Higher Degrees scheme at the University of Aston in Birmingham. The title was **initially** 'The market scope for equipment required in hydroponic culture', **to start in October, 1977.**

The objectives outlined in the project brief reflected the approach taken to hydroponics at this stage by DIS.

The project brief:-

1 To assess the current state of hydroponic technology.
2. To assess market opportunities, particularly in third world countries for hydroponic culture.
3. To assess the capacity of Angus Fire Armour (i.e. Dunlop) to manufacture and supply hydroponic equipment, and the likely profitability of such a market development.

A further general objective later appreciated was the need to develop a strategy whereby Dunlop may exploit the 'hydroponic market', whatever that may be. Following a literature review, Chapter 3 explains how this subsequent requirement was realised

1.3 Organization of the Project

1.3.1 The student's role

A team of supervisors is appointed, in this case one from the company, and three from the university. To these the student is accountable, providing them with at least quarterly progress reports. In turn, they are responsible for the guidance, where needed.

Supervisors' meetings, including the student, need to be held at quarterly intervals if appropriate, or when events occasion it. Here important implications for the project can be discussed in order for agreement to be reached on its future direction.

In particular, the student is responsive to the industrial supervisor for his work within the company. This helps to ensure that useful answers are sought to the right problems for the industrial organization.

In this project, approximately sixty percent of the time was spent with the company. Regular attendance at both bases enabled the unique facilities of each to be used and supervisors to be met.

1.3.2 Planning

It was soon discovered that a substantial technical understanding was needed 'to assess the current state of hydroponic technology', the first objective in the project brief.

Information had to be gathered from various sources and collated in an organized fashion. It is in the second function that techniques appreciated from the coursework were particularly applicable.

During the period of orientation, it was first necessary for the student to be aware of his terms of reference, and familiarise himself with the structure of the firm and how decisions are arrived at within the firm. The latter necessarily has wider implications in that interactions within the firm, its business and general environment need to be appreciated.

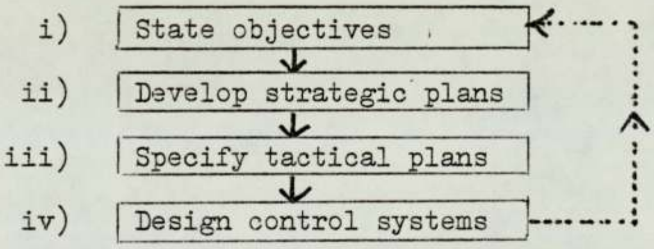
As an aid to this task the perhaps vague concept of the firm as 'an area of unified business planning' (1.1, 1.2, 1.3) was helpful This concept appears regularily in marketing literature.

Ward (2.1) suggests that:-
'Change is seen in terms of interacting commercial, economic and innovative forces, particularly those which operate between a company and its environment.' Ward further develops a theme of'dynamic planning'in marketing.
Hence,this section is devoted to a marketing assessment as a prelude to managerial decisions.

General Eisenhower was reputed to have said (1.2):-
'In preparing for battle I have always found that plans are useless but planning is indispensable.'

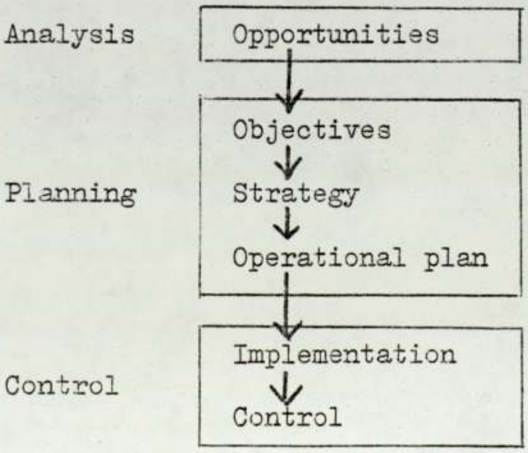
Marketing may be described as 'market-orientated planning' (1.1). The sequential stages in the planning process are shown as a closed-loop flow chart in Figure 2a (1.2).

Figure 2a Four sequential stages of planning



Thereafter Chisnall stresses four general features of an effective marketing plan namely; unity, continuity, flexibility and precision. Kotler (1.1) includes additional features as in figure 2b(adapted).

Figure 2b Steps in the strategic marketing process



The discord between the models is essentially that of illustration rather than approach, since the basic elements of objectives, strategy, tactics, and control are still present. Table 2 has been constructed (based on Kotler) to illustrate the logic of the project.

Table 2 <u>A breakdown of the marketing function</u>

Stages	Methods	Effects
Determining	Market intelligence	Collection of
objectives	Internal accounting	market data
	system	
	Marketing research	Identification of
	Management science	market opportunities
↓	Market segmentation	
Planning	and targeting	Demand measurement
of strategy	Costing for product	and forecasting
	mix and life cycle	Budgeting
	R & D requirements	Product strategy
	Technical and	i.e. items, range
↓	manufacturing	promotion etc.
Planning	capabilities – decisions	Production
of tactics	Channel and price	Distribution and
	decisions	seasonal sales etc.
↓	Organization and	Staff structure
Control	communication decisions	Service facilities
of	Sales force and	Market feed back
implementation	advertising decisions	Sales and contribution

Kotler emphasises the 'open-mindedness' helpful during analysis of opportunities as a preliminary to planning. This advice is noted when introducing hydroponics in an attempt to avoid a blinkered understanding of the subject area. Chapter 2, the literature review, performs the role of an initial analysis of opportunities.

From the objectives outlined in the following section the strategy and tactics for a hydroponic equipment and services company were developed in Chapter 6. Meanwhile Chapter 3 assesses the market scope for hydroponic technology and Chapters 4 and 5 analyse the background to the company as a basis for its future plans and implementation.

1.3.3 Objectives at the half-way stage of the project

After seven months the acquisition of a small hydroponic company became a very real possibility. This event had not been planned for such an early stage but the opportunity and potential appeared suitable, at that time in June 1978.

A supervisor's meeting on 6th July determined that the project and thesis format should be orientated towards a likely company acquisition by September. The minutes of this meeting are included in Appendix C.

The general objectives given by the project brief (see Section 1.2.3) needed clarification for two reasons. First , a hydroponic market entry strategy was required with particular systems and markets in mind. Second, it was helpful to make the objectives as concise as possible, avoiding platitudes, which enables easier and measurable action upon them.

With reference to DIS's strategy (see Section 1.1.4e) the objectives evolved more clearly over the initial six months, particularly via supervisor's meetings into (i) - (viii) as follows:

to determine

(i) the technical features and advantages of hydroponics in (a) UK, (b) Channel Islands, (c) Holland, plus general features of other European countries, USA and Middle East

(ii) the economic advantages versus costs to the grower in these areas

(iii) the present and future market size, segmentation and competition in these areas

(iv) the factors that most influence the growers' (customers') decision to invest in hydroponics

(v) appropriate systems for each area

(vi) which systems or parts of systems in which areas may be suitable for Dunlop to appraise

(vii) if there are any suitable companies which may be acquired by Dunlop

(viii) the likely sales and market share which are obtainable during the next five years.

As the project progressed three further objectives were added:

(ix) to help identify and derive a strategic plan for a known hydroponic company on a five year timescale

(x) to assess any areas of apparent need, particularly during order processing, in the acquired hydroponic company in the more immediate future

(xi) to summarize future market needs and services which may prove important to the development of the company.

It was also felt that the style of the text should serve as an introduction to hydroponics for newcomers to the industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

2.1.1 Criteria for evaluating the literature

The objective of this chapter is to critically appraise any relevant literature so that the project can coherently develop from an authoritative foundation. Accepted sources of information can be described and compared with any controversial, recent or ongoing work.

Hydroponics is approached from first principles its history having been briefly related in chapter 1.2.1. To facilitate description of the various systems a classification is outlined using diagnostic features in section 2.1.3.

For further convenience it is thought useful to distil the concepts of the 'subject area' and the 'project area'. The former is limited to hydroponics whereas the latter is concerned with the commercial application of hydroponics by the company.

Based on the issues identified in Chapter 1 the following preliminary criteria can be drawn up:-

(a) Novel and experimental systems are only interesting because ideas from these may help to improve commercial systems.

(b) We are concerned primarily with the commercial production of foodstuffs and ornamentals. Only secondly would exploitation of the leisure or novelty markets be considered,

(c) The selected systems should be potentially compatible with the semi-arid markets on which DIS is concentrating. However, it is recognised that establishment in other markets first may be desirable.

(d) The existence of commercial-scale operations would provide a good recommendation as to a system's feasibility.

At this stage it is to be noted that very little, if any, financial or management details are found in published subject literature. Although inferences such as 'costly' or 'inexpensive' are frequent any data which may be added would be difficult to assess due to the widely varying locations and dates of the sources.

Data on yields are also difficult to compare because of the various seasonal cropping regimes (e.g. location, cultivars) and horticultural practices. Often it is not stated exactly how the yield has been measured, e.g. per plant, per m^2, per cropped or per uncropped unit area.

Therefore, after applying the four preliminary criteria it is necessary to summarize the advantages and disadvantages of the systems reviewed,to provide a limited quantitative assessment in Section 3.1.2.

2.1.2 The fundamentals of hydroponics

A fundemental common feature in all hydroponic systems is the 'nutrient solution'. Since these two words will occur frequently in the text they are hereafter abbreviated to NS.

All plants require a NS in some form and so where does hydroponics offer advantages over conventional agriculture? Ideally, hydroponics should be able to supply the NS in an optimal form. In order to explain the reasoning behind this statement this section is devoted to a necessarily brief appraisal of the factors affecting plant growth, particularly those concerning the roots.

Table 3 The basic requirements for plant growth

Factor		Shoot environment	Root environment
1	Light	Optimal amount	No
2	Darkness	Inverse of above	Yes
3	CO_2	During light	Not essential
4	O_2	During darkness	Yes
5	Temperature	Optimal	Optimal
6	Humidity	Optimal	Not usually applicable
7	Water	Usually not essential	Yes
8	Nutrition	Usually not essential	Yes
9	pH	Not applicable	6 - 7 usually
10	Support	To prevent collapse	Provided by soil (usually).
11	Space	To allow 1 - 10 and propagation	
12	Disease	Freedom from toxic compounds or pathogens	
13	Cultural practices	Appropriate propagation, supporting, pruning and other practices	

Essential nutrient elements are:

Macro - N, P, Ca, K, Mg, S

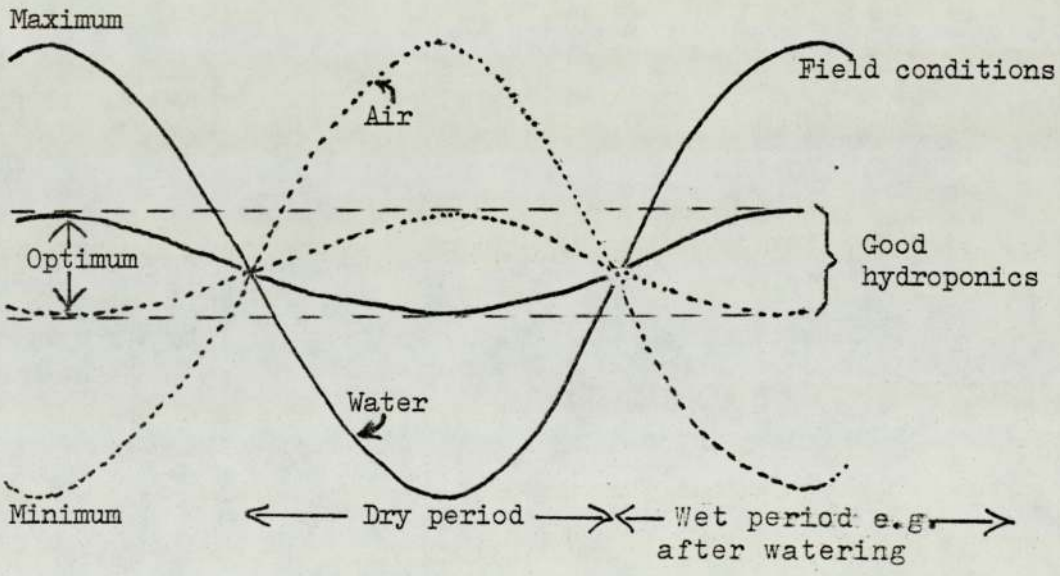
Micro - Cl, Cu, B, Fe, Zn, Mo, Mn

Trace - I, Al, Se, Na, Si, Co

The absorption of nutrients in ionic form is a metabolically active process and thus requires oxygen (4.1).

Figure 3 illustrates how a good hydroponic system may supply the roots with water (+ nutrients) and air (oxygen) better than conventional horticulture (3.7).

Figure 3 Water/air supply to plant roots in idealised field and hydroponic conditions



This periodic movement away from the optimum can occur even with the most specific irrigation methods such as trickle and drip.

Fertilizers added to the land in order to replenish the NS of the soil are those primarily of N, P and K. They can improve a yield up to a point when some other factor becomes limiting. That other factor could be water in which case irrigation possibly can be applied. The next limiting factor may be an accumulation of salts or some other deterioration of soil structure. Associated problems are those of evaporation and costly soil preparation which may include sterilization and the application of pesticides.

Two underlying reasons why these constraints are met can be seepage into the sub-soil and the fact that the soil is not inert. The soil has a physical, chemical and biological structure that requires maintenance or improvement.

In effect, the optimal association between roots and NS in the soil is difficult and often costly to control. Hydroponics offers greater control by providing a purpose-built root environment with potential for an optimally constituted NS which incorporates an inert, or nearly inert root medium.

Furthermore an effective root environment would be in darkness and providing the necessary support. In the soil the close contact between the substrate and roots required for access to the NS means the plants are anchored. At the same time the roots usually provide basal support for the shoot but this is not absolutely necessary. Such support can be applied to the root base, shoot crown, or at other positions on the shoot.

2.1.3 A classification of hydroponic systems

Open

After one irrigation the NS is not collected for recirculation. The NS may be retained in the medium for sometime but unused NS seeps away. In cases of high salinity some seepage may be necessary.

Closed

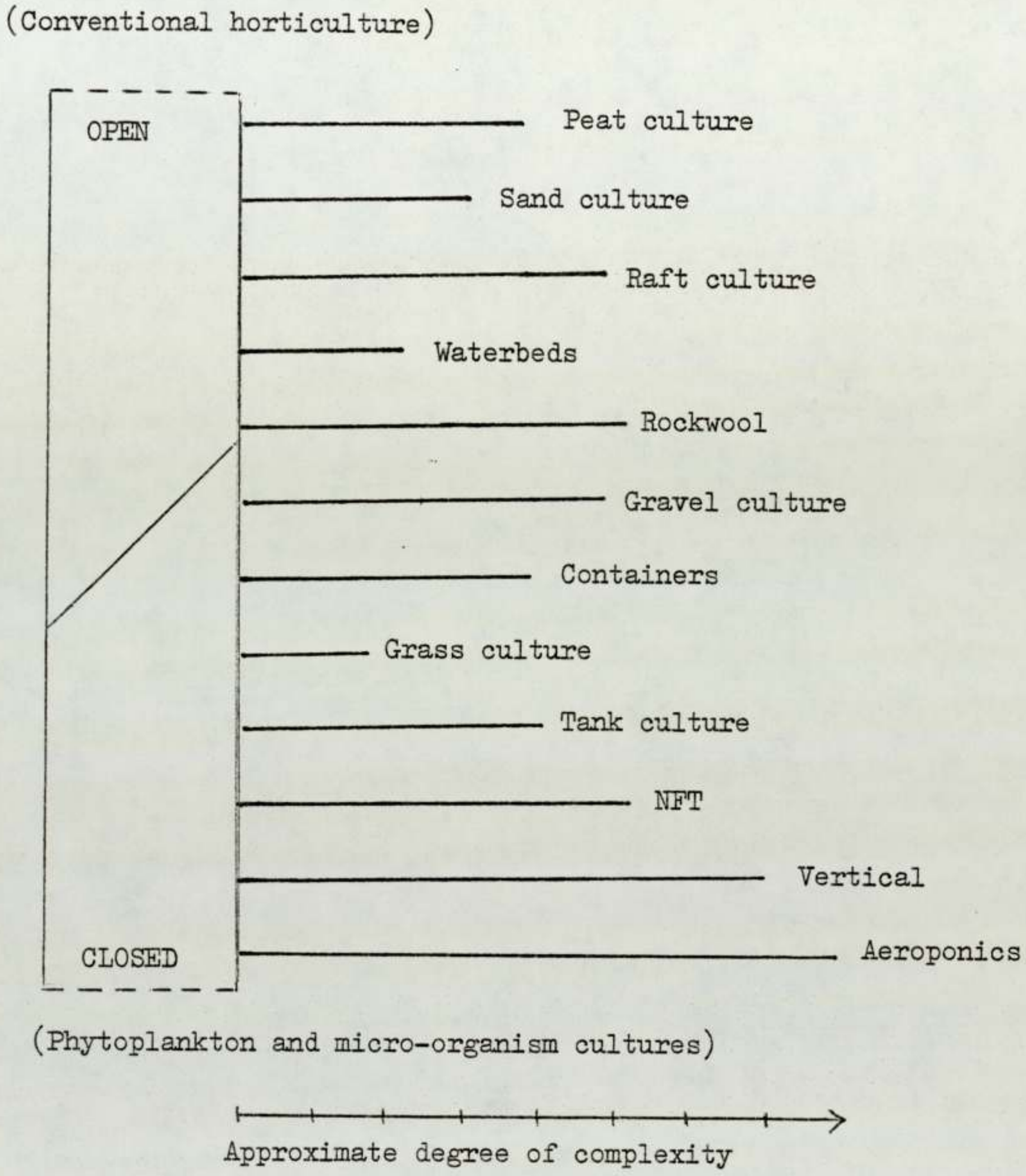
The NS is collected and recycled. Supporting inert medium, e.g. aggregate (or only the NS) is retained in water tight beds. A possible disadvantage is the accumulation of unwanted salts, phytotoxic compounds or pathogens in the recirculating NS. Although healthy plants usually have a high resistance to disease, some problems may occur. Information on this topic is notably absent from all but the most recent literature.

Stagnant

Unless nutrients and oxygen were kept available to the root surfaces, commercial production is impossible (3.1, 3.4). Agitation of the NS, if only by air bubbles, is required.

Figure 4 cites twelve systems to be reviewed classified by their location as open or closed systems. The degree of complexity is related approximately to the equipment required.

Figure 4 A classification of hydroponic systems



2.2 Narrowing the Project Area

2.2.1 Water beds

This term encompasses all uncovered, flooded beds from rice paddy fields in S.E. Asia to the water cress beds of England. Although a complete NS is not artificially created and monitored, the crop requirements are satisfied. Such established industries need large quantities of water and so are inappropriate to this project's criteria (see Section 2.1.1).

2.2.2 Raft culture

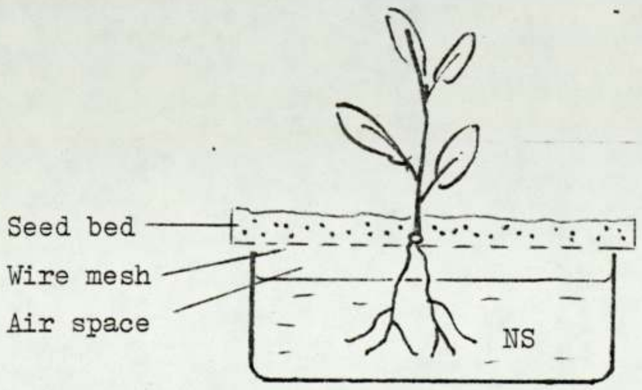
Seagrave (3.11) and others (3.4) have proposed complex rafts using networks of NS channels which can include a suspended bag of NS. Unless land is in short supply such an expensive apparatus seems unwarranted except as a novelty.

Possibly, if the principles of the waterbed and raft were combined salad crops or cereals could be grown, since each of these require least support and have the best resistance to poorly aerated NS. No work, however, along this line has been traced.

2.2.3 Tank culture

W.F. Gericke during 1929-36 (3.1) published accounts of tomato production which stated that in a basin of $9.2m^2$ 1te of good quality fruit could be grown in a year. With a constant temperature of 22 - 25°C the plants were grown to 7.5m in height within twelve months.

Figure 5 Gericke's tank culture



After the first flush of enthusiasm however, the method did not become popular largely due to the very high capital cost and degree of technical skill and experience that were needed.

The main feature of this system is the air space of 2.5 - 5cm which gives the roots access to oxygen, although aeration is still a problem particularily in damp or colder climates. Nevertheless, a similar type of tank culture is employed in Poland (3.9) and Japan (3.10) for the commercial production of some salad crops. The seed bed, in order to provide support and exclude light, has been made of various materials including dry hay, wood shavings, coarse moss peat and polystyrene blocks. Some control over aeration is achieved by adjustment of the NS level but usually injection of air into the NS performs the functions of both aeration and circulation.

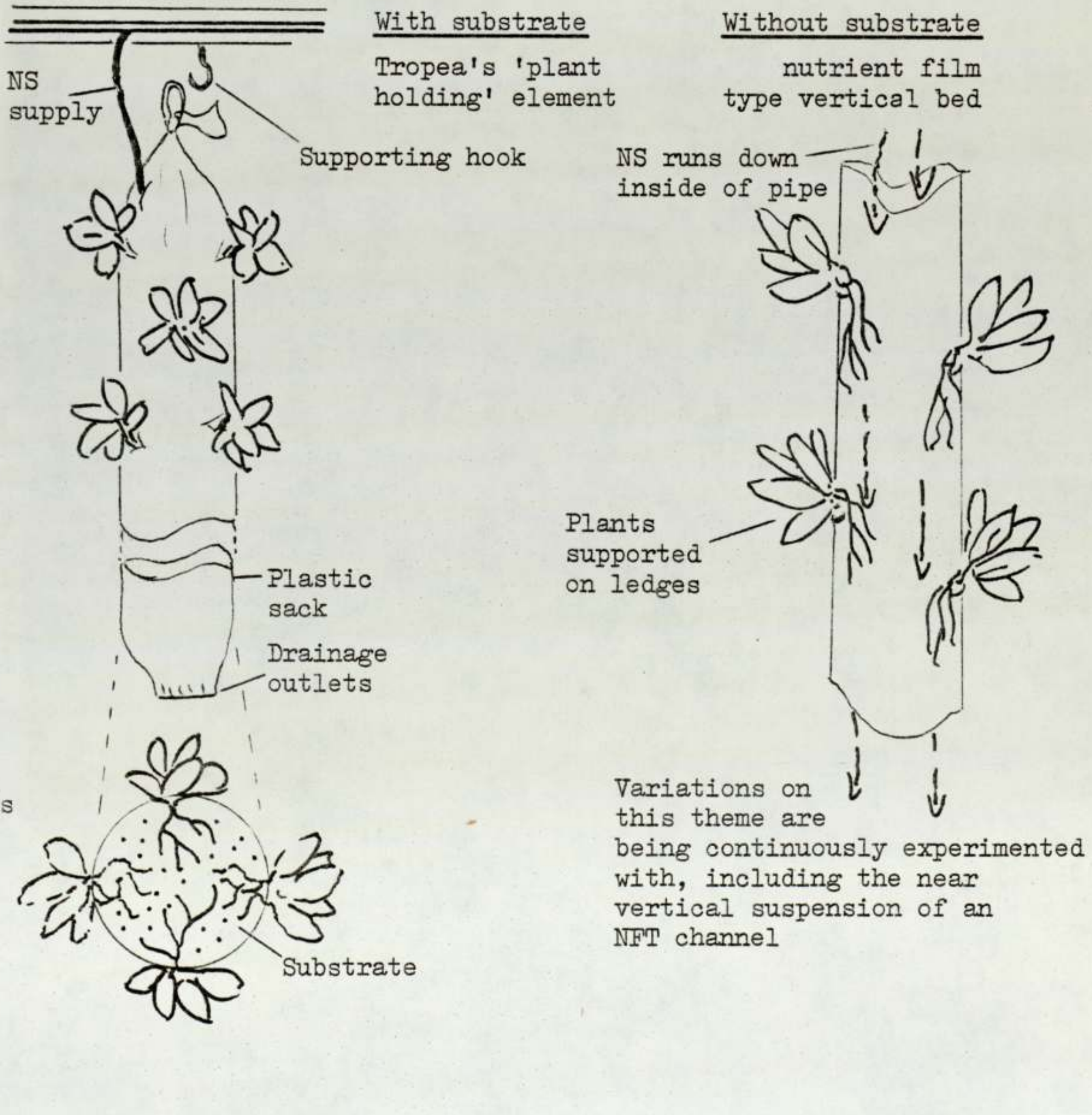
Air injection is also essential in Massantini's system (3.4) where no air space is provided since the seedlings are placed through holes spaced in floating polystyrene blocks.

Partly because of the need for protection, the apparatus appears confined to greenhouses, in areas with a supply of good quality water. Also needed is a market for high value salad crops, particularily those used for condiment purposes from the onion family. Massantini found that he could obtain greater yields than in the soil only because he could grow more plants per unit surface. He comments that 'the species from which we obtain leaves are more suitable to this kind of hydroponics than those from which we obtain fruits.'

2.2.4 Vertical culture

The least use of ground area may prove vital on oil rigs at sea or possibly (with increased costs) in greenhouses. An increase in yield may also justify the cost of above ground supporting frameworks. Tower greenhouses have been experimented with in the USSR (3.1) and by British Steel in South Wales but appear to be difficult to manage and otherwise uneconomic at present. In this section, beds such as those in Figure 6 are considered plus the possible layered beds of other systems such as NFT (discussed later).

Figure 6 Two examples of vertical culture systems



With substrate

Tropea's 'plant holding' element

Without substrate

nutrient film type vertical bed

Variations on this theme are being continuously experimented with, including the near vertical suspension of an NFT channel

The system without substrate illustrated in Figure 6, although meeting all the plant requirements becomes very difficult to set up and consequently impracticable.(DrA.J. Cooper; personal communication)

Plants dislodge from their outlet holes easily even once the NS covers the roots adequately. Especially when the plants grow larger, there is a large weight suspended from the above ground framework or greenhouse.

A third major problem is the need to pump excessive quantities of NS to the top of the beds, which may be over 2m in height, only for it to rapidly fall to ground level again.

M. Tropea (3.4) has developed a similar system but including light, soft substrates such as wood shavings, granulated cork and peat often mixed with 'agrilit.' These substrates are claimed to 'have a high water-holding capacity and allow a very good root aeration.' There are claimed to be 80,000m^2 of such beds in Compania, Italy. These consist of metal framed plastic tunnel greenhouses with reinforcements to carry the heavy beds. Only strawberry yields (at 200g per plant) are cited by Tropea although a passing reference is made; 'From the research works carried out recently in similar installations established in Sicily (one of which covers an area of 6,000m^2) it has been possible to notice that most of the vegetables, such as tomatoes, peppers, egg plants, cucumber, lettuce etc. have shown satisfactory adaption to this new cultivation system'.

Although both systems may improve working conditions with the vertical beds being spaced 80cm apart, light shading would be expected to cause a problem. Of the latter point, no mention is made (possibly due to a lack of practical experience). It is suggested that tomatoes which normally are trained to over 2m should not need a vertical system except possibly to get a greater number of early tomatoes. Similarly cucumbers and peppers would seem unsuitable plants for this system. In addition settlement of the substrates, with more water in the bottom half of the beds would be expected to cause problems. Once again, these issues are not discussed by Tropea.

Unless further acceptable work can substantiate the great potential claimed for such systems it is better to concentrate on more established hydroponic systems. Two further reasons for this decision are that water saturated tubes hanging from greenhouses in semi arid conditions appear contradictory even if a customer could be expected to make the large jump in cultural techniques or investment. The latter reason also appears to apply in W. European countries where a general enquiry amongst growers indicates a large consumer resistance to vertical culture.

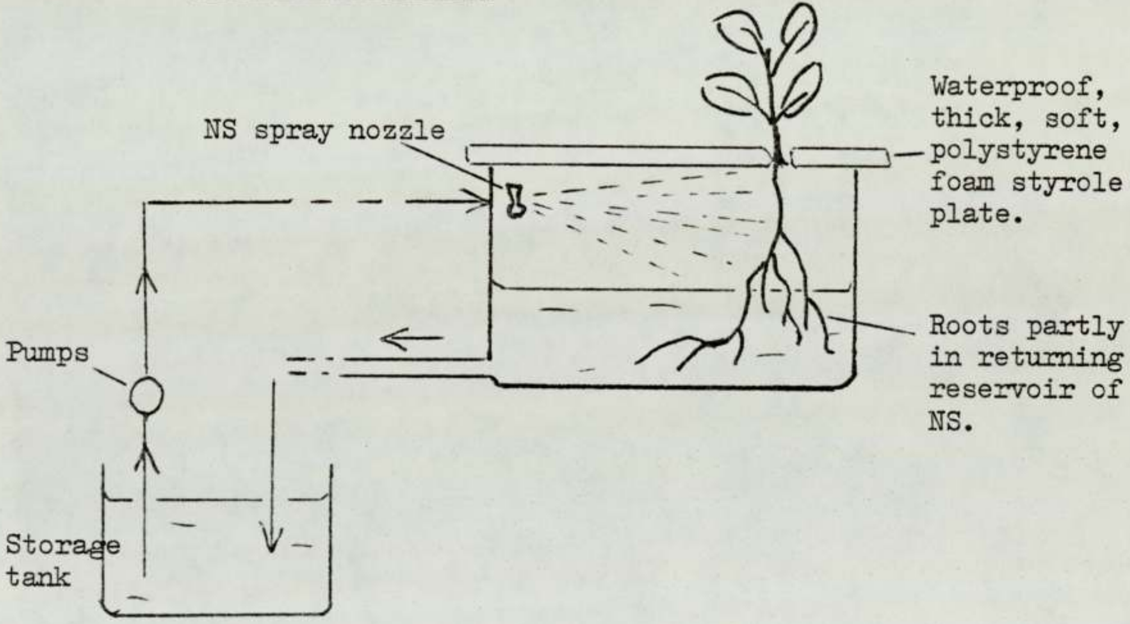
2.2.5 Aeroponics

This involves inserting the plants through apertures in vertical or horizontal closed containers through which jets force a NS spray. An immediate advantage apparent in an aeroponic situation is the plentiful supply of water, nutrients and oxygen. However, there are practical problems in creating this ideal root environment.

The plants need to be gently yet closely held in the containers at the shoot base and the spray has to be accurately and continually kept on the exposed roots. This arrangement requires high labour, material and energy costs which discourage investment even if the income from yields provides a good revenue Additionally, the problems implicit in vertical culture apply to vertical aeroponics. Hence, only horizontal aeroponics are a likely commercial prospect in the near future.

In a similar manner to tank culture semi-spray culture is used in Japan for high value salad crops as illustrated in Figure 7.

Figure 7 Semi-spray culture



A. Vincenzani (3.4) building on the work of Massantini has further developed a culture system called 'Colonna di Coltura'. Essentially it is a three layered aeroponic system. A 'hypothetical evaluation of production' for soil, general hydroponics and aeroponics is given as a yield ratio for egg plants of 24 : 40 : 60, after a trial of four months in 1976. Such results, although tentative, show the potential for giving plants ideal growing conditions, if practical and technical problems could be overcome.

However, for reasons cited in Sections 2.2.1 and 2.2.4 aeroponics in its present phase of development does not comply with the criteria defined, especially in view of the very high capital and labour costs.

2.3 Aggregate Culture

2.3.1 Introduction

'Soilless culture' is a term often used in reference to cultivation in peat, sand or a mixture of these and other partially inert particulate media. These can include: vermiculite, bark compost, kuntan, brown coal or even waste products from leather manufacture. It is in this area of overlap between conventional horticulture and hydroponics that most literature is available.

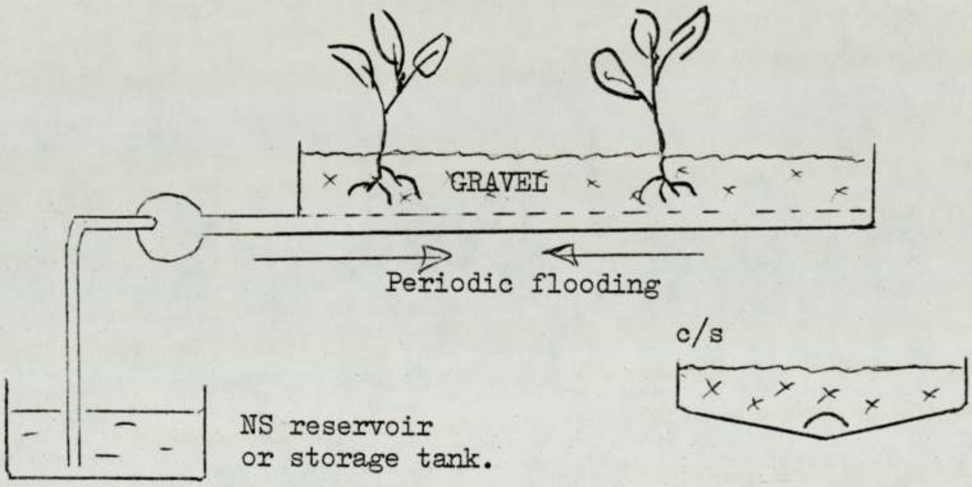
Peat 'gro-bags' are commercially marketed by several companies such as Fisons (7.1) Caledonian and Shamrock Irish Peat. In many areas of Europe the use of peat in horticultural markets provides the main competition for hydroponics (see Chapter 3).

Where sand constitutes more than roughly seventy percent of the substrate it appears to be regarded as a hydroponic medium by most sources, largely because some minor elements also need to be included in the NS, if not the trace elements. A.A. Steiner, the Secretary of the IWOSC (3.4) explains that 'In fine sand it is not possible to circulate the NS fast enough to bring sufficient oxygen to the roots by means of the NS itself. To improve oxygenation fewer irrigations have been tried but the differences between too dry and too wet are small. This is the main reason why sand culture never became a general success for commercial hydroponics, and research on this approach is declining. There are some exceptions.' These exceptions are discussed in Section 2.3.2

For these reasons, controlled circulation of the retained NS was desirable where the particle size is larger. Such closed purpose-built systems are termed gravel cultures.

The 'American system' for gravel culture was developed during the second world war, its principle being illustrated in Figure 8.

Figure 8 The American system for gravel culture

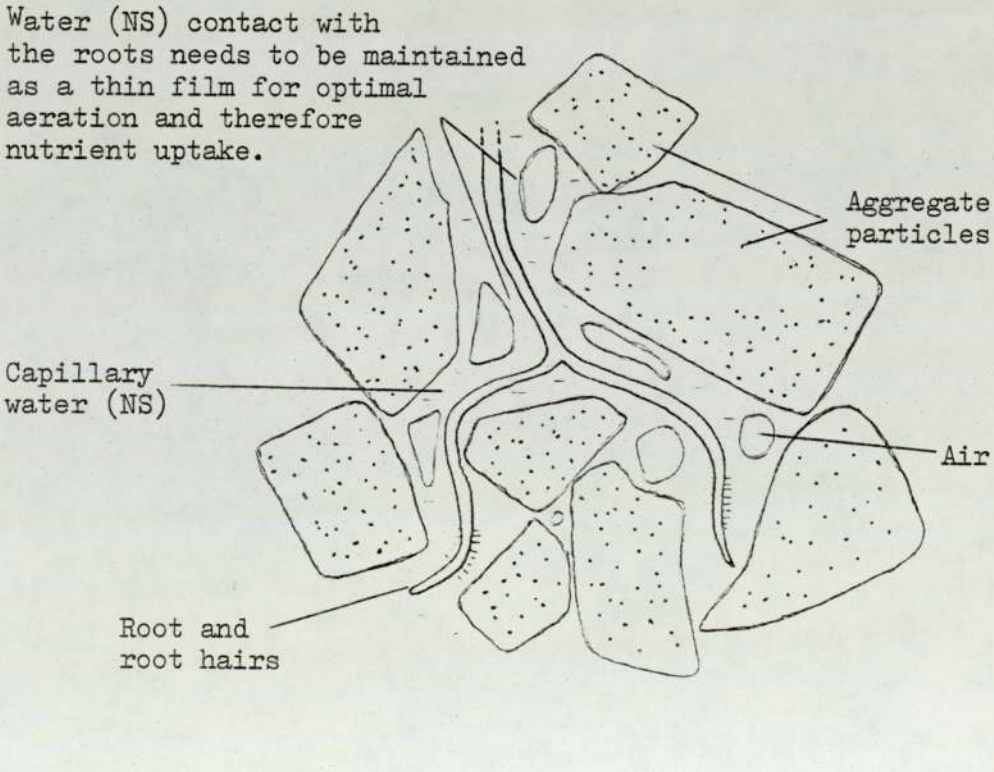


Up to 1968 (3.4) nearly every literature source mentioned that oxygen supply to the roots was excellent with this type of gravel culture. They all stated that with each periodic flooding any stale air will be driven out from the gravel while NS draining back into the tank will pull down fresh air with 21%

of oxygen. Although true this does not mean that the oxygen supply to the roots is optimal.

Diffusion of oxygen through the air phase is about two million times faster than the diffusion of oxygen through the water phase in the region of the roots. After each flooding a film of NS remains hanging on the roots and particles. The NS may completely fill up pores where roots are present, especially if smaller particles are not used between the larger ones. Hence, a prime purpose of irrigation is not to refresh the air in the substrate but rather the oxygen in the NS around the roots as illustrated in Figure 9.

Figure 9 The root - air/water interface in aggregate culture



Hence, attention must be given to this detail in the appraisal of any system, particularly those involving a substrate with pores wider than the diameter of the plant roots.

2.3.2 Sand Culture

This is essentially an open system although the beds of fine sand ($\leqslant$ 0.5mm) may be lined at a depth of about 30cm to conserve NS. In addition drainage tiles may aid aeration but the NS is not usually recycled. Drip, trickle or slop irrigation methods are used, often with a less than complete NS since minor and trace elements are available from the substrate. It would be expensive to include more nutrients than necessary because there is seepage (3.14 - 3.17).

Descriptions of commercial sand culture systems can be found from Douglas (3.1, 3.9) and occasionally in general horticultural textbooks (4.5), the latter indicating the close relation to conventional methods.

Manley Incorporated of the USA are believed to have at present 20ha of sand cultured tomatoes under polythene greenhouses whilst chrysanthemums, carnations and roses are grown outdoors on sand in Colorado. Meilland's nursery in the south of France is still successfully used for the breeding of roses with sand culture.

A noteable commercial operation is that of the Sadiyat Arid Lands Research Centre in Abu Dhabi as described by M.A. Alafifi (3.4), Miguel R. Fontes, Merle H. Jensen and Hardy M. Eisa (3.18 - 3.20). The latter three are based at the University of Arizona in Tucson, USA. In addition, press articles have publicised their work (7.1, 7.2). This centre is of particular interest in the project context since it is in Saudi Arabia and grows tomatoes, cucumbers and other horticultural crops.

In these desert areas there are frequent sand storms and the air is laden with salts from the sea. This, together with intense radiation necessitates protected cropping, in this case by polythene greenhouses. Most of the cities in these areas depend on desalinated seawater as a source of fresh water and import most of their food needs including fresh vegetables, since they are short of suitable land for conventional agriculture. This market is discussed in more detail later.

At Sadiyat, water is desalinated using excess heat from the diesel engines used for power generation. Commercial grade, water soluble fertilizers supplying macro-elements and technical grade micro-nutrients are dissolved in desalted water. The NS is then piped to the greenhouses and fed to the plants through a trickle irrigation system. Rock formation around the root areas did cause initial problems, the size of the deposits increasing with time until they became 15-30cm in diameter, depending on crop termination. Research to overcome this problem centred on the NS which is discussed separately; it is connected with the fact that the sand contains over 95% calcium carbonate. However, no breakdown of particle size is given except to say that it is a 'whitish, fine textured windblown sand.'

The yields from the station in 1972 are presented in Tables 4 and 5 (3.18) and these relative values do not appear to have altered appreciably up to 1976 (3.4).

Table 4 Comparative yield for a single crop grown in Sadiyat greenhouses vs field grown

Type of vegetable	Yield (tons/ha/crop) Sadiyat greenhouse	Good yield field grown US	Al Ain government farm
Tomato	159	67	15 - 26
Cucumber	229	27	20
Egg plant	240	19	30 - 49
Lettuce	56	24	20 - 30
Cabbage	70	27	49 - 70
Okra	52	11	30
Turnip	157	22	15 - 20

Table 5 Distribution of cultural periods for greenhouse and field grown vegetables

Type of vegetable	No days in nursery at Sadiyat	Growing period days		Harvest period days	
		Sadiyat greenhouse	Field US	Sadiyat greenhouse	Field US
Tomato	18	130	140	69	50
Cucumber	14	83	90	55	30
Egg plant	17	181	130	125	40
Lettuce	23	38	70	4	10
Cabbage	22	51	62-110	1	1
Okra	18	142	118	109	60
Turnip	-	65	40- 75	1	1
Radish	-	30	30	4	1

The yields at Sadiyat are generally much higher than field culture and even higher than many conventional greenhouse operations, due to the warm climate and high year-round solar radiation. Although many of the vegetables cited in tables 4 and 5 are not conventional greenhouse crops, e.g. turnips and cabbage, production in 1972 was to discover firstly if they could be grown, and secondly if they were commercially feasible. Altogether, fifteen kinds of greenhouse crops were sold locally and each was evaluated for marketability as well as productivity. After 1973 although the operation appears successful the published literature is scarce. This topic is discussed more fully in Chapter 5.

Apart from Sadiyat and other Middle Eastern hydroponic trials with sand culture e.g. Iran (3.4), Kuwait (3.21) and Kharg Is (3.22) sited near oil facilities , it does not appear that the area under sand cultivation has increased much since 1960-68 for several reasons. First , the market in most developed countries had only a gradual expansion. Second , other methods such as peat bags and aggregate culture emerged in competition. Third , attention has been drawn in recent years to energy saving measures as a priority on a par with the need for increased production. These issues are discussed later in Chapter 3.

2.3.3 Gravel culture

Section 2.3.1 discussed the benefits of a system with larger particles than sand for the substrate so that the NS could be retained and circulated, i.e. a closed system rather than an open sand system. Although these closed systems can collectively be termed 'gravel' a large variety of aggregates have been used.

The commercial potential of each will be a function of:

a) its availability and cost

b) the suitability of its qualities for particular crops

From trials at Jealott's Hill Research Station in Berkshire (1938-1946) and later work, Table 6 presents an overall guide to a medium suitable for most crops. For greater detail Douglas (3.1) and Schwarz (3.12) are two of the best known workers in this field with experiences of respectively 25 and 20 years.

Table 6 Guide to graded particle sizes for gravel culture

Media description	Diameter in mm	% by wt
Coarse gravel	5 - 10	15
Medium gravel	2 - 5	30
Fine gravel	0.5 - 2	35
Coarse sand	0.2 - 0.5	10
Fine sand	< 0.2	5

Table 6 is only a guide since seedlings and some commercial flowers such as carnations, chrysanthemums and roses prefer a generally finer medium.

Different yields are reported frequently with different media, the medium composition having several influential features:

1. A suitably graded medium allows the correct infilling by smaller particles to achieve optimal water capillarity and root penetration.
2. Chemically inert media such as quartz or silica are preferable for preventing detrimental reaction with the NS.
3. Rounded particles are preferable since sharp-edged ones can damage the roots.
4. Porous materials such as lavas are preferable
5. Soft materials which can create NS 'clogging' problems should be avoided.

In view of these constraints media materials which could be recommended are:

a) lava or basalt
b) granite
c) beach pebbles and shingle
d) silica gravel
e) slate chippings
f) haydite or burnt shale
g) cinders

plus other crushed rocks and bricks of various kinds

Appendix B contains further information relevant to an assessment of gravel culture as a possible system for equiment manufacture and/or supply Dunlop Ltd.

2.4 The Nutrient Film Technique (NFT)

2.4.1 Introduction

In the United Kingdom NFT is the most widely used method , although there are only a total of 43 acres including the Channel Islands. Since 1975 several companies (see Appendix F) have been formed which offer NFT equipment of various types.

In the light of this literature review and discussions with growers and researchers, NFT emerges as a prime commercial hydroponic system. The following sections outline its principle advantages over the other systems for high value crops in temperate greenhouses.

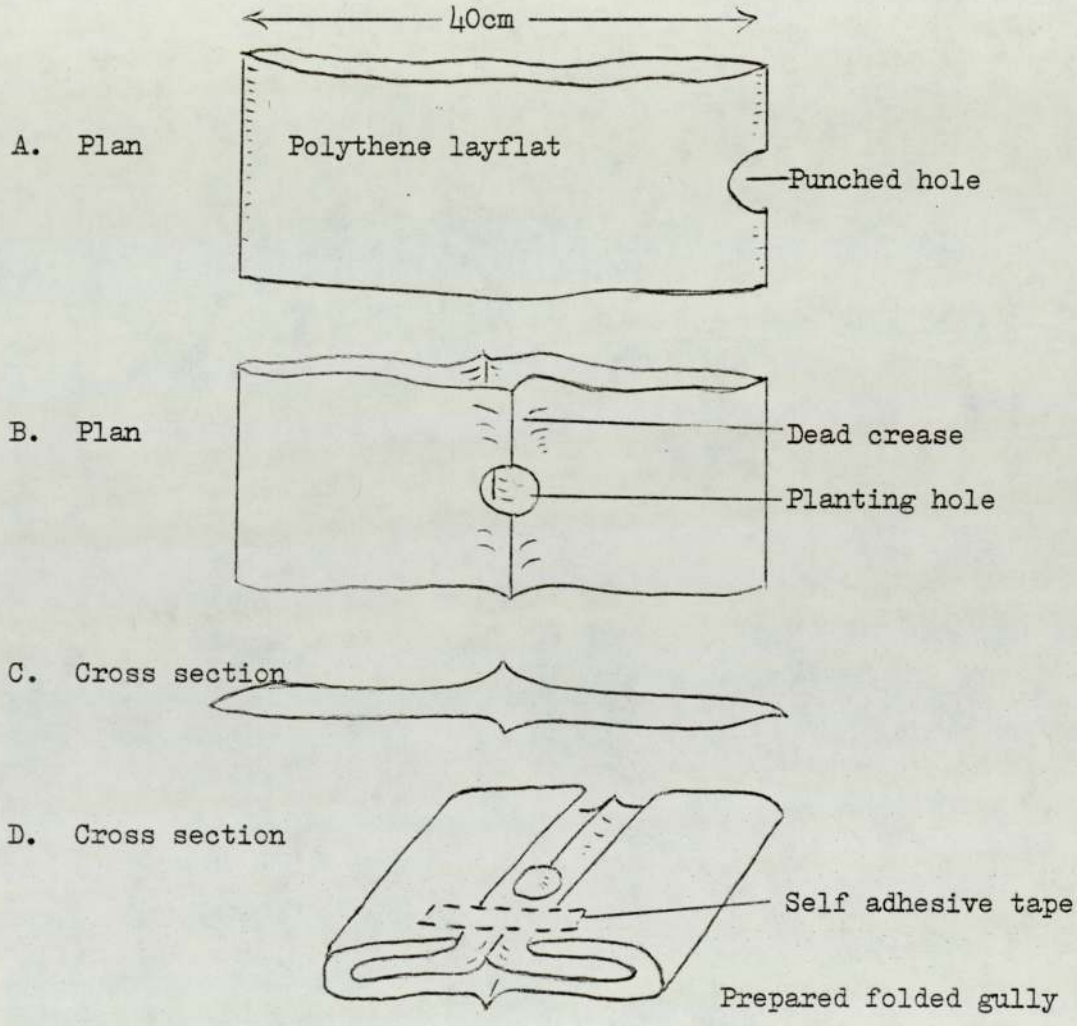
The literature available during the first nine months of the project enabled an appreciation of the new techniques brought into horticulture by NFT but gave only vague economic data. In particular, no literature was available concerning practical equipment design or the problems faced by companies attempting to gain entry to this new market.

In order to place the development of NFT in the context of the evolution of hydroponics as a whole, a description of the first NFT sytem is included. The gully or canal was the original feature prominent in the early literature on NFT and in patent applications.

In the early 1960s trials were conducted utilizing polythene layflat tubes at the Glasshouse Crops Research Institute in

England and by other workers abroad. In 1973 Dr A. J. Cooper of the GCRI published in the Grower journal a description of an experimental nutrient film technique (5.1) using layflat tubes as illustrated in Figure 10. Douglas also describes this technique (3.1, 3.26).

Figure 10 Preparation of a layflat nutrient film gully



After this labour intensive preparation of the gully it was mounted on a slope and young plants positioned so that their roots were in the enclosed space between the dead creases.

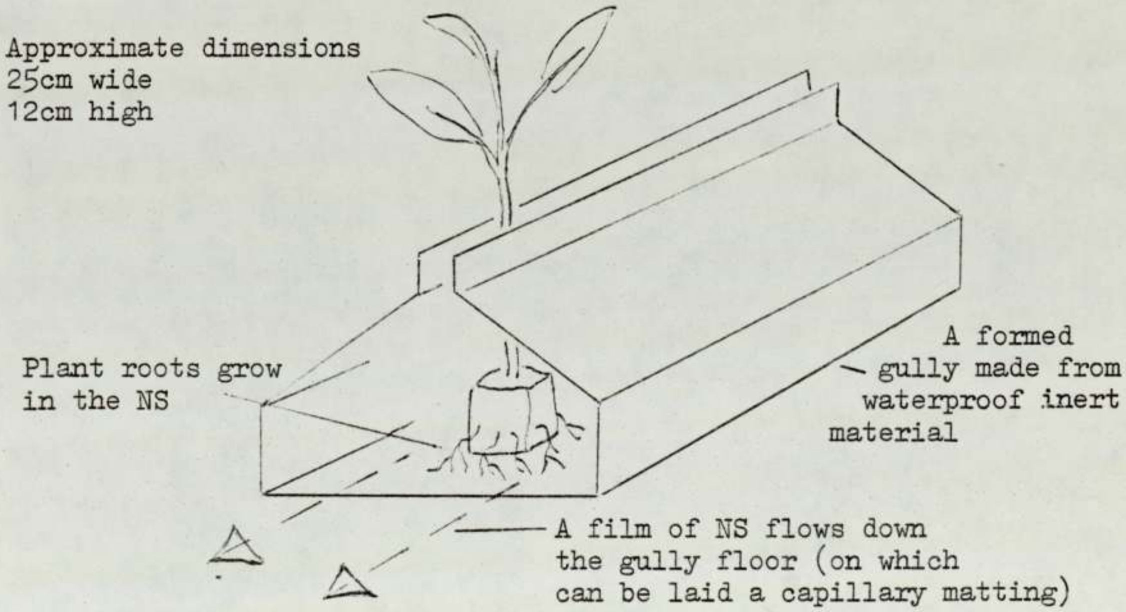
The NS was then passed down this space in a shallow stream - hence the name.

Although very good yields were obtained, in subsequent publications (5.2 - 5.4) the gully was modified to facilitate:-

- improved aeration of the NS
- easier escape for any phytotoxic gaseous root exudates such as ethylene
- easier management
- lower cost

By 1975 a simplified NFT gully was being used taking the form illustrated in Figure 11.

Figure 11 The basic NFT gully



The precise proportions and design of the gully depends not only on the nutrient film principle but also any claims to patented details of the material used and shape or construction of the gully in order to provide:-

(i) An easily managed system e.g. a preformed gully of suitable stiffness.

(ii) Support for the plant base e.g. the upper lips of the gully and retaining clips.

(iii) A shape which excludes light entry to the roots e.g. the raised upper lips of the gully.

(iv) A shape which allows undisturbed flow of the NS e.g. the side walls of the gully and smoothness of interior surface.

(v) Any additional features such as the use of a capillary matting on the gully floor.

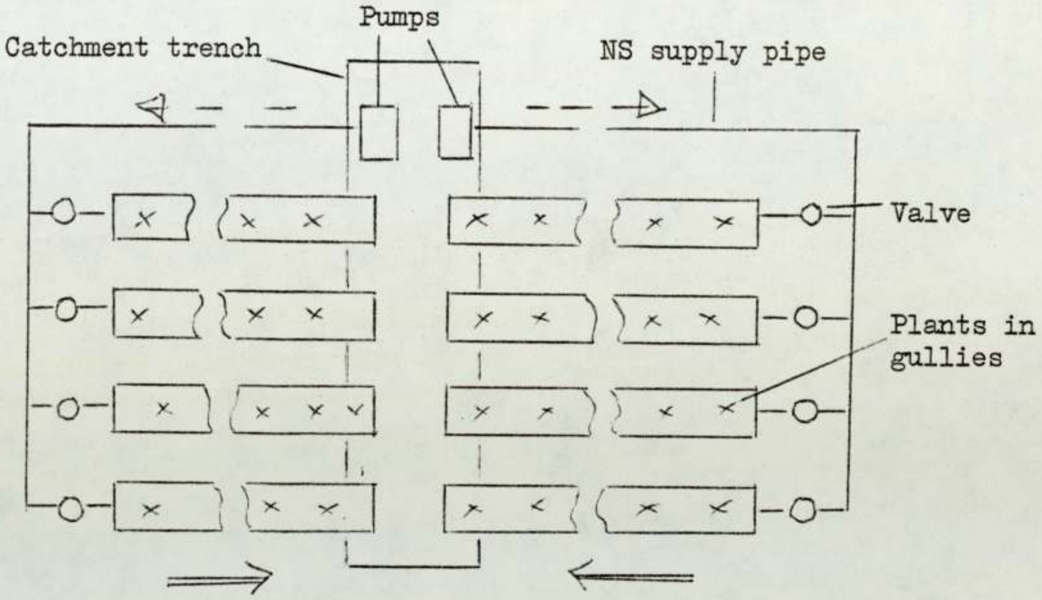
(vi) Non corrodible and non phytotoxic material.

However, the essential idea of the nutrient film is easily understood. Indeed, to prevent any possible attempt to patent such an idea the GCRI decided to publish the description of the layflat method. From these beginnings have sprung various layout and system designs; only a general description is attempted at this stage.

2.4.2 The layout and system development

When details of the nutrient film method were first published by Dr A.J. Cooper of the GCRI (5.1,3.27) he recommended a layout as in Figure 12.

Figure 12 The original nutrient film layout

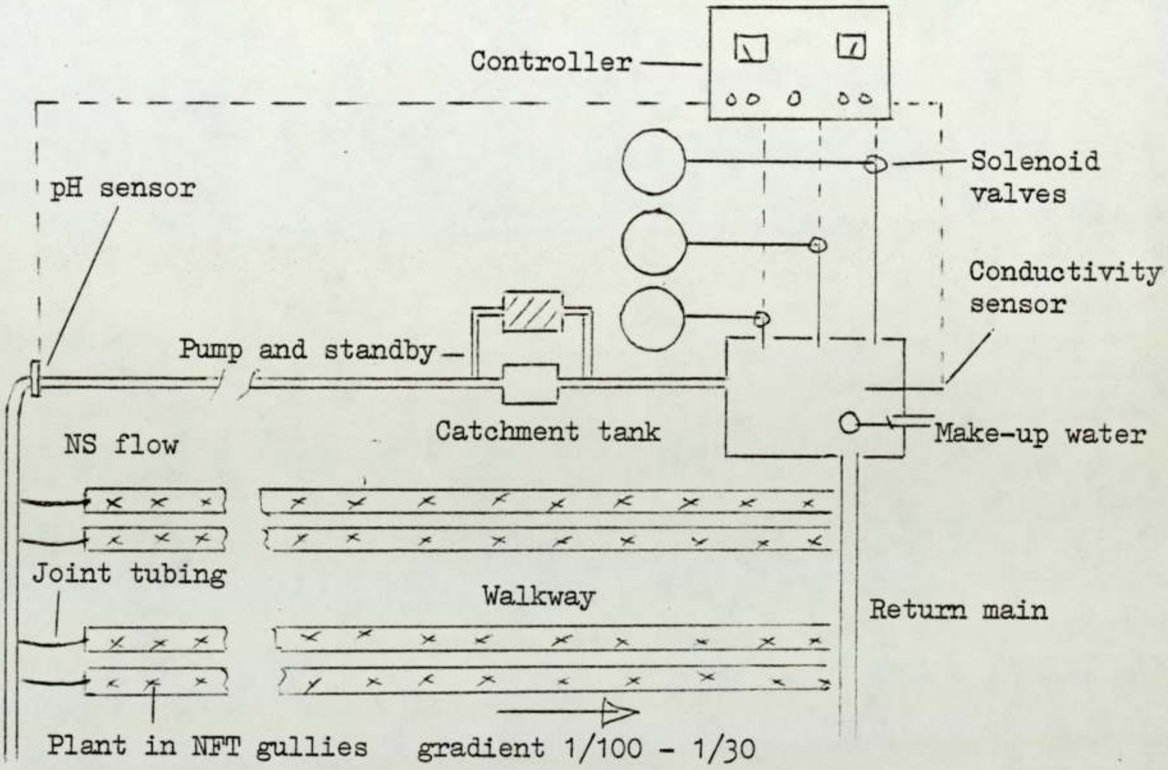


Slopes of 1/100 - 1/50 and NS flow

The original system however required an enormous reservoir plus valves and extra pumps. Further commercial development in 1976 saw the layout refined to that in Figure 13 where a smaller reservoir was used, topped up with nutrients and water as needed.

Separate nutrient stock tanks enabled finer nutritional control via pumps or solenoid valves activated by pH and conductivity ensors. Further development may incorporate sensors for individual nutrients.

Figure 13 A typical NFT layout in 1978



NFT had developed noticably within three years not only in layout and system design,but also in the use of horticultural techniques. Several people and organizations took part in this work.

Dr A.J.Cooper and other researchers at the GCRI who had first started trials in 1966, cooperated with several commercial growers in 1973. From 1974 Michael Anselm of Soilless Cultivation Systems Limited was instrumental in putting together the first commercially viable NFT system. Also in cooperation with Dr. Cooper, growers and other experimental horticulture stations began laying down trial NFT systems.

Growers who were among the first to install commercial scale NFT systems were:

Peter Lowater of Warsash, Hants.
Peter Bailey of Climping, Sussex and,
Len Dingemans of Enfield, Middlesex.

In addition growers on the Channel Islands and companies such as ICI Ltd,Stapley Bros Ltd and Van Heyningen Ltd installed large scale systems with the intention of further development work.

Apart from GCRI, research work on NFT for the Ministry of Agriculture Fisheries and Food has been carried out in recent years primarily at:-

Efford EHS, Lymington, Hants.
Luddington EHS, Stratford-on-Avon
Lee Valley EHS, Hoddesdon, Herts.
Fairfield EHS, Kirkham, Preston.
Rosewarne EHS, Cambourne, Cornwall.
Kinsealy Research Institute, Dublin, Ireland.

Along with development of the system came various large and small commercial suppliers of NFT equipment.

Hence, on a first appraisal of the situation in late 1977 NFT was believed by many people to have great potential.

Throughout this developmental period the journal that chronicled the events and opinions of many active NFT workers was the 'Grower', the largest and most influencial horticultural magazine, certainly within the UK and to a lesser extent in other English speaking and continental countries. Consequently, during the discussion of NFT regular references to this journal are made. The article headings are listed separately in the bibliography (5.1 onwards). Inspection of these headings indicates the trend in NFT developments.

2.4.3 The film of NS

Dr Cooper recommends that the depth of the recirculating stream should be no more than a film; about 1mm at first although with the development of a root mat it will become deeper. Even with the largest root mat it was believed that the stream should be kept as shallow as possible while ensuring a sufficient flow rate. That this matter was still in dispute during 1977 and into 1978 - as shown by the titles of articles in the Grower (5.5, 5.7, 5.10). The premise behind the nutrient film idea may be expanded as follows:-

(a) to allow the maximum NS (volume surface area ratio) aeration.

(b) to keep to a minimum the volume of NS required in circulation.

(c) by keeping the upper root mat moist and exposed to the air:

  (1) the NS would have a relatively unhindered circulation under the root mat

  (2) at least some of the root mat would obtain a plentiful oxygen supply.

(d) evaporation losses would be kept to a minimum, the small NS volume being covered by the gully shape and later by the roots and/or plant leaves.

In practice the depth and flow rate of the NS as a consequence of the supply rate, gradient and root development is not always maintained at the theoretically ideal level. The evidence for this from field observations is discussed in Chapter 4.

2.4.4 Gradients and plant support

Various slopes have been experimented with, the accepted minimum being 1/100 or 1% (5.4, 5.7). The maximum slope is not so easily set, gradients of 1/25 (5.2) and 1/30 (5.5) have given good results whilst vertical NFT systems (3.4) are possible. Gully slope is limited first by the cost of providing it, also by the room available (in the greenhouse) the yield obtainable and how feasible it is to cultivate the crop. In practice most NFT gullies slope at no more than 1/50.

Lettuce and other small plants can be adequately supported by the upper lips of the gully with the roots spreading from the absorbent blocks in which they are propagated. Growing tomato and cucumber plants require stringing up (as they do conventionally) but the interlocking root mat in the gullies also proffer some support and thus a fairly solid base is required for the gullies.

To meet this dual need for smooth gradients and plant support, raised variable gradient gully bases are available plus other accessories such as retaining clips.

2.4.5 Control

2.4.5a Nutrition

By the use of automatic or manual monitoring and dosage equipment, precise control of the NS composition for optimal plant growth may be maintained. This and the water requirements are explained in the section on NS.Furthermore, there is no wasteful use of fertilizers or water, a feature particularly advantageous in arid countries.

2.4.5b Disease

NFT should give the opportunity of disease control at root level by the application of systemic pesticides and fungicides into the circulating NS. Up until early 1978, trials were proving promising (5.23). Some fears of a faster spread of disease via the circulating NS had been expressed but not confirmed(5.14). Algal growth is restricted by the lack of light penetration to the root area. The enveloping gully also helps to exclude soil-borne diseases whilst a floor covering of polythene sheeting, or possibly concrete, also reduces disease risk.

2.4.6 Crop yields and turn-round

Yields

A comparison of yields that could reasonably be expected from soil, NFT or other hydroponic systems appears in Appendix E. In contrast to other systems, figures on NFT yields were becoming available in 1977. Furthermore they were directly comparable coming mostly from the UK, Channel Islands or Ireland and all within greenhouses.

Tomatoes

Approximate yield of conventional crop:-

Large grower : 80 - 100 t/acre (201 - 251 te/ha)

Small grower : 100 - 120 t/acre (251 - 301 te/ha)

Therefore average ≏ 100 t/acre.

Reported yields of NFT crops:-

t/acre	107	119	120	126	130	142	153	128
Source	(3.4)	(3.31)	(5.8)	(3.30)	(5.4)	(6.4)	(6.3)	Average

This very significant favourable comparison is important since tomatoes are the major greenhouse crop in the developed countries. However, trial crops do mean that many of the higher yields were from smaller areas in experienced hands.

Furthermore, correspondence with the Channel Islands horticultural departments indicated an increasing approval of NFT for tomato growing. Several workers of the IWOSC (3.4) had run trials comparing NFT with other hydroponic systems and soil, reporting NFT to yield good quantity and quality with respect to the other methods (see H.M. Resh of Canada, K. Miliev of Bulgaria, J.S. Douglas of India (also 3.26) and F. Verwer of Holland).

Cucumbers

Average yield of conventional crop $\hat{=}$ 35 t/acre

Reported yields of NFT crops:-

t/acre	40	45	46	57	47
Source	(6.4)	(5.13)	(5.5)	(5.4)	Average

The turn-round time for crops is about 7½ weeks which is an improvement on conventional methods. However, it does appear that cucumbers are very sensitive to variation in nutrition and pH (5.13, 5.11). Due to the lack of a buffering capacity in NFT, it must be regarded as a risky cultivation as at 1978 for cucumbers.

Lettuce

Average yield conventionally $\simeq$ 70,000 heads/acre/year with 7 crops/year.

Reported yields of NFT crop (7.3) 68,750 - 90,000 heads/acre/year with 8 crops/year.

Smaller scale trials (6.1, 6.3) also show good results.

Ornamentals

Communication with workers in experimental horticulture stations indicated a good yield potential after trials with chrysanthemums and carnations, but no figures were available by early 1978. Roses have been reported to give a 25% increase in blooms (5.5) with NFT. At the GCRI in 1975 one greenhouse demonstrated that many plant species (5.3) can be successfully grown in NFT, often using the same NS.

Crop turn-round

An advantage of NFT immediately apparent was the possibility of a shorter preparation period between crops. If this is combined with a shorter growing period and good yields, the effect on output can be substantial (5.1). With soil there is a lengthy and costly cultivation of the growing medium (4.6), even before the plants are present. This can include sterilization by steam or methyl bromide. Peat bags can be sterilized or renewed but this is costly and requires a deal of physical labour. A NFT system can be flushed with formalin and replanting can begin within a few days. This is demonstrated by Dingeman's ability to grow eight crops of lettuce in a year instead of seven (7.4) and SCS have reported ten crops grown in the open (5.4) in Queensland, Australia.

2.4.7 Costing

Equipment

Figures for costs are analysed later together with the market scope and NFT equipment breakdown. However, it appears that the extra outlay for NFT equipment (£5 - 12,000/acre) rather than conventional peat bags (£2 - 5,000/acre) is small compared to the turnover involved in commercial greenhouse growing. (See Appendix J) With equipment lifespans in the order of three to ten years, costs may be recouped as a result of increased yields plus other savings, within one or two years.

Energy saving

In early 1978 it was apparent that fuel prices, which already accounted for a third of a glasshouse's running costs, were probably going to rise rapidly inside a decade. It was frequently mentioned in the NFT literature that the heating of the NS to the optimum ($25^{o}C$ for tomatoes, $28.9^{o}C$ for cucumbers) would contribute efficiently to the heating of a greenhouse (5.1, 5.4, 3.27), although no figures were available. In addition, it appeared that greenhouses need not be heated for days before planting as is the case conventionally. Suggestions for heating the NS included solar/wind power and heat churns.

Labour saving

No figures were published by early 1978 on the manpower requirements for NFT compared to conventional cropping.

As with energy, labour accounted for another third of a greenhouse grower's total costs. Conventionally three men were required per acre of tomatoes whereas it appeared to Cooper that a NFT system could be managed by two full time workers, plus a third during picking. In other words,labour productivity would probably rise with NFT cropping.

2.4.8 Discussion

The new techniques concentrate on the root environment. It appears that the horticultural practices applied to the shoot environment need not be altered. Hence, this literature review is intended to emphasis this aspect as an introduction to NFT and other hydroponic systems and thereby explain why NFT was chosen for further study.

Once the principles of NFT (and hydroponics in general) have been appreciated there are also many finer points to understand before a grower is likely to achieve success. An example where failure can occur is by using unsuitable equipment which could prove phytotoxic in NFT. Hence Dr Cooper and the Grower commentators advised that only a trial system of a few NFT rows should be attempted in the first year. However, in the second and third years larger commercial scale systems may be installed in stages with greater confidence.

The relative complexity ofoperating modern hydroponic systems suggest that a turnkey capability may be required in order to achieve rapid commercial acceptance. Other companies, including ICI and Fisons Ltdalso see a potential for a consultancy, design, supply and installation business.

The fourth criterion in Section 2.1.1, that a persuasive factor would be the extent of the commercial operations, that is providing that there would be an adequate potential market share. The detailed description and analysis of NFT, its techniques, equipment, yields, costs, market scope and feasibility for a turnkey operation are developed in stages throughout the project. Here, only the basic principles appreciated from the literature are reviewed.

It was clear NFT was the hydroponic system favoured by the UK horticultural industry in 1977. In addition hydroponists from other countries (see Section 2.4.6) hadviewed NFT in a good light with respect to gravel culture and other systems. This however did not rule out other culture systems in the rapidly evolving hydroponics industry, which is the reason why some hydroponic systems are discussed after NFT in this review.

At this stage NFT does appear very relevant to the strategy of DIS (see Section 1.1.4e). However, other hydroponic systems may be applicable in certain circumstances e.g. gravel culture, rockwool. It is reasonable however, to pursue NFT as the principle hydroponic system of interest.

2.5 Other Hydroponic Systems

2.5.1 Grass culture

Many grasses e.g. rye grass germinate and grow very rapidly if optimal nutritional and environmental conditions can be provided. The dense, lush mat resulting within two weeks from seed spread on suitable trays or beds may be used for animal feeds or turfing. Table 7 shows the nutritional fodder value of freshly germinated grass (3.32).

Table 7 Effect of maturity on the composition of brome grass

Height inches	Protein %	Fibre %	Ca %	P %	KO_4 %	Carotene ppm
5.2	19.5	18.0	0.35	0.44	2.7	320
7.1	16.6	20.9	0.40	0.38	2.6	290
9.8	14.5	23.9	0.42	0.34	2.6	209
19.2	10.2	29.1	0.34	0.26	2.1	174
25.8	8.8	30.0	0.34	0.24	1.8	130
26.2	7.4	29.1	0.32	0.22	1.3	96

To produce grass for fodder special chambers have been made by companies in the USA and Australia. These chambers (3.32) are self-enclosed with racks of trays illuminated by fluorescent lamps. Seed is spread on the trays whilst NS is sprayed on the topmost rack. The NS then falls by gravity through drainage holes to irrigate lower racks. Systems are advertised which have rotating racks and an auger for the dispensing of the week-old grass.

For turfing it would be possible to use similar chambers or the grass could be germinated on NFT type beds which are simply sloping shallow, open-topped gullies. It is known that effluents from sewage works and fish farms have been used successfully as a NS in this manner.

Grass culture seems not to require a high degree of technology and may not be applicable to a consultancy function of a turnkey scheme. However, depending on the customer's requirements, it could be an extra item in a turnkey package.

2.5.2 Rockwool

2.5.2a Introduction

In Holland and Denmark an artificial medium, used otherwise in household insulation, was tested in the early 1970's (3.33) for the commercial growing of crops using a NS. This material, rockwool, was one of many similar media tried and has to date proved the most promising. At the end of 1975 only $400m^2$ were under trial, primarily for cucumbers. In 1976 this was 8ha and in 1977 the area in production rose to 25 ha (3.34).

Rockwool is made from a mixture of 60% diabase, 20% limestone and after adding 20% coke, it is melted at 1,500 - 2,500°C. The molten substance is extruded as threads of 0.005mm and pressed into sheets weighing $80kg/m^3$. During cooling a phenol resin is added when the temperature is about 200°C. This enables the rockwool to take up water, for the surface tension is diminished.

The pore space is about 96%, each pore having about the same size. This has important consequences for the water holding capacity or capillarity as shown in Table 8 .

Table 8 The water/air composition in rockwool

Height above water table in cm.	% water	% air
0	94	2
5	82	14
10	38	58
15	17	79

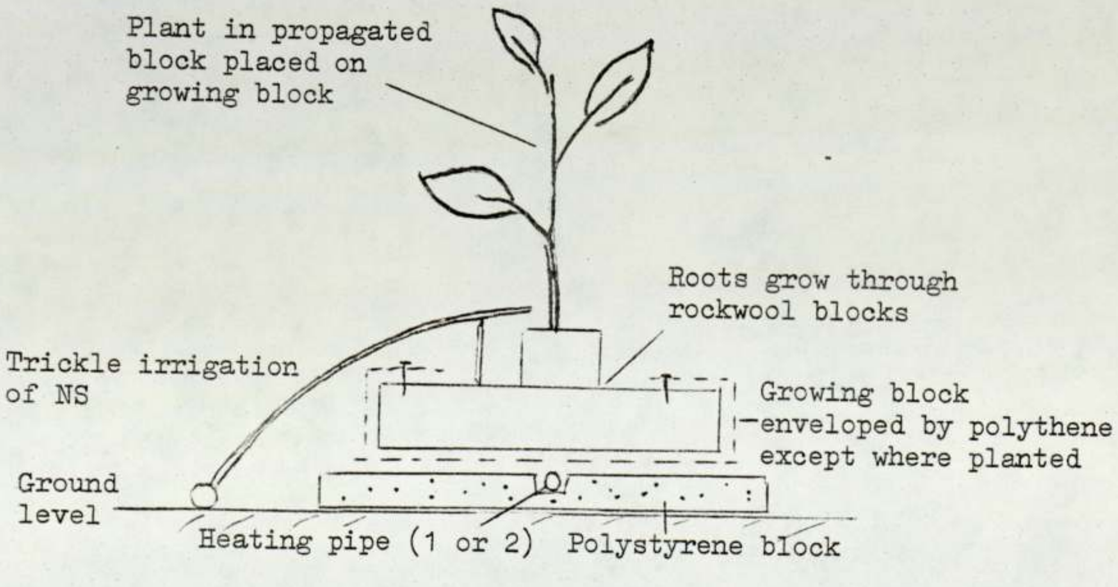
In new material the pH is high (+7) but by watering for some hours before use the pH is reported to decrease quickly and by adding some acid a pH of 6 can be attained (3.4).

Cutting blocks for propagation and pot plants, come at present in sizes of 3, 3.8, 5, 7.5cm (and larger) cubes. Growing blocks are supplied in 7.5 x 30 x 90cm dimensions. These blocks of a spongy consistancy allow the plant roots to penetrate as if in the soil. The NS is applied via drip, trickle or porous hose methods with the medium being sterile and almost inert when new.

2.5.2b Bed construction

Details on the layout and construction of the beds was difficult to appreciate within the first few months of the project because of the small quantity of literature in English. F. Verwer the principle advocate for rockwool visited the UK in 1977 and 1978 which increased the attention given to this system by English horticulturalists (3.34). The Grower discussed rockwool infrequently at that time but it was apparent that for tomatoes or cucumbers a bed as illustrated in Figure 14 may be used (5.6).

Figure 14 Cross section of a typical rockwool bed



Note (i) The NS can be irrigated using a porous tube running on top of the growing block.

Note (ii) Holes are often punched in the polythene sheeting at the lower corners to allow seepage of excess unused NS.

Note (iii) The dimensions of the rockwool blocks used for propagation, planting out, and growing can vary not only with the crop but also according to the grower.

The majority of rockwool research has been carried out in Holland at the Experimental Station for Glasshouse Crops, Naaldwijk (S.J. Voogt et al) and at Wageningen (3.33) by Verwer. More recently Stockbridge House EHS, Cawood near Selby, Yorkshire (D. Drakes et al) have been conducting trials.

2.5.2c Propagation

The major crops at present propagated in rockwool are cucumbers and tomatoes. It was becoming established that if a grower was planning to plant out onto rockwool growing blocks then he would have to propagate in rockwool blocks as well (5.11), rather than soil, peat or other blocks. This is due to the different water retaining properties of rockwool and other blocks. If a peat propagating block is placed on a rockwool growing block, the former draws too much moisture from the block below; consequently the young roots do not grow on down from one block to another. If the roots do successfully cross the interface from block to block then they are usually retarded.

Research at Naaldwijk, Holland has been directed at finding the best technique of raising cucumber plants in rockwool. A comparison has also been made between two sizes of rockwool blocks and two sizes of plastic pot filled with potting compost (5.11), as shown by Table 9 .

Table 9 Comparison of rockwool and soil propagating blocks

	Cucumber plant weight (g) per plant	
	After 3 weeks	After 4 weeks
Rockwool block (7.5cm)	34.8	93
Plastic pot (10cm) with potting soil	24	71
Rockwool blocks (10cm)	21.1	108
Plastic pot (13cm) with potting soil	30.4	97

As a result, 0.65 litre (approximately 7.5 x 9 x 9cm) rockwool propagating blocks are used, however there are some special features to note. It is necessary to wrap the pots' side walls with black plastic to prevent any drying up. In addition the blocks must be uniform with a planting hole made in the block during manufacture. As the plant seed cannot be firmed up in the hole, extra material (rockwool granulite is recommended) must be added to keep it steady.

The blocks are placed on tables which have before-hand been cleaned thoroughly (3.34), and preferably lined with new plastic sheeting.

A drain is necessary for excess NS initially when the blocks are irrigated thoroughly. Thereafter the blocks must be spaced, which allows for some evaporation, especially during the winter.

If the blocks became too wet growth suffers and hence water content must be spot-checked frequently.

To keep pythium infection under control during propagation the blocks should be kept at a minimum temperature of 21°C. This is achieved by heating underneath the propagation bench and also by using pre-warmed NS.

For pot plants, a rockwool block can be placed inside a larger hollowed out block so that the roots and the plant can continue growing. This 'pot in pot' system is probably most applicable to household ornamentals.

Planting out should be done when the young roots are clearly visible but before they have their growth checked. The blocks with the young plants are placed in the middle of the prepared beds. NS drip/trickle nozzles are placed, usually on each block and the roots will then grow into the rockwool mat in 1 to 2 days.

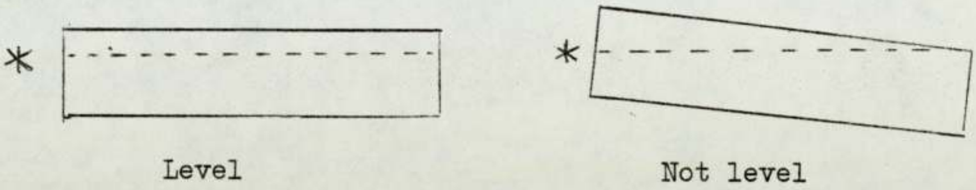
2.5.2d Management of a rockwool bed

It is necessary to appreciate some of the management features peculiar to rockwool culture, which may affect the potential commercial application of this hydroponic system. Detailed growing instructions are available from Naaldwijk in Dutch (3.36).

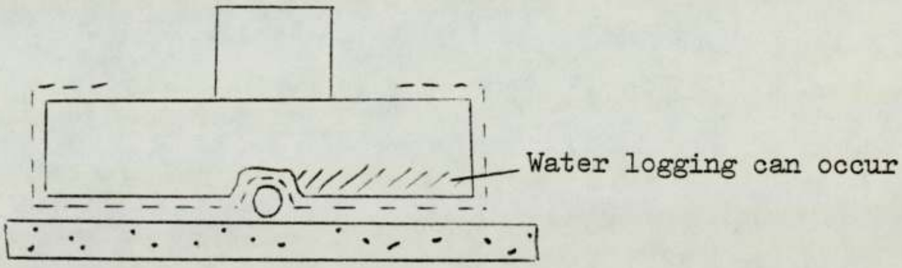
Table 10 shows the relationship between the water content of the rockwool mat and the height above the 'water table'. Hence, each growing block must be level and homogeneous in make-up in order to get good and uniform growth. (see Figure 15)

Figure 15 <u>Three possible moisture problems with rockwool growing blocks</u>

A. c/s of rockwool mat and 'water line' *

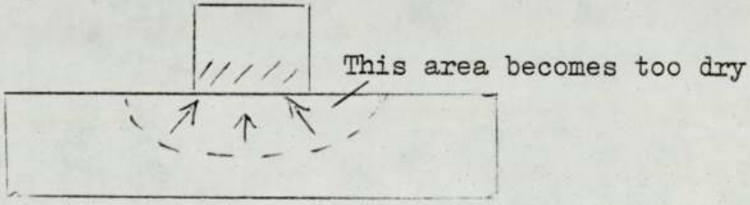


B.



When the heating pipe is not sunk into the polystyrene block

C. When the propagating blocks are not homogeneous with the growing blocks



Further problems which can be associated with those in Figure 15 may be:

D. The variable density of the rockwool itself can cause variation in moisture retention.

E. Rockwool contains 16% of CaO which is not completely inert. This results in a high pH unless the NS is acidified. Even then the pH can vary from place to place in the rockwool mat.

F. During the winter it is believed (3.34) that there is insufficient heating of the rockwool mat if only one heating pipe is used. Associated with the moisture content temperature differences occur in the mat. This may be partly solved by heating the NS. Two heating pipes can be used to improve this situation.

The latter three problems are hence less easily solved and are related to the composition and application of the NS. This complex subject is approached separately.

However, the growth of rockwool use, chiefly for cucumbers shows that it must be competetive with the alternatives, e.g. soil or peat bags. The clearest advantage is the increased yield, although this is offset to some extent by increased cost.

2.5.2e Costs and yields

The cost of rockwool blocks for 1 acre of 6,000 cucumber plants is about £2,000. Wrapping these with white polythene in threes supported on channelled polystyrene with plastic heating pipes can double the cost to £4,000 (at early 1978 prices). The raising of plants in rockwool for later planting out, costs about 2p per plant more (without including extra labour for a rockwool system).

J.P.G. Huys (5.6) of Wageningen amongst others, calculates that an increase in cucumber yields of at least 15% (and 20% with tomatoes) would be needed to make rockwool economically viable in Holland and the UK.

To date only cucumbers as a major commercial greenhouse crop has established a reliable 15 - 20% increased yield (5.6, 3.4, 3.33, 3.34) with rockwool. Although the 15% increased yield is offset by a comparable increase in costs , the better quality and quantity of the fruit (with prospects of improvement) combine to make rockwool an attractive hydroponic system - at least in Holland. It is also known that Hedon Growers, at Burstwick near Hull have about 11 acres down to rockwool cucumbers where it is estimated that such an improved crop will increase its value by 20%.

Tomatoes were reported under trial in Holland and the outcome may therefore have great influence on the market potential of NFT. Field observations in Holland in May 1978 confirmed that these trials had only just begun.

2.5.2f Summary of rockwool literature

This indicates an expanding market for rockwool cucumber production with a possible market for tomatoes. The technique has a Dutch origin, as opposed to NFT's British genesis.

It is not known whether rockwool will rival NFT as a tomato growing system. It might be combined with NFT in some form or possibly be used for cucumbers whilst NFT is used for tomatoes.

However, because of rockwool's cost, non-recirculation of expensive NS (although this may produce a lower disease risk) and lack of present home market it does not appear to warrent further study here. Furthermore, it would be highly unlikely that rockwool could be manufactured by Dunlop for the purposes laid out by DIS (see Section 1.2.4e).

Nevertheless, it does present potential competition to NFT and in any hydroponic turnkey operation the inclusion of a rockwool system should be considered (as discussed later)

2.5.3 Containers

2.5.3a Introduction

Plants are grown conventionally in containers for a variety of reasons:

(a) nursery grown stock to be transplanted

(b) pot plants

(c) as modules, e.g. peat bags and troughs.

Of these, only the first market purpose appears unsuitable to the application of hydroponics. If a plant needs to be transplanted into soil, e.g. shrubs, then it may be that the roots developed under hydroponic conditions will not prepare the plant ideally before-hand. However, no published information has been found on this aspect, although it is known that rockwool and other nearly inert media, e.g. jiffy blocks, have been used for transplanting purposes.

To determine the potential of hydroponics for transplanting stock would require further study and trial work which precludes it any further as a subject for this review, and by reference to Section 2.1.1 it also means that it is not directly relevant to the project. However, with a view to the future, especially in combination with other techniques such as tissue culture (4.7) the propagation and rearing of transplanting stock via hydroponics could be a commercial possibility.

2.5.3b Pot plants

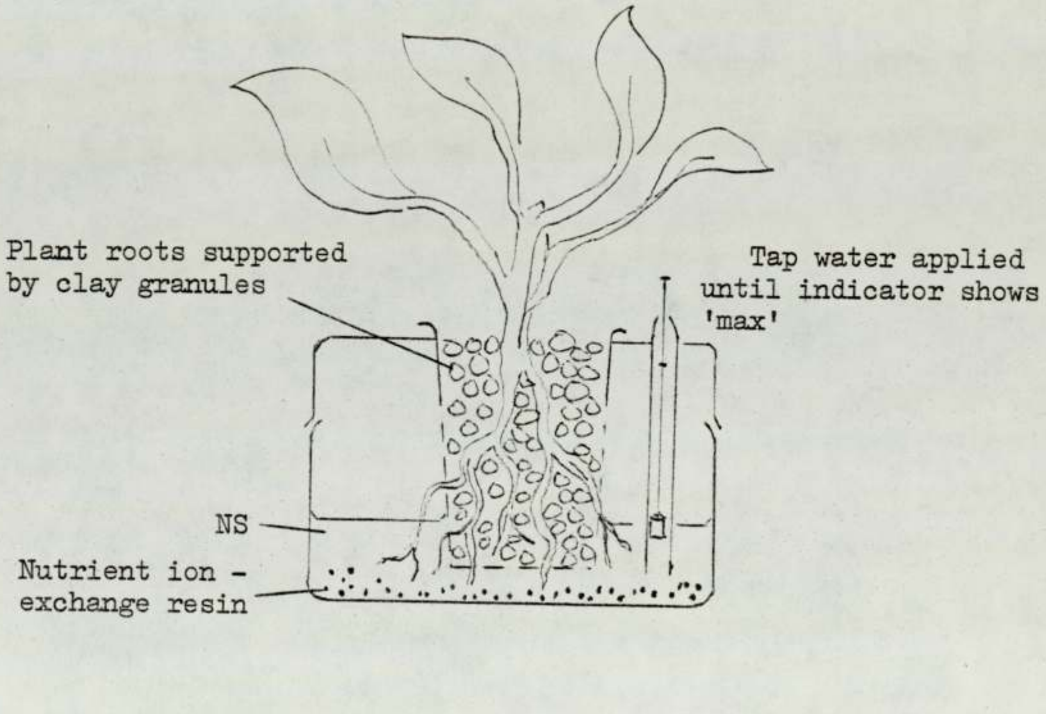
This market has already been entered by a few companies, notably Rochfords Limited of Hertfordshire. As an aggregate medium hydroleca granules about 1cm in diameter are used which are inert, rounded and can absorb nearly one third of their own weight of water. However, hydroleca is made by expanding small clay particles under great heat and hence is probably too costly for large-scale commercial food production. Hydroleca is more suitable to the decorative leisure market, the granules having a pleasing buff colour, being light in weight and clean for household use.

As part of the package Rochfords have designed a modified flower pot and used an ion exchange resin as a nutrient feed source. The latter was developed by Bayer Limited, a chemical company from West Germany and is called

Lewatit HD5. This NS source is expensive but performs quite well. It absorbs non-nutrient salts in the water and releases in exchange ammonium nitrate and potassium phosphate plus some trace elements. In this way the salt concentration of the NS will not increase during the estimated six month life of an 80p sachet of resin.

The 'hydroculture' pots are as illustrated in Figure 18, tap water being added to the indicated level when necessary e.g. every 2 - 4 weeks, so that care of the plants (watering) is made easier.

Figure 16 A hydroponic container for pot plants



This system does not seem to have achieved great market penetration which may indicate a lack of customer understanding concerning hydroponics. Although commercial office/landscaping firms and garden centres are now adopting hydroponic pots they do not appear to have gained wide acceptance among the general populace yet. Such a market development, however, is of secondary interest (see Section 2.1.1) to food production although it can be available as an extra item if required by a turnkey customer.

An example of a landscaping purpose for hydroponic containers are the 3,000 currently used by the Munich municipal authorities. These incorporate rockwool and hydroleca with a reservoir for the NS so that they require 'watering' only every month or so. For display purposes they are rotated; 1,000 at a time every four months.

2.5.3c Plant modules

The success of peat bags illustrates the potential that could be available to a modular hydroponic food producing system. Ideally, such a system should be applicable where water is scarce and possibly saline. Now that drip/trickle technology is well established (4.8) it could be utilized with aggregate media which may be locally available.

One company known to have pursued this idea is Ball Agricultural Systems of Colorado USA. Although no specific designs along these lines have been traced it appears that a NS drip from module to module would be inevitable (4.9). Collection and recycling of the NS may or may not be suitable depending on several factors, including the water quality and quantity.

Three disadvantages inherent in NS recirculation may be:

(a) equipment cost

(b) possible disease

(c) unwanted ion accumulation.

Advantages discussed previously when considering closed systems were primarily:

(a) conservation of costly NS

(b) possible disease control

(c) further control over nutrition and plant growth.

These features may be reconciled in the future to provide satisfactory yields and return on investment by using modules. The reasons are listed in Table 12. However, yields obtained at present in NFT e.g. with tomatoes, are the highest yet obtainable with any commercial growing system and as such it remains the hydroponic system of prime interest for the project duration.

Table 12 <u>Some advantages of a modular hydroponic system</u>

1. A contained drip irrigation of NS will lose less water (and nutrients) due to seepage and evaporation.
2. The NS is kept aerated yet in close contact with the plant roots thus requiring less NS in the system.
3. Less aggregate medium than with other aggregate cultures is required.
4. Easier to install requiring less ground preparation, such as levelling and compacting.

5. All systems are above ground (except where recirculation of NS is required).
6. Better light penetration and air circulation around lower leaves with correct plant spacing.
7. Easier plant removal and replacement with less transplant shock after propagation.
8. Improved management, i.e. cultivation, harvesting and crop turn-round with a robust system.
9. Module design can be patentable and sellable.
10. Less cost for the grower, i.e. lower crop maintenance, no large NS storage tanks, insulated plant roots (possible lower fuel requirements with heated NS), lower equipment cost (and possibly higher yields) plus easier sterilization.

Evidently a modular hydroponic system is worth consideration as an addition to a more established hydroponic system such as NFT. To assess the possible benefits of modules requires further investigation on a trial basis with accurate measurements of details such as the volume of NS required and the yield obtainable.

2.6 Nutrient solution (NS)

2.6.1 Introduction

Plants used for horticultural purposes (e.g. tomatoes, strawberries, potatoes, carnations) have 'basic requirements' as outlined in Section 2.1.2. Other than carbon and some oxygen,

the vast majority of elements which go to make up the plants' tissues are collected via the roots. These elements need to be available in am optimal form from a growing medium if maximal yields are sought.
Alternative physical arrangements of the NS have been covered so far. The chemical arrangement of the elements within the NS are now reviewed.

Many years of research have shown no single optimal NS formula for every crop, even in a hydroponic context. Optimal concentrations of various nutrient compounds for a NS depend on many factors:

(a) crop and cultivation
(b) plant part being grown e.g. fruit or flower
(c) developmental stage, young plants requirements differing from those of mature plants
(d) season, climate or greenhouse conditions
(e) water quality i.e. predissolved elements
(f) intereactions of ions in the NS resulting in pH and nutrient elements in a form available/unavailable to the plant (e.g. by precipitation). This can be temperature dependent.
(g) non-inert growing media e.g. limestone aggregate.

Factor (g) becomes extremely variable when the growing medium is the soil where soluble chemicals, flora and fauna (4.5) abound. Hence, by minimising this variable NS can be applied with greater accuracy. However, an advantage which the soil does possess is a buffering capacity combined with its own ecosystem.

What are the tolerances of the plants to variations in nutrient availability? There is evidence (4.3, 4.6) that in greenhouse conditions generally plants are more tolerant to varying NSs. This may be due to a lack of climatic (and competitive) stresses, a feature which varies between crops/cultivars which may be protected or in the open.

Tolerance to nutrient variability is thus one of the characteristics that can be bred for in cultivars as can resistance to climatic conditions. Examples of tomato cultivars displaying different features in both respects (6.2 - 6.5) are Sonata (greenhouses) and Moneymaker (outdoors).

Apart from plant breeding, such horticultural practices such as 'hardening off' can further adapt individual plants to particular conditions. Further advances for hydroponics in this direction can be made if more attentionis given to the NS composition.

Table 13 has been constructed as a guide to the proportions of nutrient elements which need to be available to most plants (see Section 2.6.3). The total dissolved soluble salt concentration is measurable via the specific electrical conductivity (SC or cf) of the NS. In the case of NFT (3.27) in UK greenhouse conditions, whenever the SC falls below

2,000 micromho cm^{-1} nutrients are added to increase the SC to approximately 3,000. In more tropical situations the climatic demand for transpiration water, especially in the open, can be substantially higher which necessitates a lower NS OP. The latter is related to the DSS concentration and thus the following approximated relationship can be useful:

SC in micromho cm^{-1} x 0.66 $\triangleq$ [DSS] in ppm

e.g. SC of 3,000 $\triangleq$ 2,000ppm DSS

Table 10 A guide to nutrient element concentrations in typical NS (ppm)

Element	Lower limit	Average achieved	Upper limit
N	150	300	1000
Ca	150	300	500
Mg	30	60	100
P	40	60	100
K	150	350	700
Fe	2	4	10
Mn	0.5	1.5	5
Cu	0.06	0.2	0.5
Mo	0.001	0.02	0.3
B	0.5	1.0	5
S	100	250	1000
Zn	0.05	0.5	2
Cl	0.5	2	4

Once suitable formulae can be cited for particular situations e.g. a heated tomato crop, then all a crop manager (grower) would need to do is either:

Manually - add a ready made-up powder at regular intervals

Automatically - set the controls

Hydroponics however, has not reached this state of detailed predictability yet.

A grower needs to have periodic analyses of the NS to determine what are the trends in the relative proportions of different nutrients and monitor any accumulation of undesired compounds, e.g. NaCl.

Further aspects of NS control may be the addition of specific chemicals for disease or growth regulation in addition to the physical management of the flow rate.

Certain crops require further elements than most 'standard' nutrient formulae include, e.g. legumes need small amounts of Co to fix N via their modules and Graminae crops require Si.

Allowances have to be made for water lost from the NS by seepage, evaporation or plant transpiration. Evaporation in particular can leave behind the mineral salts deposited and/or accumulating in the hydroponic system; and the rate of evaporation can vary between different systems (see Section 2.3).

2.6.2 Nutrient compounds and ions

The 'raw fertilizers' need to be relatively low in price, a factor which restricts the choice available.
In water these compounds disassociate to a degree (4.3), producing ions which can make the nutrients available to the plant roots (see Section 2.1.2). These ions can be:

negatively charged, i.e. cations e.g. nitrate ion, NO_3^-
positively charged, i.e. anions e.g. potassium ion, K^+

Usually similar valencies, i.e. number of + or −, will also enable the respective ions to combine to form compounds as exampled below where $\rightleftharpoons$ indicates a reversible reaction.

Ions		Compounds
$K^+ + NO_3^-$	$\rightleftharpoons$	KNO_3
$Mg^{2+} + SO_4^{2-}$	$\rightleftharpoons$	$MgSO_4$
$2K^+ + SO_4^{2-}$	$\rightleftharpoons$	K_2SO_4

Once in solution, it is in the ionic form that we require the nutrients. Care must be taken to create suitable proportions of ions in a NS so that none will recombine to form nutrient compounds unavailable to the roots, e.g. by precipitation. (Such a combination of unwanted ions would however be beneficial.)

A raised NS temperature can aid the dissolutionof some nutrient compounds whilst giving an optimal metabolic temperature for the roots.

The acidity/alkalinity of a NS or pH is a measure of the hydrogen ion activity in the solution:

$$pH = -\log_{10} \left[H^+\right]$$

On the pH scale 7.0 is neutral when the ratio $H^+ : OH^- = 1:1$. As acidity increases due to an increased proportion of H^+, the pH numbers decrease and vice versa.

Since this convention is based on a logarithmic scale, the acidity increases or decreases by a factor of 10 for each unit change in the pH. The buffering quality of soil keeps its pH within reasonable limits so greater care is needed with a hydroponic NS.

Plants can tolerate a remarkably broad range of pH when reviewed in this light (4.6). Most plants require a pH of 5.8 - 7.0, so it is in this range that the nutrient ions need to be available in their correct proportions. A pH of 6.5 is usually optimal.

This explains why so many NS formulae have been offered for use in varying circumstances. Details of nutrient element requirements within plants and how to diagnose deficiencies are available from many sources including ADAS publications. The evolution of hydroponics however will need a greater understanding by researchers (4.1 - 4.4) of ion uptake, osmotic requirements, toxicity and other factors.

2.6.3 Examples of NS formulae

The following references are among those containing information on NS make-up:

(3.1, 3.4, 3.12, 3.20, 3.27, 3.31, 3.33, 3.37, 4.3, 5.2, 5.4, 5.10, 5.13, 6.3, 6.5)

Before any recommendation could be made for a suitable formula, a water analysis is advisable to determine the predissolved salts; this is discussed further in Chapter 4.

2.6.3a Aggregate culture

To demonstrate the original formulation method, the Netherlands Standard formula (3.1) is chosen. This is based on:

Anions	NO_3^-	:	$H_2PO_4^{-(-)}$	:	SO_4^{2-}
	60	:	5	:	35
Cations	K^+	:	Ca^{2+}	:	Mg^{2+}
	35	:	45	:	20

Such a combination has been used with success (3.1, 3.4) for tomato, cucumber, friesia, paprika, lettuce, rose, asparagus and radishes in gravel cultures, but for calcifugous plants it is necessary to change the cation ratio:

K^+	:	Ca^{2+}	:	Mg^{2+}
35	:	20	:	45

In this way, Ericaceae, some Araceae and some orchids can also be grown.

Table 11 The Netherlands standard formula

Compound	mg/litre of water
KH_2PO_4	136
$Ca(NO_3)_2 4H_2O$	1062
$MgSO_4 7H_2O$	492
K_2SO_4	252
KOH	22.4

Used with neutral water this represents an osmotic value of 0.7 atmos at pH 6.5 ± 0.1.

The formulation of NS requires detailed study and so in the future could be a major item in a technical consultancy.

One aspect of this is the deciding of optimal osmotic pressures. Indeed NS formula surveyed differ appreciably in total salt concentrations with osmotic pressures (OP) ranging 0.48 - 2.5 atmos.

A.A. Steiner (1969) has recommended the following OPs for hydroponic tomato growth:

Temperature regions with dark winters	Winter : 1.8 atmos Spring : 1.1 atmos Summer : 0.7 atmos

Tropical regions 0.5 atmos

Table 12 Douglas Basic formula in Bengal, India (3.1)

Compound	mg/litre
$NaNO_3$	170
$(NH_4)_2\ SO_4$	85
$CaSO_4$	43
$Ca_2(PO_4)_3$	100
K_2SO_4	114
$MgSO_4 7H_2O$	70
Trace elements mix	0.5

Here the trace elements are in the weight ratios of:

$ZnSO_4 7H_2O$	:	$MnSO_4 H_2O$	:	H_3BO_3	:	$CuSO_4 5H_2O$	:	$FeSO_4$
5	:	15	:	13	:	5	:	19

This 'basic formula' has also been used for dry application at the rate of up to $60g/m^2$ of gravel bed area.

Table 13 A NS formula from the Arid Lands Research Centre (3.20) Sadiyat, Saudi Arabia

Compound	mg/litre
$MgSO_4$	10
KH_2PO_4	5.88
KNO_3	4.5
$CaNO_3$	21
Fertilon (Fe chelate BASF)	2.16
H_3BO_3	0.0776
$MnCl_2$	0.024
$ZnSO_4$	0.00855
MoO_3	0.00096
$CuCl_2$	0.00231

The pH of this NS is around 5.6 with 1,000ppm DSS whilst desalinated water at 50ppm DSS was used for NS preparation. When applied to the alkaline sand (see Section 2.3.2) the resulting pH was in the range 6 - 7. To prevent phosphate fixation due to the non-inert calcareous sand, trials with superphosphate additions to the mediums were first tried. Present experiments are concentrating on the use of monobasic potassium phosphate both in the NS and as a foliar spray.

2.6.3b NFT

From a joint study with R. Charlesworth of ADAS (Wye), Cooper (5.4) tabulated the theoretical and actual nutrient status of a NFT tomato crop. Tables 17 and 18 are arranged to compare these two states.

Table 14 Nutrient element ppm in NFT NS

Element	Desired amount	Average achieved
N	200	206
K	300	250
P	60	39
Ca	250	237
Mg	50	78
Fe	12	2.80
Mn	2	0.79
B	0.3	
Cu	0.1	0.06
Mo	0.2	0.02

Table 15 Nutrient source of supply in NFT NS

	(g/plant/week)	
Source of supply (compound)	Required rate of supply	Average rate of supply
KNO_3	2.25	2.25
$Ca(NO_3)_2 4H_2O$	2.08	2.08
KNO_3	as above	as above
KH_2PO_4	0.175	0.088
KH_2PO_4	as above	as above
H_3PO_3	as indicated by pH	0.36ml
$Ca(NO_3)_2 4H_2O$	as above	as above
$MgSO_4 7H_2O$	1.09	1.63
FeNaEDTA	0.47	0.11
$MnSO_4 4H_2O$	0.036	0.014
H_3BO_3	0.0039	
$CuSO_4 5H_2O$	0.0003	0.0002
$(NH_4)_6Mo_7O_4 4H_2O$	0.003	0.0001

This particular crop of Sonata was sown on 18th November 1974. Soon after germination 578 seedlings were placed in circulating NS at their final cropping positions in a plastic greenhouse. The crop was grown at blueprint air temperatures with CO_2 enrichment to approximately 1,200 vpm and the plants were stopped at the overhead wires. The last fruit were picked on 9th June and the total yield was 6.6lb/plant.

Whenever the pH of the NS rose above 7.0 H_3PO_3 was added to reduce the pH to approximately 6.0; the highest and lowest values achieved being 7.3 and 5.9 respectively. As nutrients were removed by the crop, the SC falling, further nutrients were added; the lowest and highest values achieved being 1,900 and 2,900 respectively.

From a comparison of Tables 17 and 18 it can be seen that in this trial the supply of N and Ca was about correct, there was too much Mg and the supply of K, P, Fe, Mn, B, Cu and Mo was low.

It was found that although no Zn or Na were deliberately added there was a progressive build-up of both elements in the NS until after 27 weeks there was approximately 7ppm of Zn and 60ppm of Na. These concentrations did not appear to have any adverse effect on yield. Although there was 113ppm of Ca in the water supply there was no build-up, the crop presumably removing it fairly rapidly.

As a result of this and other nutritional studies, two NS formula have so far been in general use, one for starting and one thereafter for 'topping-up', which are given in Tables 16 and 17.

Table 16 <u>NFT starting NS formula</u>

Compound	Stock solution g/litre	Dilution ml/litre	Concentration ppm
$Ca(NO_3)_2 4H_2O$	787	1.25	117(N)168(Ca)
KNO_3	169	3.9	254(K)91(N)
$MgSO_4 7H_2O$	329	1.5	49(Mg)
KH_2PO_4	91	3.0	62(P)78(K)
FeNaEDTA	12.3	3.0	5.6(Fe)
$MnSO_4 4H_2O$	3.0	3.0	2.2(Mn)
H_3BO_3	1.23	1.5	0.32(B)
$CuSO_4 5H_2O$	0.17	1.5	0.065(Cu)
$(NH_4)_6MoO_4 4H_2O$	0.06	1.5	0.007(Mo)
H_3BO_3	-	0.044	23(P)

Table 17 <u>NFT topping-up NS formula</u>

Compound	Stock solution g/litre	Dilution ml/litre	Concentration ppm
$Ca(NO_3)_2 4H_2O$	787	0.5 tomatoes	47(N)67(Ca)
		1.0 cucumber	93(N)133(Ca)
$MgSO_4 7H_2O$	329	1.0	32(Mg)
KNO_3	169	2.13	147(K)51(N)
FeNaEDTA	24.5	0.4 tomatoes	1.5(Fe)
		0.8 cucumber	3.0(Fe)
$MnSO_4 4H_2O$	7.42	0.3 tomatoes	0.55(Mn)
		0.6 cucumber	1.1(Mn)
$CuSO_4 5H_2O$	1.7	0.15	0.065(Cu)
$(NH_4)_6Mo_7O_4 4H_2O$	0.6	0.15	0.007(Mo)
H_3BO_3	6.17	0.3	0.32(B)

After the starting NS has been made-up in the storage tank, the stock NS is added separately when required. In 1976 (3.27) it was usual to dissolve each stock compound separately in a litre of water which was placed in individual labelled plastic containers, preferably screw topped. For each litre of water in the storage tank, the volume of stock solutions shown under 'dilution' was added. Hence, the larger the volume of the storage tank, the less frequently topping-up was required.

From this original method, others utilizing automatic control have been developed where two or three stock solution tanks are maintained to simplify the operation. The acid may be kept separately to enable independent pH control and prevent reaction with other stock solutions when concentrated.

Secondly, calcium nitrate may also be kept in a separate stock solution tank in order to give greater control over the 'hardness' of the NS with varying make-up water qualities.

The latter variation in particular has given rise to branded NFT 'feeds' of the raw preformulated compounds packed in two or three separate containers with relatively simple instructions on usage. It is fair to say that all these 'mixes' stem from the original formulae in Tables 16 and 17 but they may vary in cost and other features.

As an example of cost it is useful to describe a relatively simple NS formula used at Efford EHS in 1977 as cited in Table 18. (6.3, 5.10)

Table 18 NS formula used at Efford EHS in 1977

Compound	per litre	£ cost/acre
KNO_3	170g	350
$MgSO_4 7H_2O$	76g	60
FeNaEDTA	10g	420
$MnSO_4 H_2O$	1.2g	6
$Na_2B_4O_7 10H_2O$	0.4g	2
HNO_3	300ml	200
H_3PO_3	100ml	220
		1,258

Soil fertilizer would cost approximately £700/acre, so to make the NFT system more competitive the following adjustments were made. Iron sequestrene, i.e. the chelated Fe, is the most expensive item and so ferrous sulphate was substituted, being much cheaper. The only problem found was that it tends to precipitate in hard water. However, using nitric acid to encourage the dissolving,it gave good yields. This brought the cost for Fe from £420 to £20. Secondly, the acids were expensive so ammonium nitrate (and/or ammonium sulphate) were used; care being taken when using ammonium with tomatoes to prevent blossom end rot. The total expenditure was thus brought from £1,258 down to £738.

2.6.3c Rockwool

Because the main crop grown to date on rockwool has been cucumbers Table 22 shows the desired nutrient composition for this crop (3.36).

Table 19 Desired nutrient composition for cucumbers (in rockwool)

Element	Ion	ml/litre	mg/litre
N	NO_3^- NH_4^+	11.5, 0.5	161, 7
P	$H_2PO_4^-$	1.5	46.5
K	K^+	7	273
Mg	Mg^{2+}	1.5	18
Ca	Ca^{2+}	7	140
S	SO_4^{2-}	4	64
Fe			0.5 - 1.0
Mn	Minor and		0.25 - 0.5
Zn	trace elements		0.25
B			0.3
Ca			0.02
Mo			0.05

The Experimental Station for Glasshouse Crops in Naaldwijk, Holland cites two NS formulae (Table 20) when using either normal pH 'non-salty water' or rainwater which has a lower pH.

Table 20 NS formulae for use with normal or low pH water for cucumbers on rockwool

Compound	Normal pH mg/litre	Low pH mg/litre
$Ca(NO_3)_2H_2O$	637	637
NH_4NO_3	40	40
KNO_3	404	404
H_3PO_4	98	49
$MgHPO_4$	125	250
K_2SO_4	261	261
$MgSO_4.7H_2O$	128	64
Fe-DTPA	5.6	5.6
$MnSO_4.H_2O$	1.6	1.6
$ZnSO_4.7H_2O$	1.1	1.1
$Na_2B_4O_7.10H_2O$	1.8	1.8
$CuSO_4.5H_2O$	0.12	0.12
$Na_2MoO_4.2H_2O$	0.12	0.12

This formulation is not only designed for the crop but also takes account of the non-inert CaO in rockwool and thereafter the pH of the two main water sources in Holland, i.e. good quality (filtered) canal/tap/borehole water and collected rain water. For practical usage these formulae are recommended for make-up as in Table 21.

Table 21 Preparation of concentrated stock solutions for cucumbers on rockwool

(to be diluted 100 times)

Stock solution	Compound	weight per 1,000 litres of stock solution Normal pH	Low pH
A	$Ca(NO_3)_2H_2O$	63.7kg	63.7kg
	KNO_3	25.0kg	25.0kg
	NH_4NO_3	4.0kg	4.0kg
	*Fe chelate 330	560g	560g
B	$H_3PO_4$37%	26.5kg or 21.2 litre	13.2kg or 10.6 litre
	$MgHPO_4$	12.5kg or 8.9 litre	25.0kg or 17.7 litre
	K_2SO_4	26.1kg	26.1kg
	$MgSO_47H_2O$	12.8kg	6.4kg
	KNO_3	15.4kg	15.4kg
	$MnSO_4H_2O$	160g	160g
	$ZnSO_47H_2O$	110g	110g
	$Na_2B_4O_710H_2O$	180g	180g
	$CuSO_45H_2O$	12g	12g
	$Na_2MoO_42H_2O$	12g	12g

* or 840g of Librel FeDP

Hence in a similar way to the NFT system, two or more stock solutions can give greater control over NS pH and nutrient composition.

CHAPTER 3

STATE OF THE MARKET

3.1 A Market Overview

3.1.1 The 'controlled-environment'

The development of hydroponics requires control of the NS both in a physical and chemical manner. The purpose is to provide a controlled root environment contributing to optimal yields(in combination with a suitable shoot environment).

By controlling a plant's environment the yield limiting factors can be reduced (see Section 2.1.2) e.g. temperature. Where the climate factor is not limiting but the soil is, hydroponics may be applicable on its own.

Like greenhouses, hydroponics is capital intensive and so for reasons of cost and yield it is important to determine what degree of controlled shoot environment, if any, is required for the hydroponic systems having commercial potential. There are several types of 'protection' for such crops, cited below in the order of increasing costs.

(a) wind breaks
(b) shade netting
(c) plastic cloches
(d) plastic greenhouses
(e) glass greenhouses
(f) growing cabinets.

NFT and rockwool have to date been primarily utilized in plastic or glass greenhouses mostly in the UK, Holland or Channel Islands. The majority of aggregate culture has been practised outdoors in warmer climates.

Recently NFT has been incorporated by the General Electric Company, USA in intensive growing cabinets using their own wide spectrum lamps and reflective, insulated walls. These high-yielding, self-contained units represent the limit of capital intensive, controlled-environment facilities presently available for horticultural crops.

Mastalez (4.6) defines a greenhouse as 'a structure covered with transparent material that utilizes solar radiant energy to grow crops'. Necessarily however, a greenhouse grows relatively high value crops that otherwise could not be grown, at least in such quantity or quality, in that area. These crops must be sold at higher prices to cover the cost of providing them.

Appendix D summarising the distribution of greenhouses shows that they are concentrated in the temperate, developed countries with larger populations.

If an analogy can be made between greenhouses and hydroponics as controlled-environment facilities the averages listed in Appendix G represents the possible hydroponic market. However, the two are not directly equatable, even when considering NFT or rockwool, for the following reasons:

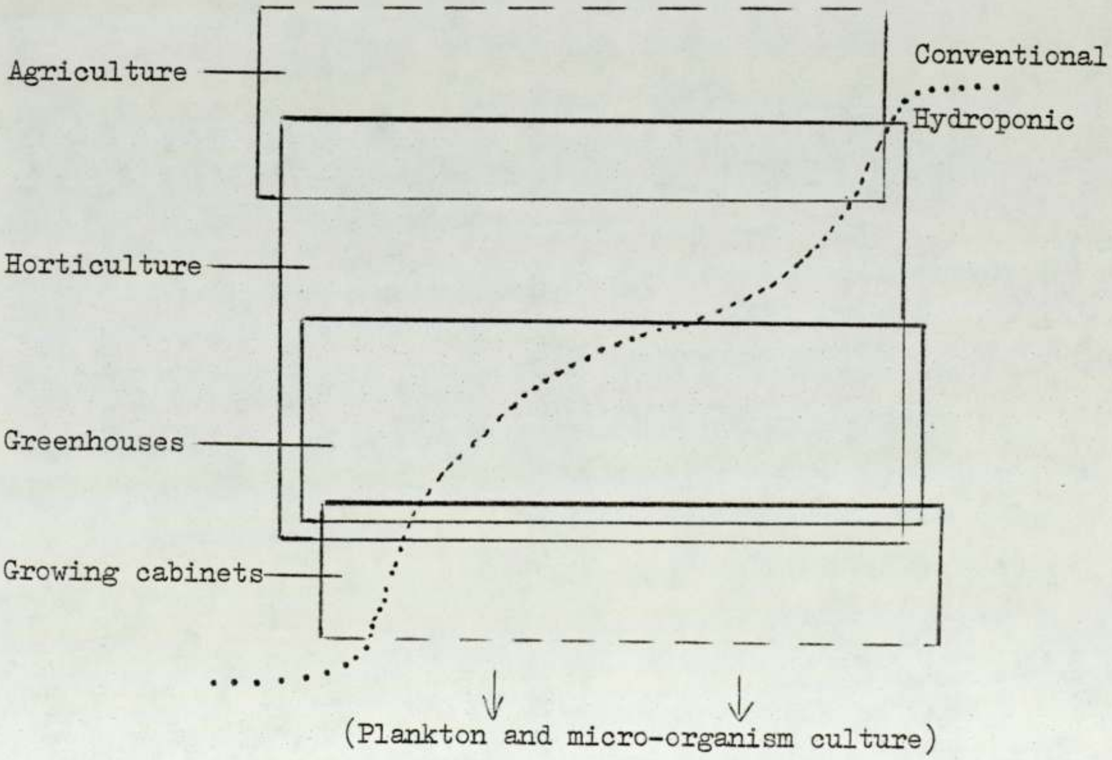
(i) the present greenhouse industry is based largely on soil or peat. If suitable water is available hydroponics is not so restricted.

(ii) a greenhouse's variable costs are divided three ways, i.e. energy, labour, and materials. If hydroponics alters the proportion spent on each, e.g. less on energy and more on materials (see Section 2.4.7) it may mean that different segments of the future greenhouse industry are suitable for hydroponic or conventional methods.

(iii) further market segmentation may result from different yields and growing techniques as discussed throughout Sections 2.2 - 2.6.

As an interim aid Figure 17 has been constructed. This model illustrates a possible segmentation of the plant cultivation market in its entirety.

Figure 17 Possible segmentation of the plant cultivation market



The important figures are the total percentage of each segment likely to be taken by hydroponics.

It is possible, particularily in semi-arid countries with a demand for high value crops, that hydroponics will allow the horticultural industry to expand.
This is why many commercial firms are investigating the subject, including DIS. In the long term, the possibility of depressing the market price with increased production may limit the room for growth in this direction.

Of the world's land area, only one fifth is of productive use via conventional agriculture (2.3, 2.4). Appendix H presents cultivatable areas with or without irrigation plus populations now and in the year 2000. Considering the conservative use made of water by hydroponics, with no reliance on soils, the scope for application appears vast, assuming that the markets can sustain the prices. On a world-wide scale the central feature is that of cost where a greenhouse/hydroponic facility may be over 60 times (in the UK) more capital intensive than conventional agriculture.

In markets where the capital cost is feasible the features (presently deducible from the literature) which may influence the usage of hydroponics are summarized as advantages or disadvantages in the next section.

3.1.2 Advantages and disadvantages

In Tables 22 and 23 rating judgement is attempted for the three hydroponic systems of commercial interest at present — NFT, rockwool and aggregate culture. From the previous review of literature, the relative importance of items affecting

Table 22 Advantages of hydroponics

N = NFT, R = rockwool, A = aggregate culture

Advantageous features rated out of 10 points	Outdoors			Protected			Greenhouse		
	(N)	(R)	A	(N)	(R)	A	N	R	A
1 No costly soil preparation	5	4	3	5	5	2	4	4	3
2 No costly soil sterilization	5	3	2	6	3	2	5	3	2
3 Reduced soil borne diseases	0	2	1	1	2	1	3	4	2
4 Efficient use of fertilizers	7	6	4	6	6	4	4	3	2
5 Nutritional/pH control	3	3	2	4	4	2	5	5	3
6 Growth/disease control	2	2	1	4	4	3	5	4	3
7 No drying out periods	1	3	5	2	4	4	3	5	4
8 No water logging periods	1	1	1	1	1	1	0	0	1
9 NS heating potential	1	1	0	2	2	1	8	6	3
10 Quicker planting	2	1	0	3	2	0	3	2	0
11 Easier harvesting	0	0	0	1	1	0	1	1	0
12 Rapid crop turn-round	2	1	0	4	3	2	6	4	2
13 Weeds non-existent	1	0	0	1	1	0	1	1	1
14 Increased yields	6	6	8	8	6	7	10	8	4
15 Good size of produce	4	3	6	5	5	6	6	6	5
16 Good quantity of produce	4	4	6	5	5	5	5	5	4
17 Good taste/colour	2	2	3	3	3	3	3	3	2
18 Clean produce for market	2	1	1	3	3	3	4	3	2
19 Suited to sloping site	1	0	1	1	0	1	1	0	1
20 Variety of crops in same system	1	1	3	1	1	2	1	1	1
21 Variable size of system	3	2	1	2	1	0	1	0	0
22 Labour reductions	0	0	2	1	0	2	2	0	1
23 Challenge/novelty	1	1	1	1	1	1	2	2	1
24 (Declared return on investment)	3	3	3	5	5	3	7	6	2
Totals	57	50	45	67	68	55	85	76	49

Table 23 Disadvantages of hydroponics

N = NFT, R = rockwool, A = aggregate culture

Disadvantageous features rated out of 10 points *	Outdoors			Protected			Greenhouse		
	(N)	(R)	A	(N)	(R)	A	N	R	A
1 Artificial beds required	5	4	6	3	1	8	4	2	6
2 Water tight system	3	1	4	3	0	3	2	0	4
3 Artificial media	0	2	3	0	2	4	0	2	6
4 Extra support	5	4	2	4	3	1	3	2	1
5 Tanks and pumps specified	1	0	1	1	0	1	1	0	1
6 Non phytotoxic materials	3	1	2	3	1	2	2	1	2
7 NS pH to be controlled	3	3	2	2	3	1	1	2	1
8 NS nutrition to be controlled	3	2	3	2	1	2	1	1	1
9 Some standby equipment	3	1	3	2	1	2	2	1	2
10 Conventional planting methods changed	1	1	1	0	0	0	0	2	0
11 Conventional harvesting changed	1	0	0	0	0	0	0	0	0
12 Culture methods changed	1	1	1	1	1	1	2	2	2
13 Disease spread risk	3	2	2	2	2	2	2	1	2
14 Extra skills required	3	2	1	3	2	1	3	3	2
15 Degree of reliability	5	3	2	4	2	2	4	3	4
16 Larger capital outlay	8	9	10	7	8	9	6	7	8
17 Risk with 'new technique'	4	3	2	3	3	3	3	3	6
18 Cost of changing if unsuitable	4	2	3	5	3	8	6	5	9
19 Replacement equipment problems	0	2	0	0	5	0	0	1	0
Totals	51	42	46	45	32	50	40	39	57

* These figures are negative values.

the usage of each hydroponic system is marked out of ten; positive for advantages and negative for disadvantages. The summation of these values provides only a general indication of the potential for commercial expansion of each system. Because there are many unmeasurable variables such as climate and country of installation, the rating system is largely subjective.

Three separate rating lists are given depending on whether the shoot environment allowed:

(a) hydroponic culture in the open (often semi-tropical)

(b) protected by shading to subdue harsh solar radiation (and possibly wind or other conditions, e.g. sand storms)

(c) greenhouse culture used primarily for maximising radiation e.g. light (and often heat) which can include growing cabinets with their own light source.

By subtracting the disadvantages from the advantages we find net positive values in seven out of the nine supposed cases.

	Outdoors			Protected			Greenhouse		
	(N)	(R)	A	(N)	(R)	A	N	R	A
Advantageous features	57	50	45	67	68	55	85	76	49
Disadvantageous features —	51	42	46	45	32	50	40	39	57
A possible net effect	6	8	-1	22	36	5	45	37	-8

<u>Note</u> (N) and (R) indicates that neither NFT nor rockwool has been under trial commercially in outdoor or 'protected' conditions.

3.1.3 An approach to market research

The greenhouse industry was chosen initially as the general market area to investigate because:-

(a) Sections 1.3.3, 3.1.1 and 3.1.2 direct research principally to controlled environment growing in NW Europe.

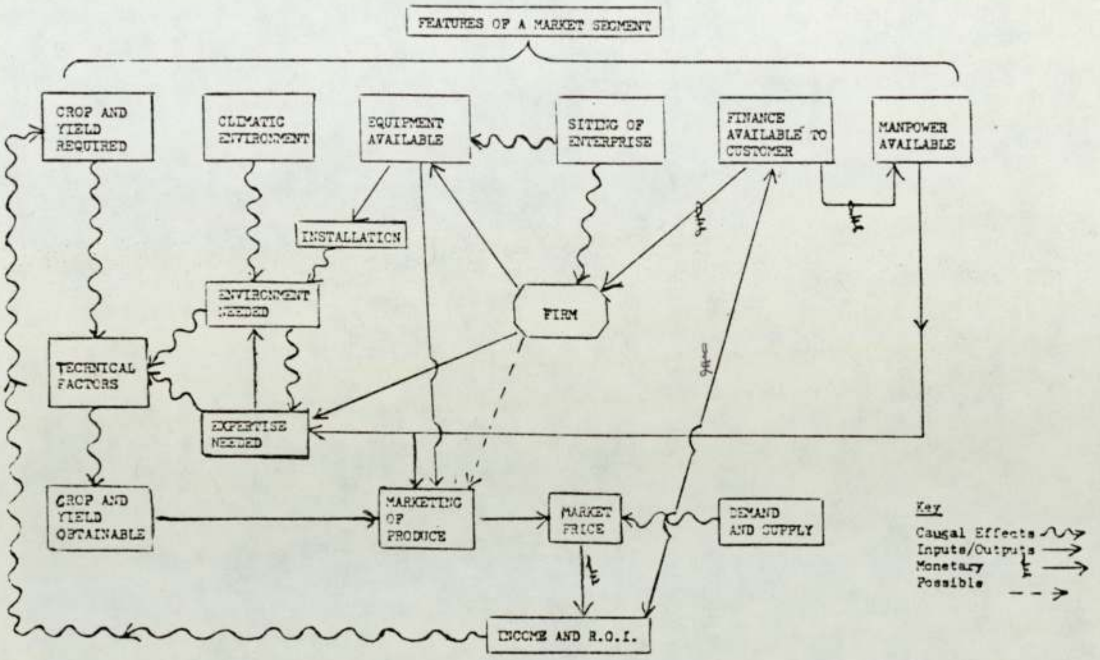
(b) Nearly all hydroponic systems have been used in greenhouses by established growers.

Nevertheless growing cabinets or more open conditions can be used for hydroponics, and potential customers for hydroponic systems need not always be established horticultural growers. Apart from small amateur and domestic units, commercial systems may be installed by industries, e.g. breweries or dairy produce companies wishing to diversify into this new area of horticulture.

Hence we are considering industrial market research rather than 'consumer research'. Ward (1.3) describes the former as 'depending more on the subtlety of interviewing and the knowledge of the informant. The researcher uses a matrix approach to the appreciation of a market situation filling gaps in a pattern of information and reconciling all data gathered to give an internally consistant picture, compatible with known fact and reasonable conjecture. It is not enough to ask how many ? But also why ?'

The literature review was the first stage of the desk research but further analysis (both desk and field) is required of the greenhouse industry to determine the market opportunities available to a company offering hydroponic equipment and services. Figure 18 is presented as a possible and simplified model of the basic factors in a greenhouse market segmentation and how they could affect the company.

Figure 18 Inter-relationships in a possible turnkey operation



By illustrating the effects in Figure 18 with four different symbols (i.e. ⇝, →, £→, - ->), a distinction is made between the types of influence each of the six 'market features' have on the turnkey operation.

We are pursuing therefore the key factors that influence the greenhouse industry and its choice of growing systems.

Sources of information may be:

Trade press, lay press and related area reading.
Government and institutional figures and publications.
Conferences, open days and exhibitions.
Promotional literature and contacts with companies.
Internal company information.
Discussion with growers and research workers.
Questionnaires/structured interviews.
Field (practical) experience.
(These are acknowledged in the bibliography and appendices.)

We must also identify the factors which limit market potential, at the subsequent stage of market research.

From initial discussions with growers and researchers plus a small scale questionnaire (Appendix E) some appreciation of the market place was obtained in early 1978.

- growers as a community (2.5 - 2.10) disliked forms, the more detailed/demanding a questionnaire the lower the return rate (1.4)
- it was more informative to discuss the possibilities of hydroponics at first hand with growers and research workers
- the trade press, in particular the Grower journal appeared an informative and reasonably representative indicator of the market place.

Tables 22 and 23, constructed in early 1978, reflect values from these early field enquiries as well as from the literature review. Section 3.2.1 is presented as a brief survey of the 'talking topics' in the greenhouse industry on the subject of maintaining or improving the business profitability and management. These topics are expanded and quantified where possible in the rest of this chapter.

Experience from late 1978 in the hydroponic company, purchased by Dunlop enabled further market features to be included which contribute to the strategic discussion in Chapter 6.

3.2 Factors Influencing the Greenhouse Industry

3.2.1 Overview

The capital invested in a fully automated heated glass greenhouse may be £100,000/acre (UK 1977/78) depreciating over an average 15 years.

Running costs (≏ £30,000/acre/year) excluding marketing can be divided into three: energy (1/3rd plus); labour (1/3rd); and materials (1/3rd) as in Appendix E.

The market price for greenhouse produce in general is not sufficiently reflecting costs to maintain adequate profit margins for the grower. Hence he is seeking improved efficiency/productivity which may be achieved in one or several ways. It is those key factors that have been given a priority ranking in Table 24 for the purposes of this project.

Apart from a qualitative judgement several approximate measures were used to aid ranking which included:

(i) for one year all the articles in the trade press (mainly the Grower) which discussed the particular topic were counted. If two or more topics were discussed in the same article this was allocated as two or more articles respectively.

(ii) from 8 questionnaires and 12 visits to individual growers plus 11 discussions with research workers an approximate 'priority marking' system was used. On a scale of 5 to zero marks were allocated on the approximate importance/proportion of the topic to the 'interview'.

(iii) an approximation of the financial implication of good or bad management as the potential difference in income per acre is also inserted in Table 24 (see Section 3.2.3).

Running parallel to these factors is the need for job satisfaction, not only for the grower but also his employees with whom he usually works closely (2.9).

Having assessed the importance of these general market needs it should be important to understand how hydroponics can meet them and to what extent.

Table 24 A ranking of key factors in UK (NW Europe) greenhouse industry

RANK	KEY FACTORS IDENTIFIED	TRADE PRESS ARTICLES 8/77 - 8/78	QUESTIONNAIRE INTERVIEW MARKING	POTENTIAL DIFFERENCE INCOME/ACRE	COMMENTS
1	Reduction of energy costs	63	105	£6,000	Several recent conferences/ papers, oil crisis
2	Yield increase, particularly when prices high (off season)	82	95	£5,000	Affected by climate Costs must be acceptable
3	Reduction of labour costs and improved man management	49	60	£3,000	Man hour reduction per ton of crop
4	Concern over costs of equipment and materials	45	56	£4,000	Purchase price important after other savings. Will improvise where possible
4	Improved quality of produce plus pride in achievement - expansion	101	49	£3,000	Close knit industry. Articles are 'individual features'
6	Continual assessment of improved physical cropping methods	42	62	£2,000	Recent ideas suggest this subject becoming important
6	Advisory service support and grant aid	69	42	£4,000	Close co-operation, grant aid is a MAFF recommendation
8	Continual assessment of cultivars and cropping regimes	53	20	£3,000	Gradual development as a rule
8	Continual assessment of pesticides and other disease inhibiting methods	56	15	£4,000	Of main interest when crop infected
10	Better trade agreements, reducing import requirement and boosting demand (prices)	49	3	£4,000	A national issue not directly in control of growers

It is argued that the emphasis placed on the yield/cost effectiveness of particular hydroponic systems should be ranked in an appropriate order, e.g. for promotion purposes, Sections 3.2.2 - 3.2.5 provide evidence based on a literature review.

3.2.2 Energy

In 1974 E.T. Wall (2.5) stated 'the change in world fuel prices during the last year has increased enormously the annual running costs of heated greenhouses ..... this has (further) altered the comparative position of the heated greenhouse sector.' Over the period 1974 - 1978 the energy cost rose £5,560 - £9,874/acre for tomatoes on Guernsey. (6.6)

A. Nisen in 1974 (2.6) believed that the shifting of 'protected' culture from the north to the south of Europe (partly as a result of energy costs) will continue, whilst a spreading of greenhouse cultivation in northern Europe seems improbable. Nisen listed his priorities for action as:

(a) reduce the heat losses in existing units, e.g. by plastic (or even glass) double glazing (4.10)

(b) restudy the planning of production and avoid cultivations which require much 'artificial' heat

(c) to study in existing units the possibility of obtaining the best from semi-forcing, i.e. without artificial heat or at best with an anti-freeze system.

Jacobs and Meijaard (2.7) also note the competition between northern glass and southern plastic greenhouses in Europe (see Appendix D). They stress that because intensive northern greenhouse costs are rising faster than the general increase, its position is weakened further.

In 1978 G.F. Sheard affirmed this message in the UK (2.8, 5.24, 5.26); that the world energy gap predicted sometime in the 1990's demanded action by growers now.'

When it is considered that oil consumption in the UK in 1973 for greenhouse heating was 496,000 tonnes, 25% of the petroleum fuel used directly in agriculture (2.14), the greenhouse industry appears very vulnerable in the long term, i.e. within 15 years.

Additionally, in temperate countries the energy balance of heated greenhouse crops is low.

<u>Ratio of energy output to input (other than solar)</u>
<u>for greenhouses and other systems</u> (2.8)

Primitive agriculture	5 ⟷ 50
Field crops	1 ⟷ 5
Livestock	0.1 ⟷ 0.5
Sea fisheries	0.01 ⟷ 0.05
Heated glass greenhouse crops	0.002 ⟷ 0.01

The situation above may place the industry low on the list of priorities in the event of fuel shortages, i.e. the industry must adapt.

A cartoon (Figure 19) from the Grower demonstrates the general awareness of the implications for the greenhouse grower of the energy crisis and the importance placed on energy saving by the MAFF.

Figure 19 <u>Cartoon demonstrating the greenhouse energy crisis</u>

"The energy consultant plans an exhaustive fuel saving programme and prescribes two energy pills daily."

Heat is lost from greenhouses by convection and radiation through the superstructure (80%), by air leakage (12%) and by conduction through the soil (8%). Since a 15mph wind causes twice the heat loss as does still air, correctly designed and positioned wind breaks, e.g. trees, can reduce heat loss by 10%, the capital cost of providing it being recouped in one year (2.15).

Thermal screens (6.3, 5.31, 5.42) over tomatoes, cucumbers and AYR chrysanthemums at night have enabled savings of 25-30%.

An opaque (to reduce radiation loss), semi-permeable (to keep down humidity) and reflective (to raise plant tissue temperature) material is sought. Whilst outside temperatures may be -3°C, the greenhouse apex 8°C, below the screen the crop can be at 16°C. At £3 - 5,000/acre and savings of £3,000 the cost may be recovered inside two years.

Automatic flue dampers isolate the boiler from the chimney when the burner is not firing and can save 5 - 10% of fuel.

Square-planned, multi-span, low-ridged, level greenhouses contribute further to the heating efficiency as does accurate adherence to the blueprint temperatures (2.8). Appendix E provides information on greenhouse heating requirements.

Of oil, gas and coal, the latter two fuels are rapidly becoming competitive (2.13, 5.45) for main bed heating. An increasing number of growers such as those of the New Forest are changing from oil to gas. Apart from cost, other incentives are the proximity of a gas main and the benefits of CO_2 enrichment.

Gas is estimated to have a 100 years reserve while coal may last for 200 years or more at projected consumption rates (2.14).

Active research into 'renewable' sources is continuing:-

Wind powered heating systems are under trial in several areas (2.16) and there are even tentative commercial versions on the market, but 'limits on knowledge of costs and technology appear to restrict the useful area of application for a single aerogenerator to around ⅓ acre.'

The use of a heat churn for giving a small temperature lift for the NS has been suggested but has yet to be tested (3.4).

The potential for using solar power for pumping or heating the NS via panels or heat pumps is still speculative at present. Development particularly in semi-tropical areas, may present opportunities in combination with hydroponics (2.18).

Geothermal steam heating is now becoming viable (2.17) with over £1.6m being spent in research by the Department of Energy over the past 2-3 years. It is reported that one project in the USSR has created more than 2,400ha of geothermally heated greenhouses on the Caspian Sea coast at Makhach-Kala.

At present, electricity (4.11) is used for boiler auxiliares, circulating pumps and motorised valves, lighting purposes at night/winter (4.12), growing rooms (4.13) and as power for ridge or fan ventilation (4.14). With an apparant potential for growing cabinets electric lamps (producing some heat) may be feasible (see Section 3.1.1).

For the greenhouse industry, one long term policy is to utilize waste heat from industry, e.g. power stations (CEGB). The Glengarioch Distillery (5.60) in NE Scotland produces 12,000 galls/hour of hot water and ran a trial ½ acre multi-span plastic greenhouse for tomatoes. This has not yet proved a success because of some organizational teething troubles.

The Dutch use mainly their own gas from N. Holland but this source has a life expectancy of around 20 years and the Government has started to aid greenhouse relocation.

Evidently, if hydroponics can reduce blueprint temperatures and contribute significantly to greenhouse heating the commercial prospects would look much brighter, particularily in NW Europe.

<u>Note</u> Details on £25m energy grants to industry (including agriculture) are available from the Department of Industry (2.19), and are not related to standard horticultural grants.

3.2.3 Labour

At the British Growers Look Ahead in Harrogate in early 1978, the main theme was the efficient use of manpower. R.W. Watson (2.10) commented on the increasing rights of employees regarding wages, grievances, holidays and possibly limited overtime. He saw a strain on staff relationships developing which may in part be generated by the rate of technological advance.

Hastings and Edmonds (2.9) discuss man management and 'spreading the labour more thinly as a result of escalating costs'. When discussing labour rationalisation it is important to appreciate the importance of job features to employees, if not to the grower, as outlined in Table 25. (2.11)

Table 25 Importance of job features to greenhouse employees (2.11)

	No. of employees considering them		
	Important	Not sure	Unimportant
Interesting work	209	3	0
Chance to see results of work	207	4	1
Friendly people to work with	206	4	2
Time off for genuine reasons	203	7	2
Variety	203	5	4
Good working conditions	200	5	7
Security	194	10	8
Job close to home	177	6	29
Responsibility	170	12	30
Convenient hours	169	12	31
Sympathetic supervision	162	23	27
Good training opportunities	146	24	42
High basic rate of pay	142	32	38
Good bonus scheme	134	31	47
Promotion prospects	126	19	67
Long holidays	77	28	107

Often however, the streamlining of production acts against these interests (which can enable the continuance of a **virtually** strike-free industry).

Appendix E gives details of man hours for crops and costs; for tomatoes an approximation is 2½ men per acre costing £8,200 in 1978. The Dutch, usually considered ahead of the UK in the greenhouse industry, use fewer man hours, the scale of their holdings being more suitable to factory style mechanical handling and automatic controls.

3.2.4 <u>New techniques</u>

These have been applied first to soil block production and pot plants. A logical progression after peat bags is conveyer style hydroponics, lettuce being an obvious candidate.

Following Dingeman's success (see Section 2.4.6), three growers in Denmark have (in early 1978) installed bench height and ground level systems on commercial scales (5.41). Next year after a five year development, General Mills (7.6) will be selling to supermarkets lettuce grown 'in moving containers that are automatically shifted through light and dark zones that simulate night and day'.

Computer sales for environmental control in Holland are steadily increasing (7.17) mainly to the larger holdings and to younger growers perhaps less conservative than their elders. Microprocessors have enabled a crop blueprint to be incorporated although many growers firmly believe in retaining human skill and judgement. There would in any case have to be competent managers to monitor the crop health and adjust the control system as necessary, which may include that for NFT, and possibly rockwool or other systems.

The problem is cost and consequent viability of apparatus that can measure, analyse and feed the computer with correct and reliable information in a suitable form.

For propagation, tissue culture has already begun to make its impact in America for ornamentals (2.12) and now for vegetables. The two prime commercial features are the production of:

- over 1,000 non variable plantlets from one explant within a year
- virus free stocks.

Against these is weighed the expense of laboratory facilities and expertise needed. There seems little doubt, judging from the interest shown by commercial plant breeders, that it will find a role in future horticultural supply of propagated stock, replacing to some extent seed, cuttings and mist propagation (the major conventional methods).

It is not known whether plantlets would need to be hardened off prior to hydroponic growth but this appears a logical extension to produce uniform, high quality produce.

Further techniques, are rotary graders, water conveyors, gantry planters and mechanised training systems. If agricultural engineering institutes and companies engineering have correctly understood the needs of the greenhouse industry, costs in the form of increased equipment appear.

to be preferred to increased labour costs.

3.2.5 Materials

Rises in raw materials costs appear less than those energy or labour, even though Sheard (2.20) records that the material cost of production for a full season's early heated tomato crop had increased in the 3 years 1974 - 1976, by more than a half. However, materials never accounted for more than 20% of total running costs. It is believed that these figures could reflect more investment by growers into energy/labour saving and improved production techniques.

If the cost index of PVC (see Appendix E) is a measure of material greenhouse costs then a 7% annual rise may be forecast over the next 5 years.

Peat costs are likely to increase markedly over the next decade in England. The latter is due to a restriction on supplies from Somerset and high transport costs. Furthermore, peat requires a deal of labour, especially for handling wet bags, and its re-use requires costly sterilization.

Provided that hydroponic material costs can remain competitive i.e. possibly $\leqslant$10% increase/annum, the comparative capital costs of hydroponic systems should not prove a barrier.

3.3 Trends in Greenhouses, Cropped Areas and Trade in NW Europe

3.3.1 Introduction

About two-thirds of the world's glass greenhouses are found in

W Europe (see Appendix D) between the latitudes 50°N and 55°N. Holland maintains the largest area, with the UK and Channel Islands in second place followed closely by W. Germany, then Belgium and Denmark.

Between the latitudes 36°N and 50°N plastic greenhouses predominate in France, Italy, Greece and eastern Europe. Particularly since 1960, plastic tunnels which enable higher CO_2 levels and night temperatures at low cost without the limiting factor of sunlight or wind have found favour in Mediterranean regions.

During the last 2 to 3 years expansion, particularly in glass greenhouses has slowed down; the area for the forseeable future is expected to remain almost static (2.5, 2.9, 2.20). In the developed NW European countries the output of various vegetables and ornamentals are now finely tuned to demand. Rising costs means that the industry must increase yield/cost efficiency whilst ensuring an adequate market price. However, increased yield can depress the market price with the result that some growers and crop areas may suffer.

From the mid 1950's metal/galvanised steel and aluminium has largely replaced timber in construction. In England and Denmark single wide span houses up to 30m built in the 1960's are now proving uneconomic with the largest span now in general production being 14m.

For vegetables, a typical span is 3.2m of the Venlo-type whilst ornamentals are usually cropped under wider spans of 6.4m.

Multispan houses may collect dangerous quantities of snow but can be used to give an extra supply of rainwater.

High winds restrict the use of plastic greenhouses in Holland and other flat/exposed regions.

In the more norther-ly regions most greenhouses use some heat (see Appendix D) and it is this feature that may substantially determine the future cropped areas and techniques in the industry.

3.3.2 The United Kingdom

Although the area has increased very slowly (almost static now) there have been marked changes in the distribution of the industry. Scotland (265 acres) together with the eastern region has declined whereas the most dramatic increases have been in East Yorkshire and the Vale of Evesham. (Appendix G)

There has been a trend for the size of holdings to increase mainly in the middle size groups (3-5 acres).

The principle crops are tomatoes, cucumbers, lettuce, chrysanthemums and pot plants.

Tomatoes

This will probably continue to be the main vegetable crop (5.25) but it is now finely tuned to demand. Fluctuations in production reflect any saturation of the market by home grown and imported fruit (see Appendix E).

Of the 310,000 tons of fresh tomatoes eaten in this country, (excluding those for processing, canning and so on) estimates of amounts and sources are as follows, in tons:

UK	125,000
Guernsey	50,000
Jersey	10,000
Holland	40,000
Canary Islands	60,000

(25,000 from other sources including: Ireland; E. Europe; Israel etc.)

The growth of output in the UK has steadily increased, as a result of increase in productivity.
from 98,000 tons in 1969 to 128,000 in 1976. The drop last year (1977) to 125,000 was said to be due to difficulties of the season which were apparently also the cause of the higher prices (Efford EHS publication dept.).

To the middle of 1978 tomato growers were reported to be faring from 'poor to moderate' although the forecasts from MAFF were expecting 130,000 tons, the increase coming off imports from Holland and Ireland. If the average price per pound is forecast at 18p then the 1978 production may be worth £50-55m. (Grower journal information dept.).

Van Heyningen Bros Ltd with a production of 25,000 tons this year is the largest single producer. Together with the Land Settlement Association (12,000 tons) they produce 20% of all tomatoes grown in the UK.

Lettuce

At £19.7m lettuce is now the second most important greenhouse crop in annual output. It is considered unlikely to take any increased acreage (2.20).

Cucumbers

This vegetable has increased its acreage significantly in the past four years but has probably reached a maximum in 1978, with market prices being depressed. The overcast summer weather did retard the demand but a surplus supply will probably restrict expansion in this crop for the next few years.

Sweet peppers

This is the only new vegetable to make significant progress in the UK, but with an acreage of only 66, it is believed there is room for expansion (5.25).

Ornamentals

The consumption of flowers in the UK is low compared to that of the continent. Public demand appears unlikely to increase very rapidly although some expansion and reinvestment has been noted in potted plants and spray chrysanthemums (Appendix D).

3.3.3 The Channel Islands

Guernsey

The island is small and at or near sea level. Consequently soil which is flat and of good quality, is limited (3.38).

By the mid 1960's, soil borne diseases were increasingly difficult to control and this plus deterioration of soil structure, enabled peat culture in troughs and grow bags to become established (in 1976, 77% of the tomato crop).

Commercial glass greenhouses in 1976 of 970 acres (see Appendix D) are not expected to expand. Of this, 234 acres were run hot during the season.

Tomatoes accounted for 60% of the total area with freesias, roses and other ornamentals making up most of the remainder.

The majority of holdings are in units of less than ½ acre which may present problems for installing automatically monitored NFT. A further problem is that of poor water quality with high levels of dissolved salts.

Jersey

The greenhouse area of 114 acres had 79 acres in 1977 used for early tomatoes with a further 6 acres for raising outdoor tomato plants. As with Guernsey, the yield varied from 80-130 tons, the average being about 100 tons/acre.

Notably, 15 acres had (by early 1978) been put down to NFT, largely on the bigger holdings. Although no great increase in yield had been recorded at this early stage (after 1-2 years) the quality of fruit had been improved. Additionally the variable costs of production were significantly reduced (H.M. Kitchener, Horticultural Advisory Officer, Jersey: private communication).

A high water table in the traditional glass greenhouse areas had made soil sterilization either by steam or methyl bromide difficult if not impossible. To avoid root diseases in particular (fusarium, verticillian, corky root rot complex) peat had been used extensively. A major incentive for the interest in NFT on this island had been the high cost of importing peat.

3.3.4 Holland

Concentrated mainly between the towns of The Hague, Rotterdam, Utrecht and Amsterdam, Holland has the largest glasshouse acreage in the world. Other regions in the SE and NE of the country contribute to the 19,000 acre (7,910ha) total greenhouse area.

The latest cropped area figures given by the Landbouw-Economish Instituut,(LEI)in 1977 are:

Vegetables (tomatoes, cucumbers, lettuce)	4,524 ha
Fruit (mostly grapes)	100 ha
Flowers and pot plants	3,241 ha
Nursery stock	45 ha

Although vegetables are most important there is a trend (2.20) towards ornamentals. Dutch tomato and cucumber growers had poor 1977 results with many just breaking even. Both these areas of 2,600 and 785ha respectively are expected to stabilise or slightly decrease.

Sweet peppers and minor crops were profitable and there is an increasing interest in aubergines, celery, courgette, beans, radish, cauliflowers and kohl rabi, for short term cropping which may be fitted into an established programme. The fleshy or beef tomato is also increasing and aimed at the W. German, Swedish and French markets.

3.3.5 Trade in greenhouse crops

The biggest exporters of vegetables (including those grown in the open) in the EEC are Italy and Holland with around 1.5 million tonnes each year, whereas W. Germany is the largest importer (3 million tonnes annually).

Most tomatoes from Italy are grown outdoors in plastic tunnels. The greenhouse industry in Holland is markedly export orientated. This contrasts with all the other countries in NW Europe (except Belgium), which supply only their domestic market.

About 80% of the Dutch production is exported with 70% of the vegetables and 80% of the ornamentals going to W. Germany. The tight control of marketing through the auction system is noteworthy. Selling is now being concentrated in a small number of large auctions which are replacing the older smaller auctions. Two flower auctions, Aalsmeer and Honselersdijk now account for 80% of the turnover of about £264m/year.

Within the EEC, Holland is the only notable supplier of cucumbers, which are exclusively a greenhouse product.

There are hardly any imports of lettuce from third countries. Within the EEC Holland is the largest exporter followed by Belgium and France, the latter crop being grown partly outdoors.

The UK plays practically no part in vegetable exports for a combination of reasons:

(a) market surpluses do not occur regularily enough for foreign buyers to depend on them

(b) big trading companies have focused their attention on UK imports rather than exports for reasons of currency.

(c) the UK is located a long way from the biggest market, W. Germany

3.4 Greenhouse Economics in UK and Channel Islands

3.4.1 Production and sales value of greenhouse crops

From Appendices D5, D6 and E the key production factors for recent years have been isolated.

Prices

For tomatoes, lettuce and cucumbers in recent years prices have not markedly improved. Although 1978 was a damp year and demand was low in the summer months prices were not increasing as fast as production costs.

Appendi es E2, E3 and E4 show seasonal prices. In the months that produce is not normally supplied by UK growers, field or semi-protected imports from southern Europe take the winter market when prices would not cover the home grower's costs. To stretch the crop production year without increasing costs is therefore very desirable as evaluated in Section 3.4.2.

Sales value

Appendix E6 approximates the returns made by a 100t tomato crop. Although there is an increase in return of 8% per annum it would provide a declining return on investment;this may be less than 13% in 1978.To remain profitable these growers must achieve greater yields with minimal increaes in costs.

A study in 1975 (2.24) showed differences of 5.2 % and 27.8 % for management and investment income between the average and the best grower at achieving these objectives.

Yields for each crop have improved until the average for a heated UK tomato crop was nearly 115t/acre in 1978 as shown in Appendix E5. For the Channel Islands Table 26 cites the yields achieved by a comparable group of growers.

Table 26 Heated tomato yields obtained in the Channel Islands (2.4)

Tons/acre	71	72	73	74	75
79.9	1 *	3	1	2	2
80 - 99.9	3 *	3	1	2	2
100 - 119.9	4	3 *	4 *	2 *	3 *
120 - 139.9	-	1	2	1	1
140	-	-	-	1	1

Increase in yield is one reason why output for the industry has been maintained although the cropped vegetable area has contracted. All three heated crops are under the same pressure and hence it is important to estimate what marginal increases in yield will mean to the grower in returns and hence how much he is prepared to pay for it by the increased capital cost of an NFT system.

Production costs in terms of labour and oil are apparently reduced marginally by NFT and so similarly the value to the grower may be estimated on a percentage basis over the year, or more speculatively at particular months of the year (depending on prices).

3.4.2 Marginal yield value to the grower

Section 2.4.6 reported tomato yield increases of possibly 35% with NFT tomatoes over conventional methods, but the increases commercially obtainable may be insignificant if the management is inexperienced or otherwise unattentive. Hence a range of yield increases from 2 to 20% are considered as increased yearly returns.

Similar approximations can be made for the other crops. Table 27 is considered an aid to estimating how much a grower may be prepared to pay if he knew that NFT (or any other system) would give him a certain percentage increased return (or conversely, cost saving).

Table 27 Reference marginal values

	£ increase in returns/acre				
Crop Return	2 %	5%	10%	15%	20%
34,000	680	1,700	3,400	5,100	6,800
38,000	760	1,900	3,800	5,700	7,600
42,000	840	2,100	4,200	6,300	8,400
46,000	920	2,300	4,600	6,900	9,200
50,000	1,000	2,500	5,000	7,500	10,000
54,000	1,080	2,700	5,400	8,100	10,800
58,000	1,160	2,900	5,800	8,700	11,600
62,000	1,240	3,100	6,200	9,300	12,400
66,000	1,320	3,300	6,400	9,900	13,200

Until 1978 most NFT tomato crops had shown about 10-15% yield increase. As yet no substantial figures have been produced on energy or labour saving, although neither of these costs have been shown to be greater than with a conventional system. Hence, a grower currently producing a 100t crop worth £54,000 may expect a further £5,400 a year at current prices.

An average NFT system (1978) may cost £12,000 complete. If the running costs are the same as conventional systems then this capital cost would be recovered inside three years. If the market price for tomatoes rises at 8% per annum whilst the marginal investment rate is taken as 10% then the gross present value, GPV for a three year project would be:-

$$\frac{5,400}{1.1} + \frac{5,400 \times 1.08}{(1.1)^2} + \frac{5,400 \times (1.08)^2}{(1.1)^3}$$

$$= 4,909 + 4,820 + 4,732$$

$$= £14,461$$

This would give a net present value, NPV after three years of £2,461.

From this simple case an NFT system should be attractive to an investor (grower). We can estimate, using the NPV method, what range of the marginal values in Table 27 would be a profitable proposition.

Depending on the acreage covered by one monitoring system and the life expectancy of the equipment, the number of years that an NFT system takes to produce a positive NPV will vary. From the descriptions given in Section 5.1, it will be assumed that the bulk of the equipment (£10,000) will last up to ten years but will be written off after five years. The remainder (£2,000) will need replacement each year.

The labour and materials replacement cost per acre for an NFT system is taken to be equivalent to that of a conventional (peat bags or soil) system for each of the five years that the capital cost is written off.

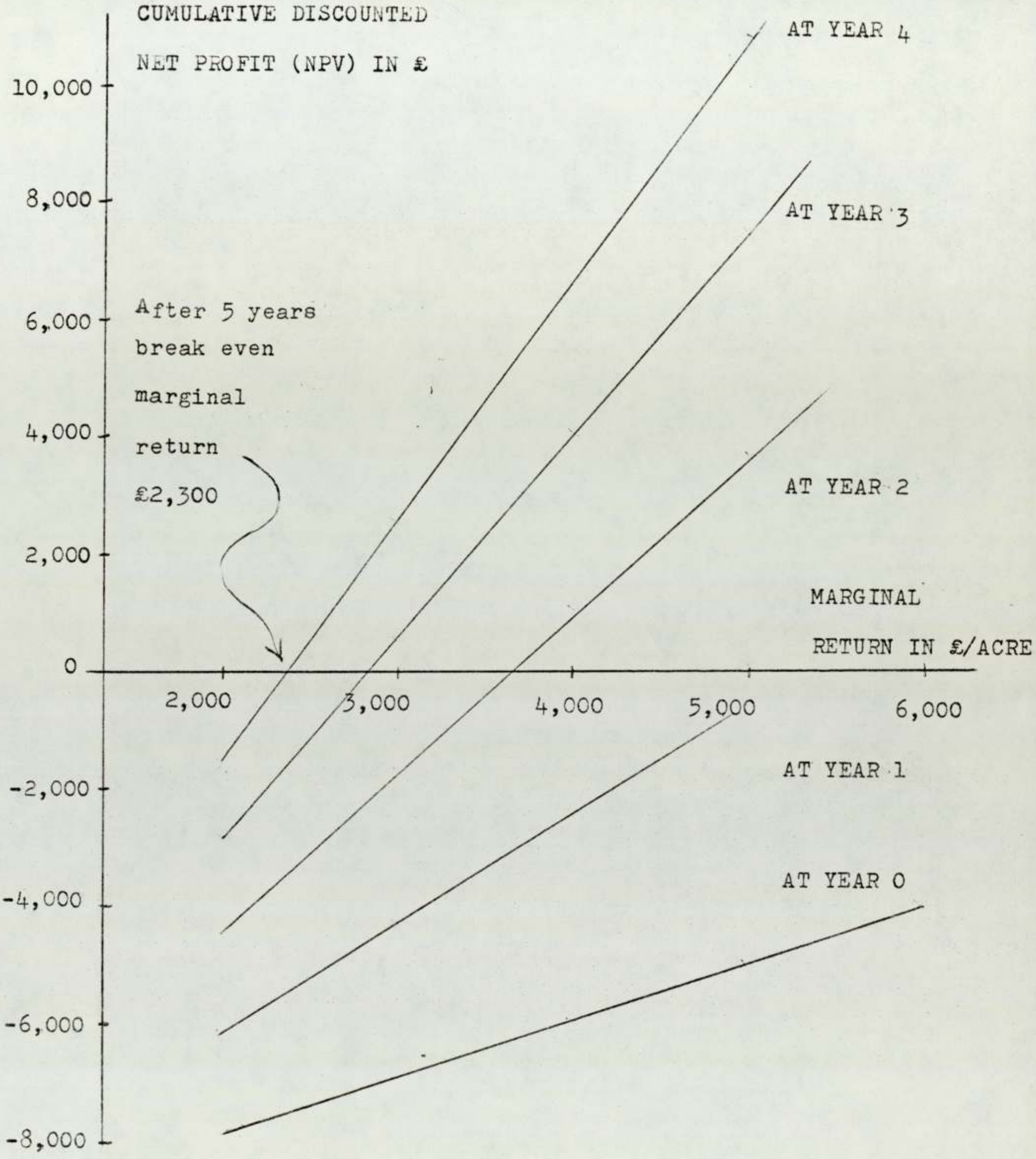
Using discount factors for a supposed grower's "marginal investment rate" the desired "rate of return" can be derived, and consequently by reference to Table 28, the desired yield increase or improved marginal returns can be discovered.

Table 28 Discounted cash flows for investment in a typical NFT system

Net capital expenditure = £10,000 at 10%

Marginal Return	Cumulative discounted net profit (NPV)					Net Profit at 5 year %
	0	1	2	3	4	
2,000	- 8,000	- 6,180	- 4,480	- 2,980	- 1,620	(16.2)
3,000	- 7,000	- 4,270	- 1,720	530	2,570	25.7
4,000	- 6,000	- 2,360	1,040	4,040	6,760	67.6
5,000	- 5,000	- 450	3,800	7,550	10,950	109.5
6,000	- 4,000	1,460	5,100	9,600	13,680	136.8
10% factors	1	0.91	0.85	0.75	0.68	

Figure 20 Discounted rates of return for investment in a typical NFT system



N.B. This graph is constructed from Table 28.

If the cost of capital is taken to be 10% then to achieve this rate of return after 5 years the grower must get £2,300 increased returns when investing in an NFT system. Therefore it can be estimated from Table 27 that he must achieve a yield increase of between 5 and 10%.

If the grower is looking for a net profit inside four or possibly three years then he has to achieve at least 5% increase in yield.

This over-simplified example illuminates how important it is to a greenhouse grower to achieve those fairly marginal increases in yield to remain profitable.

The following section attempts to introduce more variables into this model to estimate in 1979 and successive years how much the grower may be prepared to pay for a single complete acre of NFT.

3.4.3 Economic model for investing in NFT as a grower

Assumptions

By reference to Appendixes D and E as guides to the costings for heated/unheated greenhouse crops, the estimated positive or negative value per acre is inserted into the investment model.

The first two columns indicate the cash flow estimated in 1979, and the third column indicates the expected inflation costs of these items.

By balancing up the columns we can estimate the increased income as a result of increased returns plus the reduction in costs, minus the increase in costs (for each crop).

The marginal investment rate for the grower is taken as 12% , so that any project showing a positive NPV inside 5 years could be considered a profitable proposition.

The discount/inflation factors used are:-

$$\frac{1}{(1.12)^n} = 1 \quad 0.89 \quad 0.80 \quad 0.71 \quad 0.63$$

$$(1.08)^n = 1 \quad 1.08 \quad 1.17 \quad 1.26 \quad 1.36$$

$$(1.15)^n = 1 \quad 1.15 \quad 1.32 \quad 1.52 \quad 1.75$$

Assumptions with NFT:

	per acre +/- %	1979 £ value	% inflation
(a) Heat saving energy costs:			15
Hot mono-cropped tomatoes	+ 5	500	
Hot mono-cropped lettuce	+ 3	200	
Cucumbers	+ 1	100	
(b) Yield increases market prices:			8
Hot mono-cropped tomatoes	+10	6,000	
Semi-heated tomatoes	+10	4,500	
'Cold' tomatoes	+12	3,500	
Hot mono-cropped lettuce	+14	6,500	
Cold lettuce	+10	3,000	
Cucumbers	+ 5	2,500	
(c) Improved product quality - all crops	+ ½	300	8
Slightly earlier bulking of crops	+ ½	300	8
(d) Increased electricity and water costs	- 5	300	13
(e) Fertilizer increase over peat/soil	-10	200	13
(f) Replacement/maintenance cost of NFT is assumed to be a little less than yearly peat/soil	+10	300	13
(g) Labour input decreased slightly	+ 2	200	13
(h) Capital cost of NFT system less £3,000 for peat or soil systems			15
Lettuce auto system	-100	21,000	
Tomatoes/cucumbers auto elevated	-100	17,000	
Tomatoes/cucumbers auto ground	-100	10,000	
Semi auto ground (for extra labour £2,000/year deducted)	-100	7,000	

<u>Net balance of cash flows for years:</u>	0 to 4	0	1 to 4 (x2 elevated)
Discount/inflation rates	8%	(15%)	15%
Hot mono cropped tomatoes:			
auto elevated	6,600	16,500	1,000
auto ground	6,600	9,500	500
semi auto ground	4,600	6,500	500
Semi heated tomatoes:			
auto elevated	5,100	16,800	400
auto ground	5,100	9,800	200
semi auto ground	3,100	6,800	200
'Cold' tomatoes:			
auto elevated	4,100	17,000	
auto ground	4,100	10,000	
semi auto ground	2,100	7,000	
Cucumbers:			
auto elevated	3,100	16,900	200
auto ground	3,100	9,900	100
semi auto ground	1,100	6,900	100
Hot mono cropped lettuce:			
auto system	6,500	20,800	400

Each combination of figures for the particular NFT systems in this table, indicate their various commercial potentials. These figures are projected in a similar manner to those in Section 3.4.2, and the resultant NPV figures are presented in Table 29.

Table 29 Discounted cash flows for a grower's investment in different NFT systems

NFT system and crop	NPV in years				
	0	1	2	3	4
Hot mono cropped tomatoes:					
auto elevated	- 9,900	2,533	4,700	11,683	18,547
auto ground	- 2,900	3,955	10,660	17,010	23,090
semi auto ground	- 1,900	3,033	7,867	12,757	17,447
Semi heated tomatoes:					
auto elevated	-11,700	-6,388	-1,192	3,802	8,777
auto ground	- 4,700	412	5,721	9,985	14,102
semi auto ground	- 3,700	- 590	2,522	5,532	8,260
'Cold' tomatoes:					
auto elevated -	-12,900	-8,959	-5,121	- 1,453	2,115
auto ground	- 5,900	-1,959	1,879	4,590	7,420
semi auto ground	- 4,900	-2,881	- 915	964	2,590
Cucumbers:					
auto elevated	-13,800	-10,616	-7,513	- 4,409	-1,298
auto ground	- 5,900	- 2,805	302	3,412	6,548
semi auto ground	- 4,900	- 3,797	-2,674	- 1,470	- 235
Hot mono cropped lettuce:					
auto system	-14,535	- 7,878	- 976	5,922	12,921

The cash flows for each of the cases in Table 29 do not widely differ in the pattern of return from the supposed case in Figure 20.

Nearly all the cases based on a criterion of five years for a positive NPV appear attractive. The auto ground (automatically monitored) NFT system shows most favourably and with the heated mono crops, where capital is used more intensively.

Two other financial considerations are the extent to which such investments can be set against tax, and grant aid. The latter was approved by ADAS in October 1978 subject to the Horticultural Capital Grant Scheme and the Farm and Horticultural Development Scheme.

Grant aid can provide 10% of the capital cost provided (as at December 1978) that:-

(a) the NFT equipment is 'approved'

(b) the grower has been established for at least two years

(c) the income per labour unit on completion of the plan must be at least £4,200 in England and Wales and £3,885 in N. Ireland

(d) the maximum amount of investment eligible for aid in a two year period is £27,289 per labour unit.

Taken as a whole, it appears that there is a very satisfactory monetary incentive for growers to invest in NFT.

An ADAS economic analysis

In early 1979 an article published in the Grower (11th January 1979 by A.W. Hales and R.F. Potter) assessed the economic benefit gained by growing tomatoes in NFT. It was based on 1/4 acre units as at 1978 in the following combinations:

I Peat modules v low cost NFT
II Peat modules v elevated trough NFT
III Soil culture v low cost NFT
IV Soil culture v elevated trough NFT

I. The gain in Budget I was £4,444 - £3,569 = £875 (£3,500/acre) in favour of low cost NFT. Yield level was assumed the same for both systems at 100 tons/acre.

Given a 10% yield increase in favour of NFT the extra cash benefit is 2.5 tonnes at £415 (net of picking, packing and marketing costs) equalling £1,037 and added to the £875 above becomes £1,912 (£7,648/acre).

II. Given a 10% yield increase in favour of NFT the gain equals £1,562 (£6,248/acre).

III. Given the lower yield expected from a soil grown crop compared to peat (estimated at 5 tons/acre) plus the cost of soil sterilisation (estimated at £1,000/acre) the gain in favour of low cost NFT is £944 (£3,776/acre).

Given a 10% yield increase again in favour of NFT the net gain would be £1,981 (£7,924/acre).

IV. Given a 10% yield increase in favour of NFT the net gain would be £1,631 (£6,524/acre).

As a summary:-

	Net gains in favour of NFT	
£ Budget per Acre	Same yield	+ 10% Yield
I	3,500	7,648
II	2,100	6,248
III	3,776	7,924
IV	2,376	6,524

Although no allowance was made for income tax on any cash increase (depreciation and interest would have to be taken into account) or allowance for capital grants, it is clear that NFT provides a profitable alternative.

The recommendations were that growers must assess the risk and whether an elevated system would provide the extra benefits required in the long run. Although there is a greater 'risk' factor than with established methods as growers gain experience with NFT yields should increase substantially.

3.4.4 Future Pricing of NFT equipment

There are at least five factors that will affect the price that can be charged by a supply/services company:

(a) the cost that can be absorbed by the greenhouse industry

(b) the 'mark-up' on each equipment/services package that makes the company a profit margin of 10% and probably more

(c) the price level that encourages grower improvisation or competition

(d) the price charged for 'services' to supplement the equipment sale.

(e) Competitors' prices.

Both plastics and steel which comprise the bulk of equipment may rise 30% in price within two years (2.3). It is important to estimate the maximum price that a grower may be prepared to pay in the future.

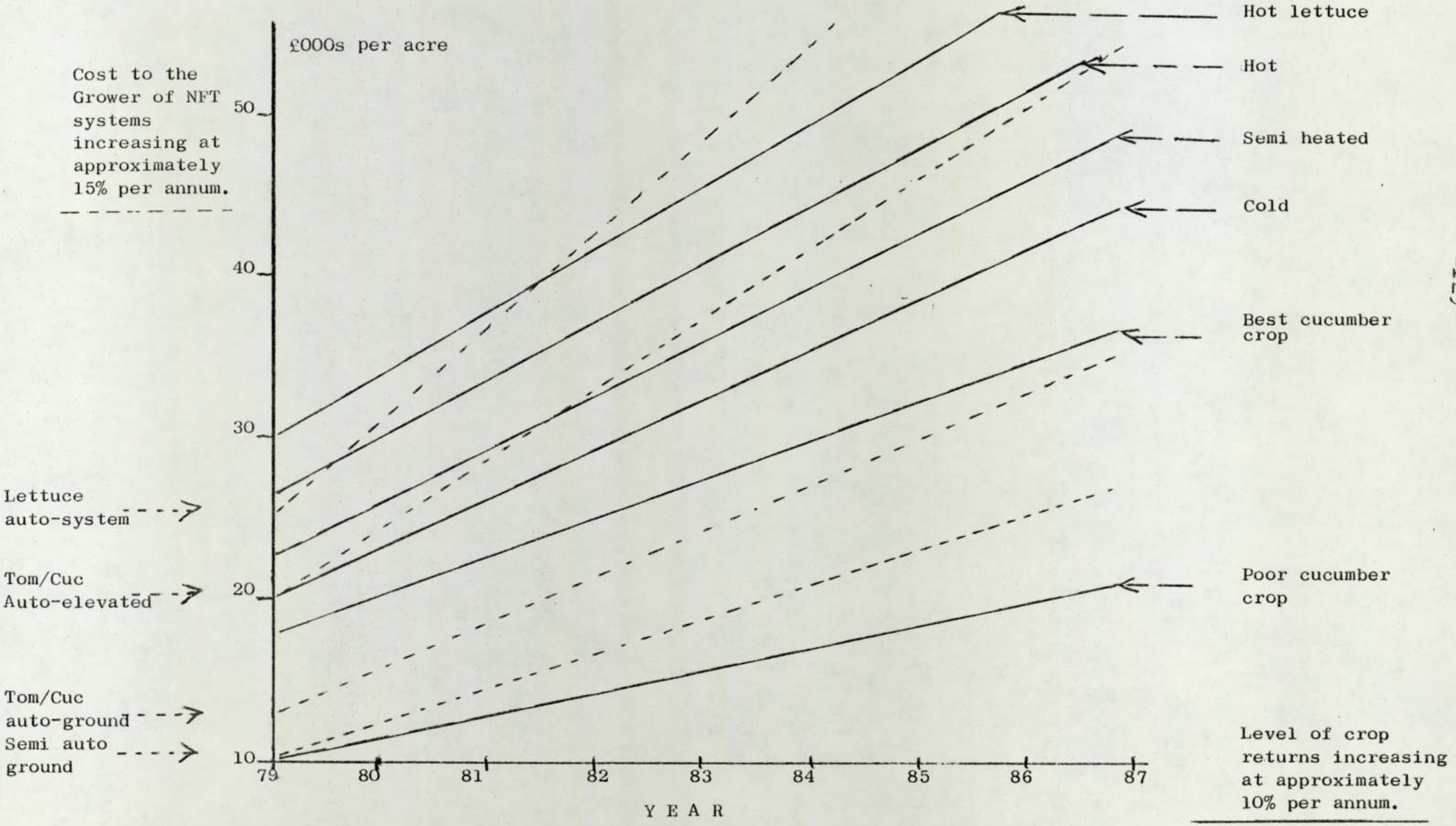
In view of the competition Figure 21 takes prices at a level which just limits factor (c) above. Figure 21 therefore projects the five year periods for each system when NPV is zero. An increasing marginal value of 10% is allowed for the grower due to good produce and experience, whilst costs of equipment are projected at 15% p.a.

Such increases in cost would probably make installation of say a lettuce auto system an unprofitable proposition by 1982. Hence with that particular design it may be expected that sales of complete elevated lettuce system would fall off within three years. Ground systems with less steel (possibly concrete) may be feasible instead.

However, there appears to be some price latitude in the next five years for the heated non-cropped tomato market. Once again ground systems are expected to be preferable in new installations after three years. Ground systems, especially in old greenhouses, can present slope problems and hence cheaper or more long term supporting systems must be found.

The price outlook in the cucumber market is uncertain and it is doubtful if any growers will consider it profitable over the next five years to use NFT.

Figure 21 Approximated 'profitable life cycle' of NFT systems based on NPV = 0 after 5 years for the grower



Summary

In the three years (1976-1978) demand and prices for the three main greenhouse vegetables were poor. Indeed the average household consumption as estimated by MAFF for fresh tomatoes has fallen slowly although canned tomato (imported) consumption was steady (see Table 30).

Table 30 Average Household Food Consumption in UK for Vegetables 1976-78

	Oz. per person per week Fresh tomatoes	 Canned tomatoes
1976	3.94	1.06
1977	3.75	1.17
1978	3.67	1.16
Value	£165 million/year	£20 million/year

During 1978 Tomatoes	1st quarter	2nd quarter	3rd quarter	4th quarter
oz/person/week	2.14	3.54	5.74	3.26
pence/person/week	5.06	9.97	7.42	4.25

Other Vegetables (excluding potatoes, peas, beans)

Total value £180 million/year

	oz/person/week	pence/person/week
1976	25.22	19.86
1977	26.76	22.94
1978	29.17	22.29

Consumption of other vegetables is slowly increasing where the market price has not exceeded 8% overall. The horticultural industry is striving to increase yields whilst keeping variable costs down and NFT therefore becomes profitable for the capital intensive greenhouse industry.

The hot mono-cropped tomato market is the most obvious target followed by lettuce and cucumbers. These markets may prove however to have an equipment sales life-cycle of only six, three and possibly five years respectively. However, improved systems and techniques can extend these life-cycles. Additionally NFT may be developed for other crops, notably ornamentals, e.g. AYR chrysanthemums, carnations and pot plants.

When the overseas market is also considered, peppers, aubergines and other crops become important. Both home and abroad, very high value 'specialist' crops would appear a market opportunity on which there is little economic information at present, e.g. strawberries, condiment and medicinal plants.

3.5 Perceived Market Trends in Techniques and Competition

3.5.1 Techniques

Brief identification of important trends for the supply company is required here. Apparent concensus of opinion amongst experienced workers in NFT is shown in ADAS 'questions and answers' (below). In the UK, ADAS, which works closely with the grower, published in 1978 'covering notes' for the guidance of newcomers to NFT. This and the Grower journal have had national market influences.

There are many specific features which may be important to particular investors, e.g. use of waste heat, diversification or possibly the use of NFT as a spring-board to equipment supply ventures of their own.

A composite of current advice from ADAS and SCS Ltd:

Questions and Answers

Q. Are NFT crops susceptible to disease ?

A. There is evidence to show that a strongly growing tomato crop is capable of withstanding a 'background level' of disease innoculum (phythium and phytophthora spp) without any ill effect, although it would be wise to take some precaution. Aaterra (a formulation of etridiazole as a 35% wettable powder) has been cleared for use in NFT and can be used in the propagating compost also.

Q. What is the danger from root death ?

A. Some die-back of the roots is normal in healthy plants grown in peat or soil and is associated with the change in the plants' activity to fruit production. It became more noticeable in NFT and prevention of too much 'browning' is a combination of heating, NS (iron) and pesticide control.

Q. How important is regular analysis of the NS ?

A. ADAS advise regular 'check-ups' so that any nutrient imbalances can be rectified quickly. After a preliminary water sample, NS analysis is recommended fortnightly for NH_4N, NO_3N, P, K, Ca, Fe, and Mg. (pH and SC) plus monthly for Na, Cl, Cu, Zn, Man, B, and Mo.

Q. How often should I dump the NS ?

A. This may not be necessary although most growers pump to waste at least once during the season. Where regular analyses are not taken, and where fairly small areas are involved ADAS recommends that for an early tomato crop, dumping should be done every two weeks in March and April, and at monthly intervals for the rest of the year.

Q. Do I need an automatic monitoring and console unit ?

A. With a commercial acreage (1/3 acre or more) it is advisable, particularly if the grower plans to expand. All controls are centralised and may be alarmed with back-up or 'guard' monitors.

Pumps are more easily controlled and many accessories can be added if required, now or later on. A maintenance service with a supplies company can be arranged.

Q. What flow rate of the NS is best ?

A. This can be varied according to the growers' needs and stage of the crop. Besides the automatic conrol, manual by-pass and in-line valves can regulate flow rate through the tomato channels, usually in the range of 1-2 litres per min. down a 1/80 slope.

Q. What is the best row length ?

A. Depending on the site the number of rows should be kept to the minimum to cut down on the cost of end crops. However, if possible row length should not exceed 20m.

Q. What materials are best ?

A. Depending on their need, pipework and fitments should be extruded uPVC, low and high density polyethylene or polypropylene. GRP or coated concrete can also be used for tanks. Pumps should be capable of handling corrosive solutions. Plasticised PVC or butyl rubber sheeting should not be used, having phytotoxic effects.

Q. What size catchment tank is needed ?

A. As a rule, a capacity of 1 litre/plant should be allowed for automatic control on 2 litres/plant for manual control.

Q. What are the advantages of NS heating ?

A. NS heating is still being tested but it is suggested by ADAS that it should not fall below 16°C, insulation of the catchment tank and particularly the canals from the ground surface is advisable. At present, the blue print air temperatures for tomatoes in stage 3 (planting to two weeks from first pick) is 16-13C night, 20C day and venting at 26C. Many workers believe that the night temperature can be reduced to 9C with NS heating, giving a saving on fuel costs.

Reduction of air temperatures with other crops on NFT has not been confirmed and any saving is probably very marginal at present. However, it is very noticeable that tomato roots regenerate much faster after'root death' with a heated NS (usually maintained at 25C).

Q. Which varieties are best ?

A. Vigorous, strong rooted tomato varieties are preferable, Sanato and Sonatine being very suitable.

Q. How competent should the operator be ?

A. After the initial introduction by ADAS or a good supplies/services company, the management of the crop is well within the expertise of a commercial UK grower. Maintenance and trouble-shooting of the pumping and control systems will probably be aided by the manufacturers.

3.5.2 Manufactured sources of hydroponic equipment

A list of equipment/services supply companies are given in Appendix F.

The United Kingdom

British based companies may be classed (on total company sales of all products) under three headings:

Large - such as ICI Ltd and Fisons Ltd.

Medium sized - such as Stapley Bros Ltd, ISC Ltd, Russell Fluid Control Ltd, and Soil-less Cultivation Systems (SCS) Ltd.

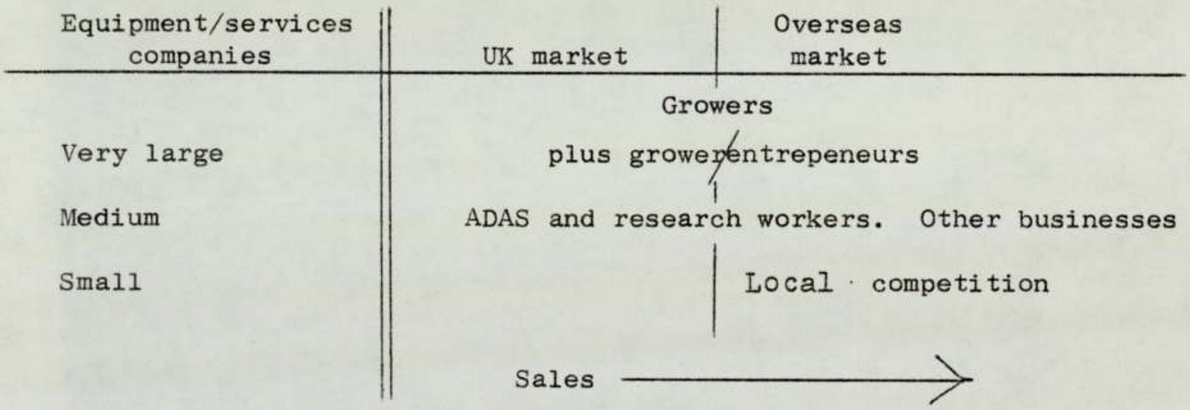
Smaller companies - such as Nutriculture Ltd.

The very large companies have vast resources and expertise in horticulture whilst the medium sized companies are possibly more innovative and fast moving.

It is therefore the very large and medium companies together with growers making NFT systems that will most affect a future marketing policy for Dunlop Ltd. Other market factors are ADAS and research workers at home and abroad plus other businesses (e.g. breweries, diaries etc) who are considering diversification and who could be customers of the supply companies whilst challenging them later in the market place.

The technology is essentially free (not patented) so a company must offer competitively priced and suitable equipment plus services required by the customers, or limit its activities to that of horticultural merchants or material manufacturers.

Hence the competitive structure could be illustrated as follows:-



To where and how should a medium sized company try to sell ? Much depends on its area of expertise, resources/overheads and contacts. Several established companies supply greenhouses or irrigation systems whilst others including Fisons and ICI supply nutrients, and services.

SCS Limited by-passed the need to be established in the industry by co-operating with ADAS and research workers during the emergence of the new technology and hence gained reputation and market penetration early on.

With the possible backing of Dunlop Limited (who themselves have no expertise or contacts in horticulture but seek diversification) they would need to turn reputation and expertise in the area of NFT into increased sales.

It appears inevitable that SCS Limited's large market share of the as yet small NFT acreage will be eroded in many sectors. They must therefore choose target market segments most suitable to their short term limited manpower giving a short term (one year) and longer term (five year) profitability.

It was from appraisal by Dunlop of the various companies products, reputation and resources that SCS Limited was decided upon for acquisition and in preference to attempting penetration by itself into a new market. This decision is discussed in Section 5.2.

Overseas

Apart from the Channel Islands, the European continent appeared to have no active NFT companies although there are many potential equipment/ service supply sources available. Until 1976 at least interest in hydroponic techniques was more academic and directed towards various other systems as outlined in Chapter 2. This included rockwool which was most notable in Holland having 175 acres by 1978.

Austria has a large tower hydroponic greenhouse built commercially which, if successful, may be attractive to heavy investors, possibly from diversifying businesses.

The USA now has large prototype hydroponic factories built by large firms diversifying into fresh food production eg.General Electric and General Mills Inc. The declared intention is to develop high yielding indoor food factories near large markets. At present the economics limit it to high value salad crops. Sand culture controlled environment facilities in the Middle East were backed by USA universities and businesses. Hence, they have some established contacts in a potentially large overseas market.

In Australia there are several companies interested in supplying equipment/services to the increasing demand from growers for information on NFT. Many growers are improvising their own systems and by 1978 over 30 acres will be established.

In each of these countries the prime crops concerned are tomatoes and lettuce although in Holland, cucumbers have so far been more important, (as they may become in the USA).

CHAPTER 4

MARKET POTENTIAL

4.1 Introduction

Forecasting of sales of NFT or related equipment plus services in the selected countries requires wide margins of error, because we are at the start of a life cycle with no past sales records. Perhaps the horticultural product which most resembles NFT in its effects and potential in recent years is peat bags.

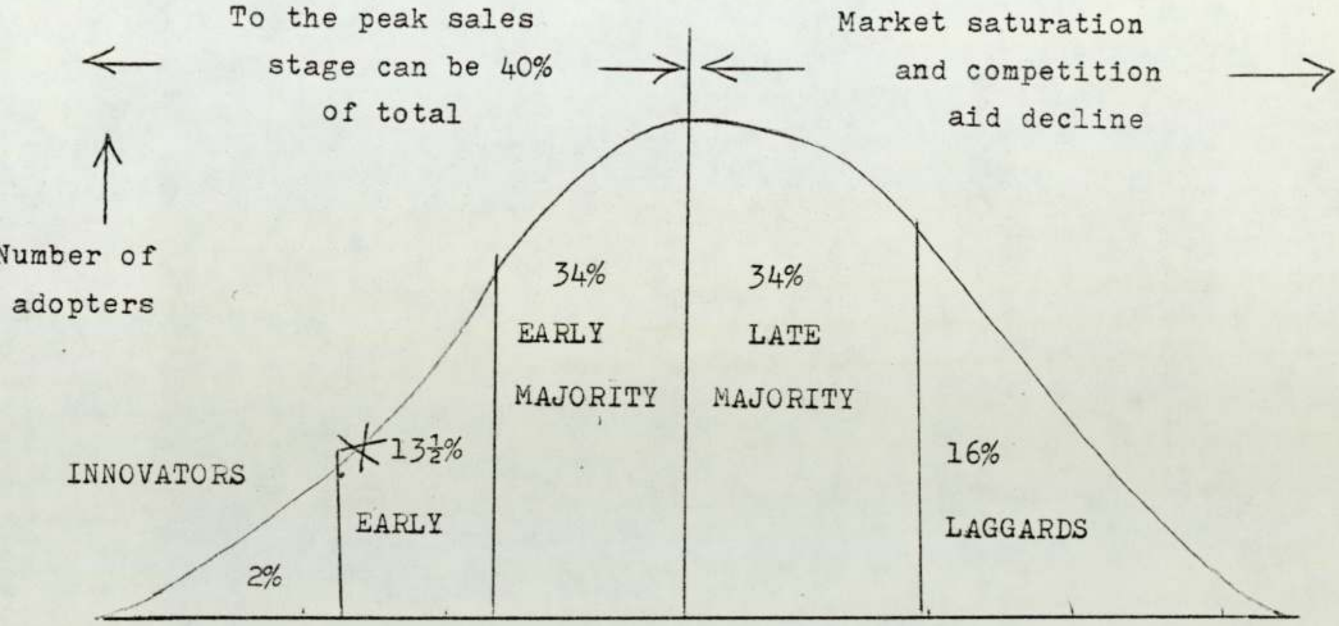
After the 1973 crisis, the tomato industry was threatened by substantial increases in costs of heating. In 1974,(2.22) thefirst commercial acreages of peat bags improved yields and profitability in the industry. By 1975, Fisons Ltd were advertising that 'bags are here to stay' (2.23), and by 1978 they had at least 50% of the greenhouse tomato acreage and sales were still rising. Domestic 'gro-bags' were also very successful and peat modules were also used for other commercial crops in the UK. 90% of the Channel Islands' tomato industry and an estimated 60% of the Dutch tomato industry were using peat bags. The majority of these greenhouses were heated.

Within 5 years therefore in these countries, an estimated 5,300 acres of commercial peat bags were in use; marketed by five main companies.

To date, about 80% of NFT systems have been used by growers who used to use peat bags, but it is unlikely that the sales curve of NFT will be similar to that of peat bags. The technology is more sophisticated and must be tailored to each site and crop. The capital cost of NFT is greater with many more pieces of equipment and alternative systems. Furthermore, slopes and tank installations must also be considered.

Figure 22 shows a theoretical adoption process. Most products show a cumulative curve normally distributed over time (1.1, 1.2, 1.3, 1.5) and so an important consideration is:'At what stage has NFT reached?' Chapters 3 and 4 argue that NFT had in 1978 just passed the 'innovator' stage.

Figure 22 A theoretical market adoption process (1.1)



✱ If NFT is at this stage then it has taken 4 years, and hence further adoption can be expected to be slow but not necessarily small.

These complicating factors may slow down the market adoption rate of NFT to 50% in 10 years. To estimate the potential market size is therefore the first requirement and then secondly, to forecast possible sales in the specific market segments. This can then enable Dunlop Ltd to opt for the most suitable strategy.

Subsequent sections in this chapter segment the known market (from Appendix D) by the parameters developed so far.

No time series or projection analysis appears practicable and the actual acreage statistics in Appendix D are probably not known in detail by many horticulturalists and so panel concensus on Delphi methods may prove misleading. However, the following market estimates can be based on a loose consensus of judgement from several quarters including growers, research workers and the staff of SCS Limited. Appendix I maps the possible regional distribution of greenhouses and hydroponics worldwide in the long term.

4.2 UK and Channel Islands

Table 31 Present NFT acreage

	United Kingdom		Channel Islands	
	SCS Limited	Total	SCS Limited	Total
1976	9	9	-	-
1977	19	27	7	30
1978	13	15	1	2
Totals	41	51	8	32

The current total of 83 NFT acres is small, and 17 acres in 1978 is not a large increase. Reduced light meant that the poor season for many greenhouse growers inhibited much expansion into new investment and technology. Now that the 'experimental period' for NFT is over great interest is being shown for the 1979 season.

(a) Heated tomato crop

UK Appendix D6 shows that 336 acres are made up of holdings less than ½ acre in size. For this forecast they are regarded as being 'uneconomic' for NFT. Of the remaining 956 acres it is the estimated 600 acres of mono-cropped greenhouses, mainly in the eastern and south eastern regions, that are believed to represent the total UK market potential for this crop at present production acreages. About 500 of these acres use peat bags and about 300 acres are within a 75 mile radius of SCS Limited.

In 1979, a total of 40 acres may convert to NFT and if a growth of 40% each year is assumed over the next five years, about a third of the market potential will have been reached. In the light of the adoption rate of peat bags (see Section 4.1) and the economics favouring NFT (see Section 3.4), this may be a conservative estimate.

Channel Islands

About one third of Jersey's acreage is on NFT but only two acres of Guernsey's 505 mono-cropped acres are on NFT. A principle reason is that Guernsey glasshouse units tend to be smaller which means they are less suited to NFT.

Furthermore, each island has its own co-operative organization which accounts in part for the discrepancy in NFT average.

Water treatment in Guernsey may allow good quality water to be used with NFT inside five years (2.4). If a similar take-off for NFT as on the mainland is assumed, the market potential may be 400 acres, with a 1979 (or 1980) installation of possibly 25 acres.

b) Cold tomato crop

A larger proportion (482 acres) is in small sized holdings and therefore is considered uneconomic (see Section 3.4) for NFT. Not more than 300 of the remaining 420 acres could be called mono-cropped. Most of this is in the eastern region, a small proportion being grown in peat bags.

This crop has therefore only a maximum market of about 200 acres for NFT, with less monetary incentive for the grower to invest. (The Channel Islands have only a total of 47 acres of NFT of mono-cropped tomatoes.)

A low growth rate of 20% can be expected with only 10 acres of NFT being used for cold tomatoes by 1981.

(c) Lettuce

Principally because of the cost of trays only hot mono-cropped lettuce is considered with a market potential in the UK of about 200 acres. At least half of this is in Yorkshire and Lancashire.

This crop has the most unpredictable future on NFT since there are several different growing methods. High factory productivity possibilities could increase the market potential but also saturate the market quickly. Combined with high equipment cost this could make NFT unviable financially inside five years as a new venture. With 5 acres in 1979, growth may be 50% for possibly four years.

(d) Cucumbers and other vegetables

Most of the 440 acres of cucumbers on holdings over ½ acre are in the eastern and Yorkshire/Lancashire area. The majority of this is in rotational cropping with lettuce. With this pattern it is unlikely that more than 100 maximum is available at present for a potential NFT market, especially when cucumbers as yet cannot be grown reliably on NFT. Rockwool has already made substantial inroads (see Section 2.5.2) and can be expected to make more.

Hence there would be a very slight penetration by NFT into cucumbers of only a few acres per annum (possibly 5 acres in 1980 and onwards).

At present peppers and strawberries are the only other promising vegetables although celery & onions may in future be feasible on modified NFT. 'A' frames for strawberries in particular may provide sales to catering or waste heat industries from 1980 onwards of possibly 5 acres per annum.

(e) Ornamentals and pot plants

Few commercial sales of NFT are made although growers and research stations were using various 'bench flow' methods in 1978. The potential in this market for Dunlop is restricted by established firms but there may be an area for nutrient control techniques, although this too is becoming increasingly competitive.

Therefore, in totalling up the market potential for NFT sales over the next five years all sales in this sector are counted at 5 acres from 1981 onwards.

4 .3 N.W. Europe

By the end of 1978 commercial NFT acreage in Europe was estimated by SCS Ltd as:

Holland	1	Spain	1
Norway	2	Canary Islands	3
France	1	Ireland	1
Austria	3	Others	4

Limiting Factors

Appendix D lists estimates of the maximum mono-cropped acreages for each of the selected vegetables; the total shows the maximum market potential for NFT.

Countries with high cost established glasshouse parks all have the same limiting factors as the UK plus that of water quality and differences in language and technique.It is known that European horticultural supply firms are becoming increasingly interested in NFT equipment.

As in the UK, until a more significant research and trials programme by advisory services and growers is completed market development would probably be too expensive for individual companies. Commercial development is lagging behind the UK situation by possibly two or three years.

The size of small holdings and their sparce regional distribution may reduce the economic and social(prestigious) incentive to use NFT. If several growers are competing in a local market, then NFT may appear to each grower to offer a competitive advantage.

On the other hand, good soil and/or peat supplies would encourage a grower to retain conventional methods, a factor which applies to Scandinavia.

Poor water quality presents a disadvantage for NFT (notably in Holland) whilst scarce water is an encouragement to use NFT. However, current water purification costs in N.W. Europe probably outweigh the benefits of conserving water.

All developed N.W. European countries have thier markets for high value salads well supplied, particularly in summer. For full use of NFT, a year round cropping system is necessary, because a grower would need to alter the system for different crops. While increasing equipment and labour costs encourage mono-cropping, increasing energy costs favour rotational cropping with conventional systems. Some energy saving with NFT can be expected to make mono-cropping more viable, but the overall trend towards rotation reduces the market potential for NFT.

Hence, each of these factore reduces the market scope from that which may be expected on a first appraisal. Nevertheless, substantial NFT acreages may develop in NW Europe. Table 32 shows an estimate of the percentage reduction of the total NFT mono-cropped 'market potentials' in the temperate European countries.

Table 32 Possible reduction of NW European NFT market potential by limiting factors

% reduction by factors	Scandanavia	Holland	Denmark	Belgium/Lux.	W. Germany	Ireland	France
Holding size				20	20	20	10
Grower distribution	20	5	10				10
Peat supplies	25		10			20	
Soil quality	5		10		10		
Water quality		50	10	10			
Seasonal price					10		20
Costs			10	10		10	
Language/techniques		10			10		20
Cumulative reduction	50	65	50	40	50	50	60

Apparent market growth

This suggests that at least fifty percent of the mono-cropped greenhouse vegetable areas of these countries will be unavailable for conversion to NFT. Assuming a pattern and rate of market growth similar to the UK, but two or three years behind, a NFT acreage projection can be postulated as in Tables 3.3 and 3.4.

Table 33 <u>Total apparent NFT market potential in NW Europe</u>

Country	Tomatoes H & C	Lettuce H & C	Cues. and other veg.	Total vegetables	* Ornamentals and potted
United Kingdom	700	200	100	1000	300
Channel Islands	400	-	-	400	100
Holland	350	100	200	650	500
Norway	40	40	20	100	50
Sweden	40	40	30	110	100
Finland	40	50	30	120	50
Denmark	60	40	30	130	100
Belgium/Lux.	200	200	100	500	150
W. Germany	100	100	100	300	500
France	200	200	50	450	100
Ireland	60	40	30	130	-
Totals	2190	1010	690	3890	1850

*Special NFT systems required.

Table 34 <u>Projected NFT acreage growth rate in NW Europe</u>

Country *	1979-80	1980-81	1981-82	1982-83	1983-84	Total 1979-84
United Kingdom	45	79	105	149	194	572
Channel Islands	25	35	50	69	98	277
Holland	5	20	50	70	100	245
Norway	3	6	10	16	25	60
Sweden	1	2	5	9	20	37
Finland	1	2	5	10	25	43
Denmark	1	2	5	10	25	43
Belgium/Lux.	2	4	10	20	40	76
W. Germany	1	3	6	11	30	50
France	3	8	15	25	50	101
Ireland	2	4	8	15	30	59
Totals	89	165	269	404	637	1563

* Forecasts are based on a 1st July to 31st June figure.

Southern Europe

Southern France, Spain, Italy, Greece and the Canary Islands have little heating requirement. Some frost protection may be needed, but more generally protection from overheating is necessary. Shading, especially in the most southern latitudes (and south of the Mediterranean) may be essential.

Apart from excessive ultra-violet light and evaporation, wind and/or wind-blown sand may often be aproblem. Arid regions often have saline soil and/or water sources. Good water is scarce and rainfall is sporadic, but occasionally heavy. Under these conditions, aggregate culture is the only outdoor system which has been used (see Section 2.3).

Except in the most sheltered climates, the crops most appropriate for NFT are semi-protected tomatoes, lettuce, cucumbers, aubergines and other native high value salad or ornamental crops in local demand. It is not clear whether the benefits of a higher yield over a smaller area would make NFT economically competitive with the large established field and loose polythene protected industry in southern Europe. Despite a relatively large capital cost, NFT does appear viable for specialist markets since a few installations catering for high grade tourist and other outlets have been reported (3.4).

To estimate the scope for such specialist operations would require further research, possibly in co-operation with the tourist catering business. Because this market is marginal, and requires specialist equipment and specialist marketing, it has not been investigated further here.

4.4 USA and Southern Canada

4.4.1 Introduction and market segmentation

Hydroponic systems in the USA, mostly aggregate, total 215 acres, largely in the more arid regions where there are local markets for high value salads. The water conserving and high yielding aspects are important in these cases to justify the high capital outlay.

There are three general groupings of commercial greenhouses in the USA:

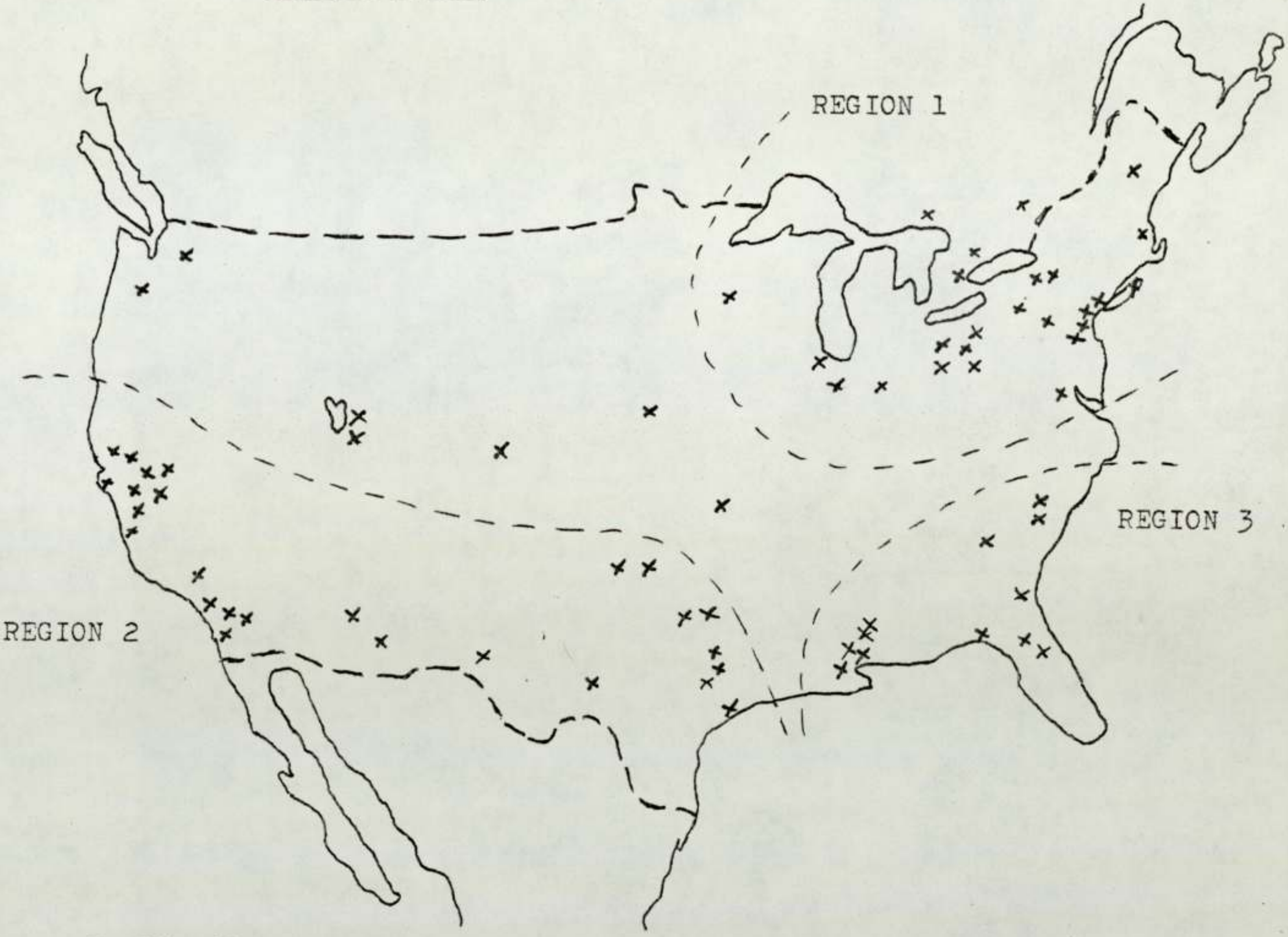
1. Great Lakes area where the climate has low light, low heat and variable water (2.28, 2.31).
2. South west area where the climate has low water, high heat and light levels (2.28, 2.30).
3. South east area where the climate has sufficient water but variable light and heat (2.30).

In addition, there are:

4. Metropolis area 'factory farms' where a high value salad market is immediately available (2.32, 3.39).
5. Small domestic units.

Compared to NW Europe greenhouses in the USA are dispersed in small pockets. Figure 23 oulines locations where known interest in hydroponics has been identified by membership of the International Working Group on Soil-less Culture and through other published sources.

Figure 23 Distribution of individuals in the USA with a known interest in hydroponics



A climatic segmentation for the USA greenhouse industry:

	Water	Heat	Light
Region 1	variable	low	low
Region 2	low	high	high
Region 3	sufficient	variable	variable

Regional NFT potential

1. Great Lakes area: Only the temperate regions of North America (see Appendix D4) have significant greenhouse parks using heating systems similar to those in NW Europe. Much of this 'park' is in Ohio which may have a total NFT potential of 200 - 300 acres largely of tomatoes. Rising fuel and capital costs have limited further expansion in this region.

2. In the south west there is more interest in hydroponics, stimulated by work at the universities of Arizona, California, New Mexico and Texas (private communication: Prof M. Jensen, University of Arizona). Hydroponic facilities are mostly experimental and only found 'cost effective in specialized applications..... to permit monolithic concentration on high profit crops with maximum production timed to coincide with seasonal scarcity (of produce) and highest market prices' (3.20). Some usage of NFT, especially near San Francisco, Los Angeles, Phoenix, Dallas and similar cities is expected. The area for each such city may be 10 acres over five years. Transport to more distant markets would incur high shipping costs. On the other hand, little heating fuel would be needed.

Section 4.4.2 discusses the market potential further, following some brief field observations in this region by the author in August 1979.

3. South east area: The reasons for recent growth in this largely polythene industry are (2.30):
- aggressive promotion by greenhouse manufacturers
- appeal to retiring people and as alternative enterprises for rural development.

However, the US Department of Agriculture emphasises that a high degree of managerial and marketing skill is necessary to get an adequate return on 1½ acres for two people. At 1977 prices, capital costs for equipment and land were approximately $170,000 (an annual interest cost estimated at $11,500). Production costs for one crop only in the spring and fall were $75,500. Break-even market prices averaged between 40 and 60 cents per lb. Greenhouse tomatoes are apparently prefered by the American public and command prices between 55 and 60 cents per lb.

In each of these areas resident supply companies would provide strong competition to Dunlop Ltd, reflecting the need for local back-up. So the most likely access to the market would be through an agency or joint venture. In this case, licencing fees, expertise and specialist nutrient control monitoring equipment would be the possible products.

4. Metropolis area 'factory farms' : In early 1979, an article summarizing the apparent potential for factory farms was published in Business Week (2.32). It suggested that the greatest production could be achieved with high value crops in totally enclosed and controlled environments. In addition to air composition and air temperature, the light must be artificially controlled with NFT used for the root medium.

The degree of sophistication and the costs are extremely high, so the returns must reflect this. General Electric and General Mills both have large operations close to large cities; Syracuse and Minneapolis respectively. They are following the successful factory produced mushroom industry at a level of investment of about $1.25 for each pound of annual production capacity. This rate of return could recover the cost inside five years.

If these installations prove successful , there may be a market for both large and small growing rooms. The latter may be a viable product for Dunlop Ltd in 5 years.

5. Small domestic units: Home production of fresh vegetables is increasing in the USA and includes the market for hobby growers (2.29, 2.31). Several US companies offer NFT greenhouses. This market would also be better approached initially through an agent.

The market potential for the whole of the USA could be approximately 1,000 acres. Much of this will be installed by growers or resident companies, while entry via agents into the market for control technology may be feasible for Dunlop Ltd in five years, since sufficient expertise could be acquired in the home market.

4.4.2 The south west USA.

This area is of particular interest because of the scarcity of good quality water and the projected growth in this region's population; there is a gradual migration at present from the east coast to the west (2.29,2.30).

Many existing greenhouse growers use sand and chip irrigation because of the poor soil, or import expensive peat. Other aggregate uses include bark compost and sawdust.

Only very high quality tomatoes from greenhouses are economically marketable due to the large field production. Recently greenhouse growers have been promoting the thin-skinned, seedless 'Europe n' cucumber as a salad vegetable, with market advantages over the field grown varieties.

Premium priced cucumbers and crops such as kiwis and ornamentals are directed at the major cities such as Los Angeles and Pheonix, with some air freighted north as far as south west Canada (despite the high transport costs, p.150).

Because mono-cropping is rarely practised at present only a few tomato growers practise it NFT has no commercial acreage at present. However, the use of NFT for the other crops may become important since high light levels allow very high yields and there are very low heating costs. With greenhouses the greatest energy consumption is in ventilation during summer, but shadow halls may alleviate this.

In the four south western States at present, total greenhouse area is about 250 acres of which a quarter may be receptive to NFT.

4 .5 Australia

Introduction

A marked feature of outdoor horticulture in Australia (see Appendix D) is the relatively low yield from large production areas — 20 tons per acre of tomatoes is the maximum. This is concentrated in the south west and coastal regions. Yields have increased due in part to irrigation and in part to control of diseases and insect pests.

Because of the wide climatic range, supplies for main city markets are drawn from widely different areas. Historically, market gardens were located near urban centres. However, it is reported (34) that rising urban land values, improvements in transport and irrigation plus developments in freezing, canning and drying have extended the industry far from the cities. Top grade salads and nursery products are still apparantly supplied by specialist growers grouped around the main cities.

Market segmentation

W. Australia, with a year round warm climate has few greenhouses. Adelaide, Melbourne and Sydney have nearby many small holdings. The Adelaide plains produce most of the S. Australian tomatoes which are grown in glasshouses. With the rapid expansion of Melbourne many specialist native plant growers and plant hire firms have arisen; many of the larger nurserymen establishing controlled environment glasshouses.

Hence there appears a fairly well defined target market of established and developing commercial growers, particularly near Adelaide and Melbourne. Most of the 34 IWOSC members in Australia are in these regions, whilst enquiries received by SCS Limited indicate that New South Wales and southern Queensland may have commercial potential also.

Three other market segments have been identified by SCS Limited:

- self sufficiency/remote locations
- domestic units
- export to Pacific regions.

The two major inhibiting factors are the climatic variations and limited pure water supply. Study of these and of regional economic factors is being conducted by the Department of Agriculture and resident growers.

As with the USA, and for the same reasons, any market approach by Dunlop Ltd in Australia would have to be via an agency, possibly supported by Dunlop Australia Ltd, and best based near Sydney.

4.6 Middle East and other arid areas

The Middle East, particularly the oil-producing areas, offer the best potential, if the problems of developing a water supply, a growing environment and a produce market, can be overcome. The poorer arid countries such as regions of Peru, India and mid-African states probably could not support capital intensive projects such as NFT except as a'one-off' basis of orders by individuals or companies.

Desertification, falling water tables and increasing groundwater salinity are problems which face many areas using irrigated agriculture, in addition to the best known examples of California and Isreal. Water management conventionally utilizes: rainwater and run-off harvesting, wells, reuse of water and even irrigation with saline water (2.1). Water conservation is the focus of many research projects aimed at reducing evaporation and seepage losses, and requires careful study of soil and crop requirements.

A major incentive to use NFT and CEH is their potential for water conservation, particularly since desalination costs have not been as low as projected (3.19, 3.20). It is also possible that plastics' prices will remain low enough in the oil producing countries to enable lower component costs than in other countries.

Many companies are attempting to develop NFT in the Middle East. Oman and Saudi Arabia have taken deliveries of systems although there have been problems with both operation and marketing produce from these.

Methods of hydroponic growing

NFT will partially always need some form of protection, even if only by screens or ditches as proposed by A.J. Cooper (3.27). The returns of closed sand culture warrant polythene protection according to the University of Arizona. Gravel culture is the only method robust enough outdoors but to date, economics have restricted this to small areas in Israel.

Greenhouses can either be totally enclosed or patially open. If enclosed, CO_2 and air must be continuously circulated, but it does use less water than the latter. In both, the high humidity suppresses transpiration.

The NS in the NFT channels can become too hot if external temperatures are high, and care must be taken to shade, reflect, insulate or otherwise protect the plastic canals from overheating and U/V light degradation. The use of white or silvery high grade canal materials can limit this, but at a cost. If the greenhouse materials provide this protection, they will also probably be more expensive. Shade netting appears to be a promising method; enabling a degree of equilibrium for light and temperature at low cost. On site development work is required to discover the practicalities of such partially protected methods.

Middle Eastern countries priority for hydroponics

Information from DIS (see Appendix C) suggests a ranking of countries in the following manner:

Rank	I	Kuwait, United Arab Emirates
	II	Qatar, Iraq, Saudi Arabia
	III	Oman, Iran, Bahrain, Syria
	IV	Lebanon, Jordan, Yemen, Yemen PDR.

Market contacts and on-site economic assessments can be made via DIS/SAIDCO (see Section 1.1.4) whilst equipment design and preparation could be performed by a specialist hydroponic division.

CHAPTER 5

Market Entry By Dunlop Ltd

5.1 Options for Market Entry

5.1.1 Entry by in-house resources and innovation

Section 1.1.4 e outlined the current strategy of DIS. Opportunities for growth are sought in the irrigated agricultural sector and a geographical concentration is required 'almost exclusively' on the Middle East and North Africa in the immediate future. However, market development of NFT in the UK plus adjacent Europe may provide experience and revenue as a preliminary for sales to DIS's current target market plus possibly the USA and Australia. Such a division of effort and resources was not desirable in 1978.

NFT was considered an important allied interest to DIS's operations. Assessment in 1977 included the option of recruiting two established workers in the hydroponics field. Such an 'in-house' operation may have been aided by the acquisition of a small electronics equipment assembly company. The costs to Dunlop over three years were estimated at £100 K until a profitable turnkey capacity for NFT could be established. Resistance by growers to the Dunlop name (normally associated with tyres) and established competition could be strong.

It was also becoming clear that the sales potential was in specialist markets. Such a specialist capability would not fit within DIS's general project organisation.

5.1.2 Entry by acquisition

In early 1978, an opportunity arose to acquire Soil-less Cultivation Systems Ltd. (SCS), a hydroponic systems company described in Section 5.2. Two other large companies were also interested in SCS (whose principal attraction was an excellent reputation in NFT). Purchase would provide their name plus technical knowhow, probably at less cost than DIS could have achieved with an in-house operation.

If no acquisition alternative had been available the 'no-entry' or possibly 'sub-contracting' options might have been considered.

SCS however fitted DIS's strategy well with a similar turnkey approach, and otherwise appeared preferable for acquistion than any other small company marketing NFT. It was known that SCS was searching for funding to further develop the market. SCS had few financial assets and seven staff. Appendix A lists a checklist for an acquiring company; the project made inputs to sectors A, H, and I primarily.

Section 1.3.3 discusses the effect on the project of this acquisition possibility. A particularly relevant paper on 'Diversification via acquisition: creating value' in the Harvard Business Review (1.8) discussed possible decision factors. The following two fit our context:-

- investments in markets closely related to current fields of operation can reduce long-run average costs, and improve competitive ability.
- diversification into related product markets can enable a company to reduce systemic risk.

Both these issues are reflected in the strategy from Chapter 1 for Dunlop Ltd., and were of consequence in the decision to acquire **SCS.**

5.2 Soil-less Cultivation Systems Ltd until 1978

5.2.1 Introduction to SCS Ltd

Section 2.4.2c mentioned the early involvement of SCS with NFT. Since 1975 the company had established a leading reputation and by 1978 had experimental NFT systems in many colleges and research stations, with additional sales of about 40 acres for commercial growers. The company used the very effective tactic of maintaining close collaboration with NFT pioneers and generating publicity, largely through the Grower.

However, the financial burden of such early development work, and the cyclical nature of the business, generated cash flow problems. Lack of capital in 1978 threatened SCS's ability to build upon its initial investment of money and effort. Funds were needed to exploit their reputation and expertise, before their market position was eroded in an increasingly competitive new industry.

In 1978, SCS was located in a leased and converted printer's warehouse in Aldershot's town centre, with no growing facilities of their own. Cramped warehouse and awkward office conditions added to the operating difficulties discussed in Appendix G.

At the time of acquisition on 31st October 1978, there were seven full time staff in the following functions:

- Managing Director
- Project co-ordinator and office administrator
- Design engineer
- Secretary to MD and secretarial co-ordinator
- 2 employees working on system component processing and fabrication
- Book-keeper and credit control

5.2.2 Acquisition

SCS was preferable for Dunlop Ltd from the other options (see Sections 5.1.2 and 1.3.3) for entering the hydroponics market.

Many of its suppliers were local businesses with whom close working relationships had been achieved. Plastics, constituting a large proportion of the equipment value, were supplied by companies from which good discounts had been obtained.

By October 1978 the SCS system had become recognised for a 10% horticultural grant by the MAFF to the grower customer. The Grower journal and other publicity outlets had produced good coverage of the Hydrocanal (registered trade mark of SCS) system. However, Dunlop's legal department expressed doubts whether the Hydrocanal patents taken out the UK and USA could be defended against infringements. The problem was the varied shape NFT gullies could take.

However, Dunlop management weighing all factors decided an 'independant' market penetration by Dunlop would cost more in time and money than the cost of acquiring SCS.

The controlling shares were owned outside the company and this led to protracted negotiations. After the acquisition was completed Dunlop kept cash injections to a minimum until the accounts could be sorted out. By February, 1979, an extensive audit had been completed and a new book-keeper was appointed. Unfortunately the cash-flow problems continued through the peak 1978/79 selling season, compounding difficulties in order processing.

Consequently the student was assigned to SCS in early November 1978 with a brief to review and aid the order processing function.

5.2.3 Requirements of the project for SCS Ltd

Although the general objectives (section 1.3.3) remained the same, they could now be expressed in greater detail after five months practical experience within SCS.

The student was involved in various functions from purchasing through stocking, fabrication and delivery to installation.

Adequate systems to accommodate the increasing design complexity of equipment and co-ordination of new and existing orders were needed. Work experience in this area is summarized in a 'report to management' in Appendix G. In the event the recommendations were overtaken by a more radical restructuring of the company.

5.3 Strategic Discussion

5.3.1 Strengths and weaknesses of SCS Ltd

Appendix H discusses in detail the structure of SCS, and using features from this discussion the strengths and weaknesses can be summarised.

Strengths:-

- SCS's reputation for technically proven NFT systems
- several staff with marketing expertise.
- availability of Dunlop resources in terms of finance and contacts for new markets.
- contacts with research establishments and some journals.
- Hydrocanal name well established and operating central console equipment.

Weaknesses:-

- SCS is relatively unestablished in the broad horticultural market compared to competitors such as Fisons, ICI, Wilco Heating etc.
- NFT is a 'free technology' so that competition could come from growers and many small companies.
- presently weak administration and order processing systems.
- no 'in-house' analysis, reference or show facilities at present.
- SCS as described in Appendix H performs largely as a horticultural supplies merchant and hence is susceptible to price cutting or direct purchase by customers.
- difficulties in resiting and staffing the company adequately for next season.
- problems of selecting and developing overseas markets whilst consolidating home market.

There are additional macro-environmental factors discussed in Chapters 3 and 4, two primary ones being rising costs of oil/ high energy materials (plastics and steel) plus the implications of the micro-electronics controls discussed in the following sections. A secondary feature may be the overall stagnation of the high-price salad market in developed countries discussed in Chapter 3.

5.3.2 Market segmentation, opportunities and needs

Appendix I segments worldwide market potential by broad parameters using as a base the known methods of intensive horticulture, extent of production and relative populations from Appendix D.

N.W. Europe (Section 4.3) appears the most concentrated 'commercial NFT' market with established glasshouses striving to remain profitable (see Sections 3.2 and 3.4) with the trends (see Sections 3.3 and 3.5) producing expectations of NFT acceptance for certain crops (mainly mono-cropped tomatoes).

The technical nature of NFT will produce uncertain sales levels to hobbyists and colleges of small 'commercial' or domestic units. To date there has only been a lower acceptance from traditional growers and home gardeners than several firms (from Appendix F) expected. However the MD of SCS believes that opportunities exist (partly via liaison with a garden supplies firm), particularly in the USA self-sufficiency market.

The level of NFT technology in which SCS are established (i.e. medium grade within glasshouses) is progressing towards greater control of the environment (CEH). Increased control mechanisms, notably microelectronics, are now being applied to CEH and NFT becomes a likely application. As discussed in Section 5.3.4, SCS could pursue this application to further the penetration of the N.W. Europeon CEH market.

Polythene covered horticulture in large areas of the world (Appendix I) allow at present a semi-controlled environment. Outside temperate regions, controls aim primarily to conserve water and overcome wilting by high humidity and shading. Problems of salinity must also be accommodated. Monitoring control uses of microelectronics may be found in large complexes.

Later developments particularly in the semi-arid 'developed' countries i.e. south west USA and Australia (from current research activity) are fodder production, bioplexes (including solar desolinators and plankton based aquaculture). Commercial development of such high grade 'biotechnologies' are estimated by some workers in the field (personal communication, Prof. M. Jensen, University of Arizona) to be 'still a decade away.' Section 7.2 outlines some of these notable future opportunities.

More immediate service and product development opportunities are considered in Chapter 6.

5.3.3 Competition and market share

Section 3.5 and Appendix F show the competition in all geographic markets. In addition growers may buy an SCS system to cover 10% of their growing area and later order the remaining 90% direct from the manufacturers to assemble themselves where possible.

To counter these threats and maintain a substantial market share in the supply of the simpler components, i.e. canals, supply and catchment pipework, a list of possible SCS policies can be to achieve:

- volume sales and hence suppliers discounts.
- rapid turnover, minimal handling and warehouse use by routing direct deliveries from suppliers to site.
- efficient advisory, design and quotation procedures.
- minimal order processing overheads whilst maintaining the turnkey philosophy.

Consequently, in-house processing needs to concentrate on the 'not-so-free technology' of control equipment, manifolds etc. As discussed more fully in Appendix H recommendations to improve order processing will increase the competitive ability of SCS.

Via such policies, costs and selling prices for hardware installations should enable an average market share by SCS to be maintained above 50% in the UK for several years. It is possible that differing 'product areas' and market shares may begin to emerge e.g. 'advisory and feed,' 'control equipment,' 'canals and pipes' etc. whilst SCS are endeavouring to provide turnkey systems.

A link-up with other companies (e.g. Fisons with regard to 'advisory and feed') could be beneficial in certain cases.

It is probable that most of the overseas markets would not yield more than a 50% acreage market share for SCS. Dunlop and SCS management are likely to select the following order of market approach:

I. UK. II. Channel Isles plus sales to Ireland and Norway.
III. France. IV. Belguim. V. Holland. VI. Germany.

Meanwhile special projects via DIS in Kuwait and UAE etc. may allow SCS to gain experience and market penetration in these markets.

Australia and the USA would require local approaches against established competition and entail problems of dispersed market areas. However, certain segments (see Sections 4.4 and 4.5) may be concentrated enough for SCS appraisal.

5.3.4 Product and service opportunities

To summarize Chapter 3, SCS may be able to pursue the following developments:-

Product:

- more flexible and possibly reliable control systems utilizing microelectronics (see section 5.3)
- trace-element feed supply (linked to laboratory service of Section 5.4)
- cheaper, thin-walled supply pipework (Section 4.3.2)

- diversifying product range into greenhouses, heating systems etc. However this would be costly for SCS in the short-term until established; a co-operative agreement may be sought meanwhile.
- long-term product potential of solar panels under latitudes of 40° . Meanwhile a tag should be kept on existing expertise, e.g. University of Arizona, and manufacturers e.g. Mabosun s.a.s. of Cremona, Italy. In addition the latest developments of wind, methane and other power sources can be reviewed via the Natural Energy Association.
- desalination technology has an application potential, particularly if linked to the above five product areas. Product investigation may be via DIS, meanwhile standard units e.g. Elga Products of Lane End, Bucks, should be tried when well or rainwater is inadequate in temperate regions.

Service:

- laboratory analysis and advisory service (Section 6.1)
- follow-up maintenance contracts, possibly including that of programmable microelectronic controls.
- design facilities for linking a customer's present operation to desalinators etc.

These are in addition to pre-sales survey and quotation.

5.3.5 Strategic policy and turnover projections

The choice of overseas markets will be based on:

(a) Probable size and types of NFT markets

(b) SCS's market contacts and experience

(c) Dunlop's possible back-up contacts (DIS)

(d) Financial (and personnel) resources required

The limiting factor will probably be the risk for Dunlop of (d). Initially ventures into only the best markets are feasible whilst consolidating in the UK. 'Special projects' ensuring possibly over 20% profit on capital employed for under a year are considered by SCS valuable not only for profit but also experience and prestige.

The target market options were assessed (SCS) as:

(i) England and Wales only (concentrating on south and south-east regions) with replacement sales.

(ii) As (i) plus laboratory service (and product development).

(iii) As (ii) plus Channel Isles and adjacent Europe.

(iv) As (ii) but with project sales to developing countries.

(v) As (iii) but with project sales to developing countries.

(vi) As (v) but also extending to 'Other Europe' and USA

(vii) As (v) but operating under license elsewhere

(viii) As (ii) plus Channel Isles, project sales to developing countries and under license to USA and Australia.

At present the plan is:

1979 (i) with some attention to adjacent Europe and developing countries' projects.

1980 (ii), 1981 (v), 1982 (vii).

At present, an acre of NFT sells for an average £12,000 including services.

At these prices turnover figures of:

1979/80.	1980/81	1981/82	1982/83	1983/84	1984/85.
£600K	£1.3m.	£2m.	£3m.	£4.5m.	£6m.

would reflect NFT acreage sales alone of:

50	108	167	250	375	500

From the market projections in Section 3.6 and the strategy above, these figures would be equivalent to a market share of between 40 and 50% in target markets.

5.3.6 Profit, cost and selling price possibilities

A guideline objective from Dunlop management for profit after all costs (including overheads) would be 10% of sales in the short-term, rising to 20% in the medium term. The sales/capital ratio should improve with a rate of return (% profit to net assets) rising to at least 30%.

At the 1978 year end SCSwas making a loss, after allowing for stock correction, of approximately 15% of sales value. To turn this into profit one, or a combination of the following must be implemented:-

(a) Selling prices increased

(b) Product mix adjusted for standard systems and revised mark-ups.

(c) Overheads reduced.

(d) Direct (purchase) costs reduced by:

(i) different/reduced specifications or suppliers

(ii) volume purchase and improved discounts.

(e) Strategy i.e. target markets plus product and service developments.

All the above methods are applicable at present to SCS as shown by the following indices for costs and sales values.

Index projections.

Using indices based on 100 for the purchase value (direct cost) of incoming goods to SCS, the cost of sales index at the 1978 year end was 197, whilst the sales index was about 172 (i.e. loss of 15% of sales value).

If the selling prices were increased by 10% overall in 1979 on top of inflation, producing a sales index of 182, and a profit of 10% on sales sought in 1980/81 onwards at the turnover projections exampled in section 5.3.5, the following budget figures would emerge at current sterling values:

INDICES	1980/81.	1981/82	1982/83	1983/84	1984/85.
Sales=182.	£1.3m.	£2m.	£3m.	£4.5m.	£6m.
Cost of Sales=164	£1.17m.	£1.80m.	£2.70m.	£4.05m.	£5.41m.
Direct cost=100	£714K	£1.10m.	£1.65m.	£2.45m.	£3.30m.
Total=64 overheads.	£457K	£703K	£1.05m.	£1.58m.	£2.11m.

At these levels if the rate of return is at least 30% then net assets required could be:

	1980/81	1981/82	1982/83	1983/84	1984/85
Net assets required	£433K	£667K	£1.00m.	£1.50m.	£1.97m.

However, it is clear that for the strategic plan up to 1982 only a faction (possibly a third) will be required, in which case SCS would be self-financing from 1981 onwards.

These figures may give broad parameters to budget within but do account for likely operational costs in establishing larger premises and recruiting staff particularly during 1979/80. In addition, sales obtained from services are not distinguished from hardware sales.

To acheive such figures overhead and direct costs must be reduced by an overall 16% by 1980/81. Implementation to some degree of the recommendations in Appendix G may aid this function.

Within these constraints operational plans may be drafted for 1979/80 and 1980/81, assuming that the financial year for SCS will run from May to avoid clashing with the main selling season.

Chapter 6

Service and Product Developments

6.1 A Service Development

6.1.1 Present analysis and feed requirements by the grower

Analysis Section 3.5.1 states that a grower on average may analyse the NS for NFT every three weeks over a ten month season for tomatoes. Analyses for NFT (or peat or soil) are performed primarily by ADAS with private companies e.g. Camland Ltd., also offering analysis and advisory services.

The cost to the grower in early 1979 was £5.04p. inclusive for pH, PO_4, K, NO_3 and Mn (Service 2) plus £9.40p. for B, Cu, Co, Zn, Cr, Pb, Ni, amd Mg (Service 13). Conductivity (soluble salts) and Fe measurements were also included for a total NFT analysis charge of approximately £14.50p. In each case recommendations for nutrient adjustment are included in the service. An increased number of analyses required would enable a grower to get an improved quotation (from the private sources at least).

If, over the season an NFTgrower spent £200 on analyses, a peat bag grower might spend £300 (because several bags need checking).

Feed. The total cost to the grower in early 1979 for a ten month tomato crop in NFT is taken to be £1,500/acre. Trace elements account for approximately a third.

ICI, with their proprietary 'Solufeed F', Fisons and Interlates (Librel) are the prominent feed suppliers, the latter concentrating on trace elements.

It is the specialist supply/service of the trace elements (requiring no bulk handling) that are considered potentially useful to SCS's marketing policy.

6.1.2 The proposed strategy for a laboratary service

By providing an analysis, feed and advisory service it is possible to create a self-financing division to back-up SCS's present operation, if a certain schedule for the number of clients could be met.

Such a division of SCS (initially of one person) could also collate feedback from growers and other workers, aiding the marketing function e.g. through exhibitions and talks. The service package could be offered as a supplement to the hardware NFT systems installed by SCS, and this could include a technical bulletin which would have a standard charge, but at a small discount if the subscriber had a club membership.

The division would need to be operable from the beginning of the growing season, i.e. February. The equipment required in addition to desks etc., would primarily be an atomic absorption spectrophotometer plus the necessary accessories. i.e. fume cupboard, glassware, chemicals etc.

Only returns from analyses (not bulletin sales) are considered at present because:

- a bulletin service would require costly manhours and resources for a limited edition in the short-term.

- competition with the trade press and research establishments would not be immediately feasible.

Occasional newsletters may however be appropriate.

6.1.3 A cost and revenue schedule for an analysis service

Capital cost over 3 months.	£
Separated laboratory premises (because of fumes) of 150 sq. ft.	300
Salary of 'NFT Scientist' plus overheads	1,700
Installation of fume cupboard plus tanks for acetylene, argon, NO and compressed air.	4,000
Glassware and chemicals	1,000
Atomic absorption spectrophotometer	5,500
basic, plus lamps for 7 elements	400
plus auto-sampler	2,500
(with graphite furnace	3,000)
Colourimetric assay equipment for non-metallic nutrients.	3,000
Estimated total capital cost.	£18,400

It is estimated that the equivalent of seven full analyses could be completed in a full working day. With a revenue of £105 a day (£15 per analysis) for 200 days in the growing season a £21,000 gross revenue would result.

Cost items for the first year of operation are estimated at £9,000 for the salary and overheads of a NFT scientist plus £2,500 for the running costs of the laboratory.

Hence, the total cost at the end of the first year of operation would be £29,900 whilst the revenue could be £21,000. Under these conditions the laboratory service would recover its capital investment in the second year.

However, this rate of return would require over 100 regular customers requiring analyses which would account for every NFT grower in the UK. Even if peat samples were also attempted this turnover of analyses would be difficult to sustain and a full-time HNC standard chemist may have to be recruited. Under these conditions the total revenue may fall to £15,000 whereupon a capital return may be appreciated in the third year.

An extension to the laboratory service might be a trace element feed supply and advisory service. Since trace elements cost a grower on average £500/acre/year, 50 such customers could realise a turnover of £25,000. It has been estimated (MD of SCS) that three bulk orders by SCS through the year could enable a mark up of 20 - 25% on purchase cost in order to cover handling and storage and then show a profit.

In 1979 a half acre greenhouse facility for the economic production of tomatoes and lettuce at a site near Halsemere, Surrey, was being considered by Dunlop management. This would have the important secondary function of a demonstration unit. A capital sum of £50,000 would be required.

A ready-made company name of 'NFT Developments Ltd.' for such ventures has been registered for three years.

6.2 A Product Development

6.2.1 Nutrient monitoring and dosage control

In addition to the maintenance of NS circulation the various nutrient levels (and the resultant pH level) need to be maintained as near the optimum as possible. On commercial NFT systems of over half an acre it becomes highly desirable to have an almost totally automated control system with both audible and visual alarm signals to safeguard the cultivation of a valuable crop.

At present SCS produces an electro-mechanical control console with a wired logic system for co-ordinating the following inputs and outputs:-

Inputs

- pH probe and meter, plus back-up
- cf probe and meter, plus back-up.
- catchment tank high and low mercury float switches
- thermostat (plus thermometer)
- flow sensor or other failsafe device from NS circulation pump manifold.

Additionally there may be:

- three pairs of high and low mercury float switches from nutrient feed tanks.
- pH probe and meter from 'make-up' water.

Outputs

- relay for solenoid/pump for acid.
- two relays for solenoids/pumps for feeds
- three volume or timer meters for acid and feed injections.
- two or three relays for NS circulation pumps
- relay for NS heater
- relay for power failure and battery alarm.

Additionally there may be:

- three relays for feed dilution pumps
- relay (and timer) for 'make-up' water pump.

Each of these control systems have been incorporated over a period of five years to enable a grower to supervise his crop and produce a profitable yield. There are two aspects to this control, the first being the continuous data provided by the equipment to the grower, and the second the continuous and corresponding adjustments to the equipment maintaining the plant growth variables, i.e. pH, cf, temperature, NS flow rate etc.

The total cost of this automated control to the grower in 1979 could be £1,000 - £2,500 when all the various alarm and control points are mounted on a central console.

It has been noted in section 5.3.4 that micro-electronics were being applied by other firms in CEH and that the control features of NFT may be on application.

6.2.2 The case for a feasibility study into micro-electronic controls for NFT

Questions raised were:

(a) Could micro-electronics technically be applied to NFT controls, with a possible extension to other CEH controls?

(b) What would be the probable cost?

(c) Given the present and forecast NFT market could a micro-electronic control unit be effectively marketed, both technically and profitably?

(d) What advantages (if any) would such a unit give to SCS in the market place?

(e) What advantages (if any) would such a unit give to the grower so that he might buy it?

It would be difficult to rank these questions in order of importance since failure on any of these counts could invalidate the case for micro-electronics incorporation in NFT controls.

After background reading and consultation with university sources several features appeared possible if micro-electronics could be incorporated in NFT controls:

(i) The reliability and flexibility of control units made by SCS may be improved.

(ii) With a grant from the Department of Industry under the MAPCON scheme the cost of a feasibility study into the incorporation of micro-electronics, could be covered.

Without a feasibility study it was difficult to determine the likely cost of software development and hardware implementation.

(iii) It was believed that provided a 'silicon chip' control system could be proved more reliable and less costly than existing systems, that it would be acceptable to the market place.

(iv) An advantage may be gained by SCS by reduction of costs on quantity production of NFT control units. In addition an in-house capability might possibly be developed by SCS for maintenance/production of units to reduce reliance on suppliers and increase competitiveness.

(v) Advantages to the grower become more obvious the greater the number of control circuits he requires in his system. Reduced hardware cost with large systems plus the flexibility of using a software programmed to include, for example, monitoring of individual nutrient ions or a printout when required of various crop data, would be advantageous.

Features (i) - (v) equate approximately with the questions (a) - (d) and in this state of knowledge it was decided by SCS to proceed with a feasibility study.

6.2.3 Conduct of the feasibility study

A small micro-electronic software consultancy company (Michael Oakley Co. Ltd.) based near Birmingham and connected with the University of Aston were employed to undertake a feasibility study for SCS. The study was mediated by the student.

After a proposal to conduct a study was submitted to the Department of Industry a letter of intent from them to cover the cost of the study up to £1,000 allowed SCS to proceed. The proposal allowed about four site visits for the student with a representative of the contracted consultancy company. This enabled the parameters within which the micro-electronic unit would need to function to be delineated e.g. high humidity, background 'noise' from pumps, plus a construction of the inputs and outputs into a flow chart.

A report presented by the consultancy company to SCS outlined a project proposal to design and develop a prototype central control unit. The key feature was the description of how a software programme to incorporate the inputs and outputs cited in section 6.2.1, may be evolved. In addition the project was to seek to incorporate the following features:

Additional inputs

- One or more selective ion electrodes e.g. Fe, N.
- Improved non-glass pH probe plus possibly an associated calibration programme.

Secondary input data

- The volume of NS and water analysis
- Memory capacity for acid and feed injection periods plus possibly yields and solar radiation information.

Additional outputs

- One or more injection controls for specific nutrients e.g. Fe, N.
- Alpha numeric display and pen recorder for information on alarms, injections etc.

6.2.4 Summary of proposal to incorporate micro-electronics into NFT control unit

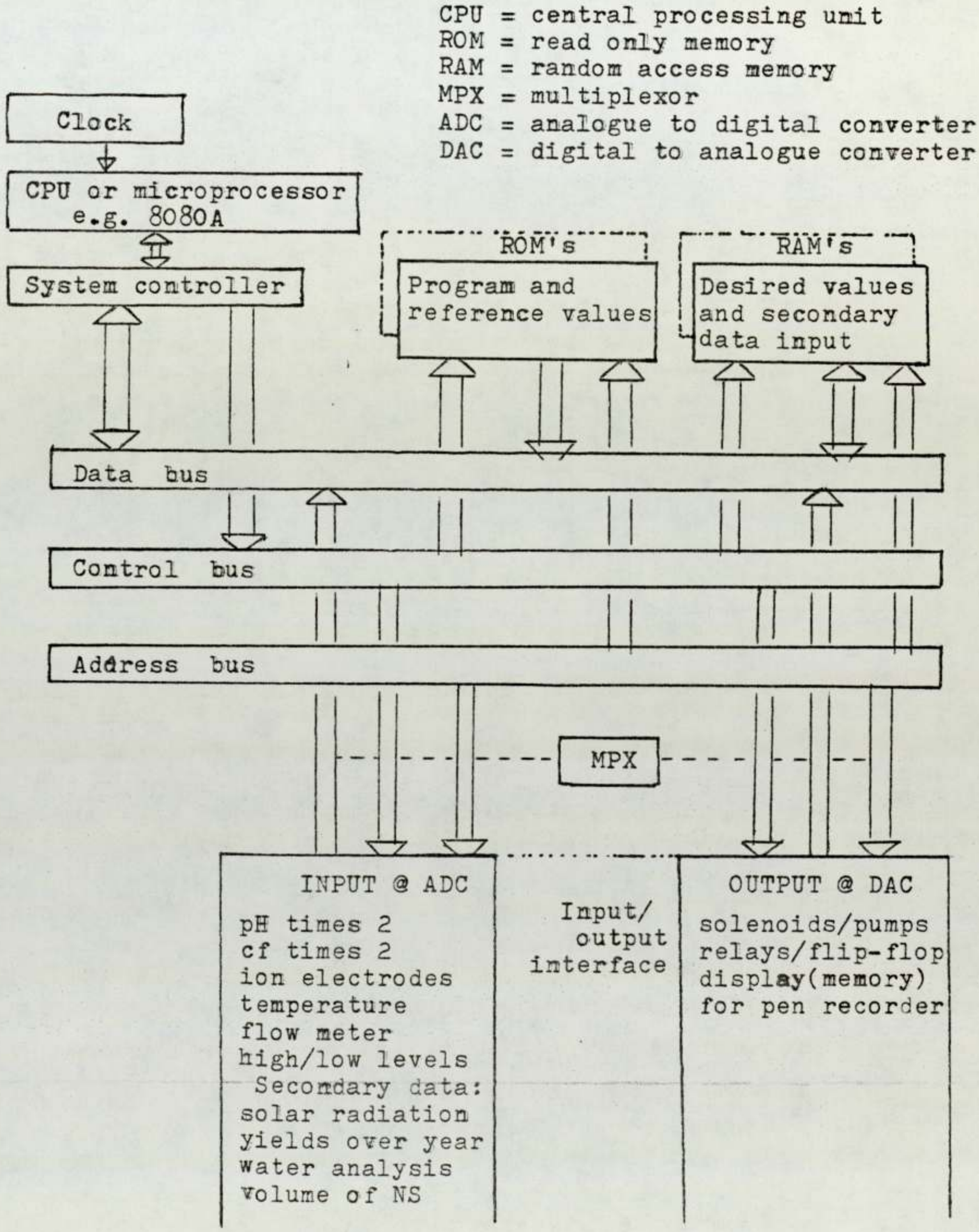
Background information on micro-electronics is available from many sources (3.33) ;it is a vast subject. For the purposes of SCS, there appeared two systems types to chose from. Either a more elementary programmable controller could be used or a system incorporating a microprocessor.

The proposal assummed the use of a microprocessor and a very generalised layout of this system type is exampled in Figure 24. The details of the system design are not of concern here but rather the software programme to be used, how the hardware is installed and the likely costs.

Dutch companys such as Brinkman B.V. have been utilizing computer control for the shoot environment in CEH for about three years and have experienced difficulties in translating greenhouse data (in analogue form) into suitable data (in digital form) for computer control. It is at the input interface in particular that difficulties would be expected when trying to effect the much simplified algorythm shown in Figure 25.

Because Aston University, Dunlop's in-house capabilities and the consultancy company were all in the Birmingham vicinity it was suggested that the project be based there. Development of the software and laboratory trials for the prototype it was estimated would take four months. An on-site commercial trial at SCS could take place by mid - 1980 with an aim to trial market

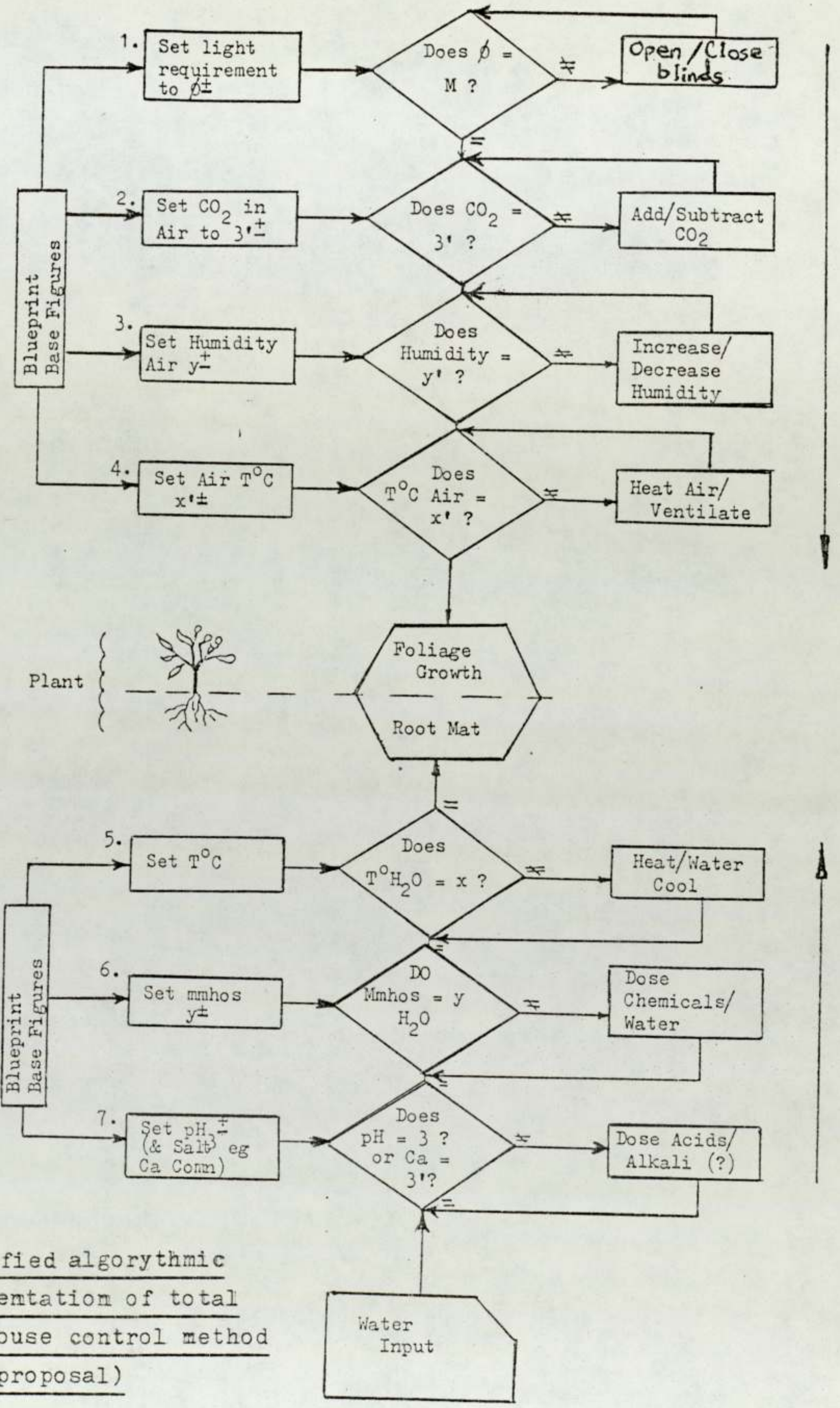
Figure 24 Generalised layout of a micro-electronic system to show the prime functions



Key:

CPU = central processing unit
ROM = read only memory
RAM = random access memory
MPX = multiplexor
ADC = analogue to digital converter
DAC = digital to analogue converter

Figure 25



Simplified algorythmic representation of total greenhouse control method (from proposal) the following growing season.

Initial costing estimates to include consultancy fees were about £13,000. However a minimum expenditure by Dunlop of £6,000 may have been possible by using in-house capabilities and the grant likely to be available from the Department of Industry.

6.2.5 Outcome of micro-electronic control proposal

After consultation with in-house micro-electronic design expertise the view as taken by SCS management that the micro-processor based system would not be needed in order to rationalize the size and logic circuits on the present SCS control boards.

A micro-electronic system would have duplicated some of the effort put into an improved solid state control unit and added undesirably to the R & D costs of SCS at a time when sales could not justify it.

To properly utilize a micro-processor based unit, interdependent sub-routines should be necessary. Such programmes would be that for controlling pH calibration, plus the timing of the acid and two or more feed injections.

A programmable controller would not allow complex inter-relations between several inputs and outputs but could adequately replace SCS's present units. The in-house budget cost as in 1979 was estimated at £12,600 delivered ex works.

The prime reason for the elevated cost was due to the requirement to monitor anologue inputs. The bulk of the cost would then be devoted to hardware.

Hence, the cost and difficulty of applying micro-electronics in the CEH situation became too great at the time in 1979 for SCS to pursue further.

CHAPTER 7 COMMENTS AND CONCLUSIONS

7.1 Review of Methodology

The thesis text has been divided into chapters which chronologically correlate to the progession of the project.

A summation in Chapter 1 of the industrial base, DIS followed by a discussion of the planning concept as used in a marketing context is intended to outline the methodological approach made to the business problem.

The original business problem was an unknown equipment sales potential but after several months further problems became evident. Section 1.3.3 discusses these problems and derives objectives as the first stage in the problem solving technique described in Section 1.3.2.

Chapter 2, discusses the technical advantages and disadvantages of hydroponic systems described in the literature and draws conclusions where possible on each system's commercial applications. A series of criteria (see Section 2.1.1) are constructed to enable this initial analysis of opportunities.

Chapter 3 combines the economic data available for assessing the potential of hydroponics with the apparant advantages and disadvantages as drawn from both field observations and the literature review. By reviewing the state of the greenhouse market primarily, the salient factors that would decide the commercial potential of NFT in particular are discussed. Through this process NFT emerges as the most commercially promising system for Dunlop Ltd to consider marketing.

Market potential for hydroponics was the original business problem and Chapter 4 ~~sought~~ to assess as accurately as possible the acreage that could be expected in the next five years. Because there were not enough directly comparable figures available on previous or present hydroponic acreages, no statistical analysis could be justified.

The opportunity to acquire SCS Ltd, altered the intended progession of research at the 'half way stage.' Based on the assessment of market potential, a decision had to be made by Dunlop management whether or not to enter the hydroponic market via acquisition of SCS Ltd. After an appraisal of the assets, SCS was acquired and the student progressed to a function in order processing. During this phase, because of pressures within the firm based in Aldershot, difficulties arose in the co-ordination of the project, thus hindering the logical development of the research.

Chapter 5 and Appendix G discusses and makes suggestions for SCS's operating procedures and strategic plans to approach the hydroponic market.

Two specific developments which are argued to form a logical progression of the project are discussed in Chapter 6. These proposed developments contributed to the tactical or operational plan of SCS and hence enable part of the final stage of the planning sequence described in Section 1.3.2 to be completed.

7.2 Future Prospects

7.2.1 Research and development in NFT

Horticultural techniques have until recently been directed towards the plant shoot. Although the discipline of soil science has been established, research on the roots and their environment on a large scale has been inhibited by the roots being 'below ground.'

Now that hydroponics and NFT in particular is being used on a commercial scale it can be expected that an improved understanding of root functions can be achieved. Improved techniques and possibly cultivars may result (see Chapter 2). Research and development in some measure is being conducted by all the establishments named in Sections 2.4.2 and 5.2.1 and by many firms cited in Appendix F.

As yet, staged or moving racks of hydroponically grown vegetables have not been adequately demonstrated (see Chapter 2) as economically viable. Small plants of high value e.g. strawberries and ornamentals may prove commercially attractive when a staged system is used. However, large plants such as tomatoes, even though bush varieties are available, appear too fragile for use on moving racks. A promising development area may be that of mechanical cropping for NFT lettuce, so saving high labour costs.

NFT has not been used commercially in the open although shadow halls in sheltered, no frost, high light regions e.g. south west USA and some Middle Eastern countries, may be feasible. Specifically manufactured netting or native materials such as foliage can be used to cover the shadow halls which produce internally a sheltered, more constant climate for plant growth.

Shadow halls have been used with success in combination with aggregate culture (Mr D. Dugger, Fort Myers, Florida USA: personal communication). This combination of cultivation methods is often described in the literature (3.4).

Enclosed high humidity conditions in arid areas may be combined with 'passive environmental control' methods e.g. saline water might be evaporated from pads into polythene greenhouses and the condensation collected from the walls for use in the NFT system. Overheating might be avoided by directing ambient air to the plant bases via ducts during the day.

The accumulation of salt i.e. NaCl has been a problem in conventional agriculture and NFT alike. However, in the latter it is in solution, so salt crystals do not form on the roots but rather the overall NS osmotic pressure rises. Salt resistant cultivars such as those studied by Epstein (4.14, 4.15) may be developed, otherwise a physical method of reducing the osmotic stress must be sought. Presently, the physical methods are desalination by reverse osmosis or by a change of NS.

A 'drip-type' modular aggregate system may be used to leach out high NaCl levels from the root zone. Another suggested method is solar desalination (see Section 2.6). Meanwhile, run-off and fresh ground water supplies must be fully utilized.

Nutrient stripping from agricultural or human effluent has high potential particularly where removal of nutrients from discharges are desirable to avoid the consequent putrification of rivers and coastal waters. The chief problem is the variable quality of effluent which may contain toxic chemicals and heavy metals. Prior bacteriological treatment could introduce a high background level of potentially harmful organisms. High pressure filtration may be an area for consideration in such cases.

Conventional soil sterlization costs over £1,000/per acre whereas systemic or non-systemic fungicides may be used in NFT (see Section 3.5.1). Other possible methods for sterilizing the NS are the use of ozone or ultra violet lamps. Because ozone tends to oxidise heavy metals (including some nutrient elements) it could only be used for incoming water, whereas U/V lamps are more likely to be used for 'in-system' sterilization.

The trend discussed in Chapter 3 towards improved control over the NS and blueprint regimentation provides a possible application for micro-electronics. The economic and technical drawbacks of developing a micro-electronic control unit for NFT, will not enable SCS to implement the proposal discussed in Section 6.2.

7.2.2 NFT related technology

The use of medium need not be excluded from Dunlop's marketing policy. The Dunlopillo division has been conducting trials with particulate foam and peat with a view to the 'grow bag' market.

Rockwool or gravel culture may be more suited to particular crops in certain conditions. For instance, a medium such as rockwool can alleviate some salinity problems with cucumbers by allowing leaching.

Propagation by tissue culture is becoming a commercially accepted technique for producing uniform, virus-free seedlings. Instead of using peat blocks, seedlings may be planted out in agar blocks at a different stage of growth to promote an early establishment in NFT.

Improvements in solar, geothermal, wind and coal may become applicable to greenhouses, with rising oil prices,inside five years. Solar pumps for small installations using shadow halls in high light, sheltered Mediterranean areas may be an attractive commercial proposition.

Fermentation and phyto-plankton production techniques appear a logical business development for an established turnkey hydroponic company. Experience and design expertise in the 'control tecnology' of hydroponics would give SCS advantages over many competitors in these new and potentially important 'biotechnologies'.

An example would be the controlled growth of marine phyto-plankton and halophytic algae on diluted sewage effluent. These organisms are possible primary food sources for brine shrimp and thereafter fish e.g. mullet. The use of algae for cattle fodder would also require considerably further experimentation and assessment.

7.3 Summary of Conclusions

The following list is intended to cite conclusions derived during the project. The relevant sections in which each topic is discussed, are indicated.

Principal conclusions

Sections:

2.6.1 Hydroponics is progressing towards greater control of the NS and an optimal root environment.

3.1.1 A high degree of root environment control is justified only if the shoot environment is at, or nearly controlled at, optimal conditions.

3.2.1 Capital intensive controlled environments require high value crops.

4.1 High value crops find markets in developed or 'rich' developing countries and only rarely in the 'poor' third world countries.

3.2.2 Off season crops are expensive to produce, primarily because of rising heating costs; traditionally this has been provided by oil.

3.2.1 and 3.4	There are a series of functions that a hydroponic system must fulfill if it is to be commercially acceptable.
3.1.2	NFT can fulfill the functions of yield, management and energy in certain stated circumstances, as can rockwool and possibly aggregate culture.
4.1-4.6 incl.	The limitations and sophistication of NFT narrow its market application, but there is a substantial market potential. A market scope was projected.
3.1.1 4.1 and 5.3.2	A market segmentation can be identified on a national scale (Appendix D) and, speculatively, on a world-wide scale (Appendix I).
5.1	Market entry by Dunlop Ltd independently was estimated to be too costly in money and time (plus expertise and reputation) when SCS appeared a suitable company for acquisition.
5.1	Based on the advantages, disadvantages and market scope of NFT discussed in Chapters 1, 2, 3 and 4 it was concluded by Dunlop management that SCS was to be acquired.
5.2	SCS had definite strengths and weaknesses which were to be accounted for in their planned market development.

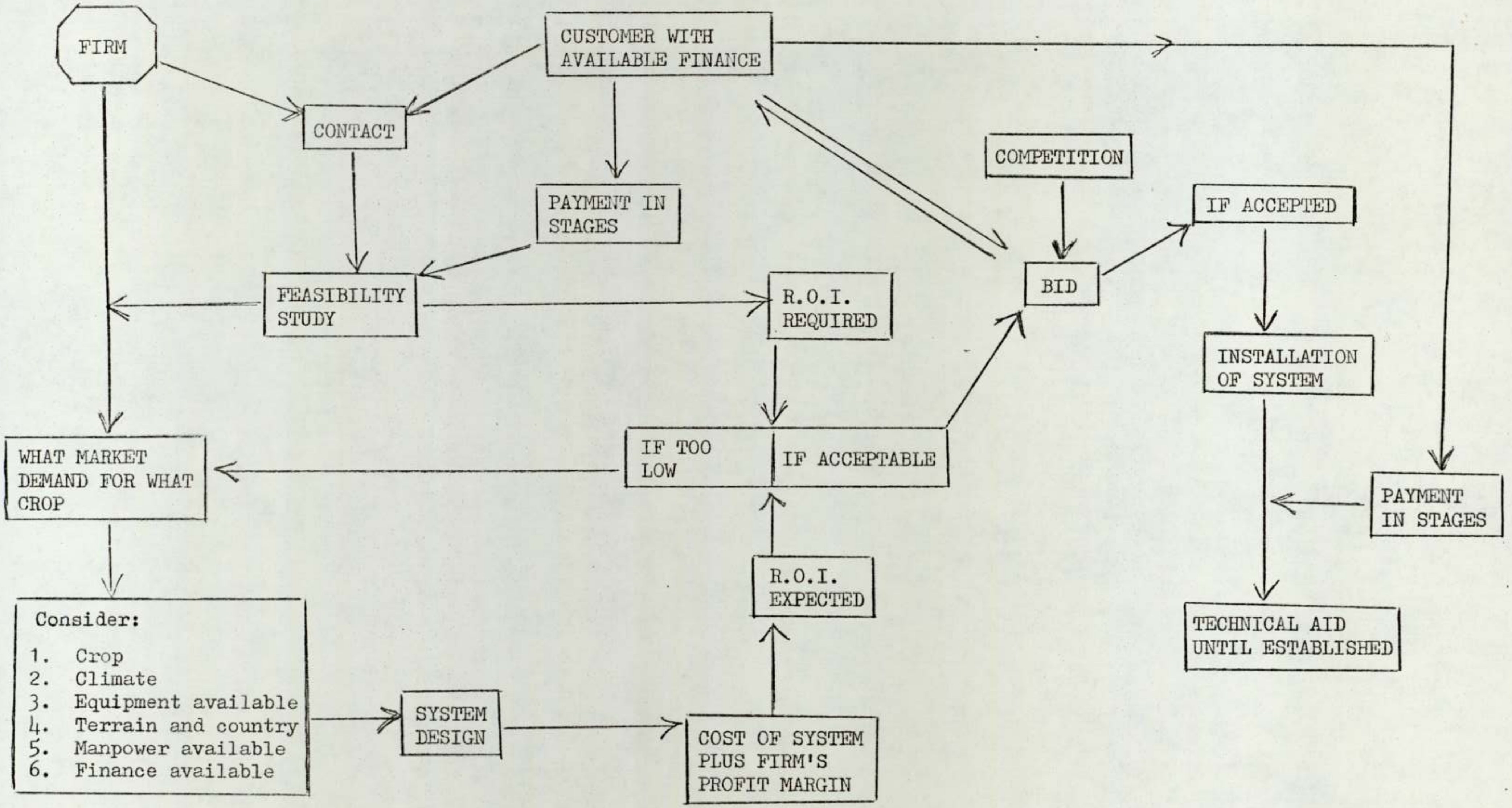
5.2.3 For the short-term order processing and administrative problems, more systematic procedures are needed. A possible system could be based on the requisition and procurement (R/P) sheet (see Appendix H).

5.3.4 SCS needs to concentrate on home market consolidation
6.1 and in the short-term, partly by development of its
6.2 control equipment and possibly a laboratory service.

5.3.5 The strategic discussion outlines probable target markets overseas, and describes the methods of approach available.

1.1 The turnkey philosophy is the basis of SCS's
and (and DIS's) business and hence design and technical
5.3 development with or ahead of the competition is
essential, provided that costs are acceptable.

AAPPENDIX A1. SIMPLIFIED DECISION FLOW CHART IN A TURNKEY OPERATION



Appendix A2 - Minutes of Supervisors' meeting held on 6th July 1978 at the IHD Office, Aston

1. It is envisaged that a company acquisition may be completed in September and therefore the project and thesis style should be orientated in that direction.

2. The assessment of current hydroponic technology was sufficiently advanced to justify writing up in a thesis context for completion by the end of September.

3. Item 2 can take the form of 5 chapters under the headings of:

   (1) Project background

   (2) Organisation of the project

   (3) Review of literature

   (4) State of the art/science
   This chapter can perform the role of a training manual for newcomers to NFT and bordering techniques used, principally within the UK.

   (5) State of the markets
   This chapter can include the market and segmentation size, technical, economic, social and competitive aspects of:
   (a) UK, (b) Channel Islands, (c) Holland
   plus general features of other European countries, USA and Middle East.

4. Dependent on a review of the situation in September, proposed further study and chapters will fall within the following areas:

   (6) Strategic discussion
   This can include proposals and reasons for country priority or market selection on a 5 year timescale, including the need for research and development.

   (7) Tactical discussion
   More detailed forecasts (regional UK) for 1979, supplied in a matrix form to allow for different options.

(8) Efficiency review

A few orders may be followed through within the acquired company to identify any areas of need.

(9) Market needs and services

This can collate features of the hydroponic market important to the implementation of recommendations for the company.

(10) Comments and conclusions

What has been learnt including any gaps in present knowledge. Contribution to knowledge with a view to future developments.

5. The main selling period for a hydroponic company is over the winter and therefore item 5(8) can be carried out then, enabling the thesis to be written up by mid 1979.

APPENDIX A3 Questionaire for pilot survey of UK horticultural market

HYDROPONICS

Mr Julian Wright
c/o The IHD Office
The University of Aston
in Birmingham

Dear Grower

I am trying to obtain the opinion of growers on the potential for hydroponics as a method for increasing yields and returns for various crops.

At present the nutrient film technique or NFT has found most favour with tomato growers. NFT is also applicable to other crops though it is not the only method and there is always room for improvement.

By assessing the market in the hydroponic field I am aiming to investigate any problems that occur and am willing to help with any queries you may have.

Crops grown

Crops grown	Approx acreage in:-			Tons per acre	Approx temp °C	Any possible expansion
	Open	Glass	Poly			
Tomatoes						
Lettuce						
Cucumbers						
Roses						
Carnations						
Others -please specify:						

Water available and ground conditions etc.

Please describe the quality i.e. hard, soft, saline, impurities if any:-

Is the quantity of water a limiting factor in your present production:-

Yes/No (please delete)

Comments:

Appendix A3 cont.

Brief Hydroponic Review

Hydroponics can simply be defined as the growing of plants in a solution of the nutrients necessary for plant growth, rather than directly in the soil.

The contenders for the most commercially viable systems appear to be those where the nutrient solution is recycled.

Two principal types of systems are the aggregate culture and the nutrient film technique or NFT.

Using aggregate such as fine gravel, charcoal or mixtures of materials the nutrient solution is irrigated onto or through the medium in some way. This has a bearing on providing optimum root conditions for growth. The main reason for this is the need to provide adequate aeration.

Aeration is also a prime concern with NFT and is achieved largely by the nutrient solution flowing along a gully in a thin film, hence the name. This gully slopes at approx. 1:80. Although no substrate is provided for the roots the plant finds support from the sides of the gully, stringing, and by the root mat developed with neighbouring plants.

Included in both systems are usually storage and header tanks plus the piping and double set of pumps - a standby pump is recommended.

The nutrient solution can be monitored manually but auto-electronic controls are available. The latter measure the pH and conductivity of the solution to determine nutrient concentration. Extra acid and nutrients are added when required.

An advantage here is the degree of control that can be exercised. Fertilizers are most efficiently used and can be varied according to the type and stage of the crop. There is increasing evidence to show that heat and fungicides can more efficiently be used in conjunction with the circulating nutrient solution.

Indeed, the problems feared by some of disease transmission and root death are being studied and are not proving a problem. The ability to cope with such problems appear to increase with the understanding of certain rules and experience. One such rule is to eliminate any phytotoxic materials from the system. Healthy plants appear to have remarkable resistance to pathogenic organisms.

APPENDIX A4

Company Data Summary (1.3 modified) -a check list

A Identity

A1 Reputation and business history
A2 Ownership and associates
A3 Competitors

B Management

B1 Composition of board and top management
B2 Prior experience and ages
B3 Responsibilities

C Facilities and skills

C1 Site and factory area
C2 Employees, subdivided
C3 Production facilities
C4 Design and development facilities plus personnel

D Financial background

D1 Balance sheet
D2 Profit and loss account
D3 Sources and application of funds
D4 Auditors
D5 Cost accounting and depreciation practices
D6 Deliveries and stock position
D7 Indebtedness

E Business ratios

E1 Net income on sales
E2 Net income on net worth
E3 Inventory turnover (each line)
E4 Current ratio

F Labour

F1 Composition of work force
F2 Union affiliation and labour practices
F3 Hourly rates and methods of payment
F4 Lost time record and labour relations

G Contract practices

G1 Duration, size, type, number
G2 Collection period
G3 Default rate

PTO

APPENDIX B FURTHER INFORMATION ON AGGREGATE CULTURE SYSTEMS

Calcareous gravels are often abundant, particularly in semi arid parts, but they are not chemically inert. With standard NS yields are usually reduced because the phosphate has been precipitated as calcium or magnesium salts. This can cause both rock deposits (as in Section 3.2) and lime-induced chlorosis. If it is the only available material a NS with extra phosphate and iron (3.13), will often improve yields. In this way limestones, marbles or corals can make up to sixty percent of the media without too much trouble.

Various man-made materials such as vermiculite, hydroleca, particulate foam plastic and fibreglass have been used with success. They could be considered if they proved non-phytotoxic, being light to transport if there was a cheap industrial excess.

A test for phytotoxicity is the germination of oat or other seeds on soaked blotting paper placed upon the doubted material. If any scorching of the root tips is observed the material should be avoided. It has been found (3.1) that toxic products left from manufacture can sometimes be washed away by up to ten days of running water. However, any new media material should be given a careful trial if literature or advice is not already available.

Aggregate culture is used extensively in terms of geography if not in terms of quantity, with installations in Israel, India, Africa, Europe and North America. Davtyan (3.7) is an authority from the USSR where he is studying the gravel cultivation of medicinal, essential oil and condiment plants, Table A showing some of the best yields reported for outdoor gravel culture from his 1976 review.

Table A <u>Comparative productivity of celery</u>

(average data 1966-68)

Yield, kg/are (i.e. kg/100m^2)

	Soil-grown control	Outdoor hydroponics
Total mass	110	2300

<u>Composition, kg/are</u>

	Edible portion		Unused stalks	
	Soil grown control	Outdoor hydroponics	Soil grown control	Outdoor hydroponics
Dry matter	9.5	152.5	5.8	83.6
Raw protein	1.3	39.9	0.9	16.0
Ascorbic acid	0.030	0.740	0.010	0.230
B carotene	0.004	0.080	0.001	0.009
Raw ash	1.8	40.0	1.1	18.5
K	0.500	7.300	0.400	7.100
Ca	0.300	4.600	0.100	1.200
Mg	0.100	1.000	0.020	0.230
P	0.060	1.100	0.030	0.500
S	0.140	0.240	0.020	0.300
Fe	0.010	0.200	0.002	0.050

Table A shows the excellent quantity and quality that can be achieved in hydroponics - in case it might be suggested that hydroponic produce was more 'watery' than soil grown. Indeed, hydroponic produce quality has only been reported as exellent, giving an increased number of grade one fruit and vegetables (3.4) with no loss of taste.

In the vein of pioneer 'hydroponists' Davtyan (3.7), Douglas (3.4) and Schwarz (3.25) have published optimistic remarks on the future food producing role of gravel culture and hydroponics in general. Only Schwarz (3.12) has presented any detailed guidelines for the operation of a gravel culture farm. The opinions of most literary sources are based on experience, ocassional yield tables and technical discussion with little mention of the economic necessities. To put the expected yields and costs into perspective, Appendix E has been constructed.

Mentions of disease problems in aggregates is rare in most subject literature, although this is claimed as a drawback by some acknowledged horticultural authorities such as A.J. Cooper and D. Price of the GCRI, England. However, sterilization with formalin, KOH, or other chemicals circulated for a few hours in a similar way to the NS is cheaper and easier than the conventional steam sterilization of horticultural soil. In this way hydroponic media have been used for seven or more years without the need of replacement (3.4).

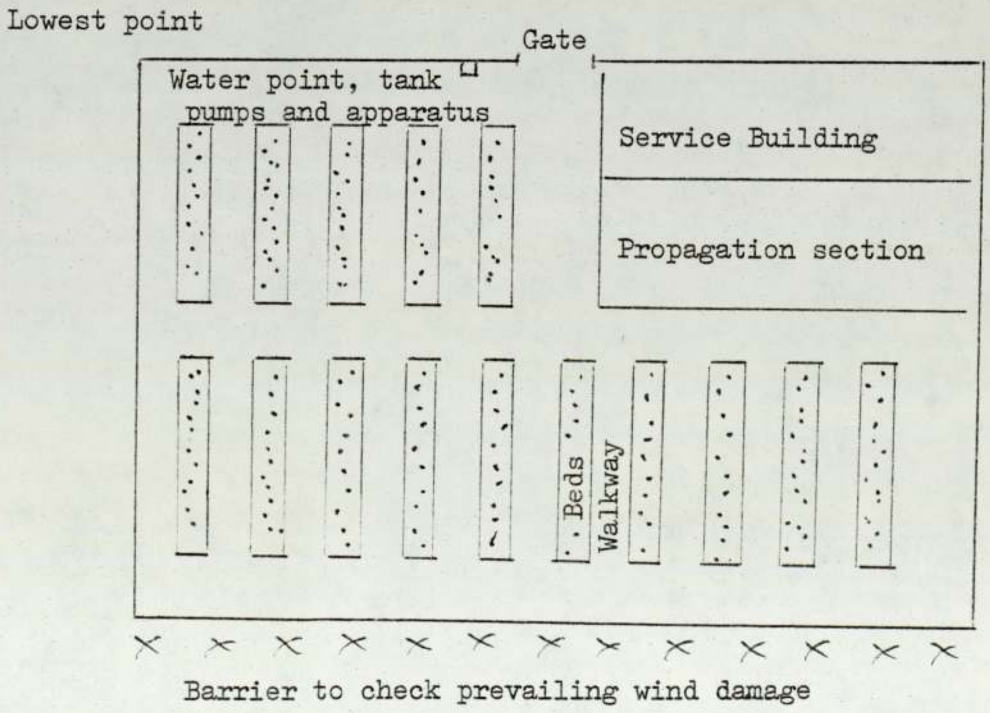
Discussion in more detail of various gravel culture techniques can be found in the Procedings 1976, 1973 and 1969 of the IWOSC which are available from the Secretariat (3.4).

Bed layout possibilities

An economic farm size upwards of 1,000m^2 ($\frac{1}{4}$ acre), depending on crop, country and market would probably employ one person full time. The basic parts of each installation would be a propagation section, the main bed section and service buildings (3.1, 3.12). The main bed section includes the pumps, tanks, pipework and equipment for the make-up of the NS. Careful planning of the layout before installation can keep down the cost of such equipment appreciably in terms of quantity rather than quality, e.g. the length of pipework between beds and the main tank. There are three general layout plans depending on topography, crop, farm size and system chosen.

(a) The commonest plan is that of parallel narrow beds about 30m long and 1m wide. This applies to sand and gravel cultures as illustrated in Figure A .

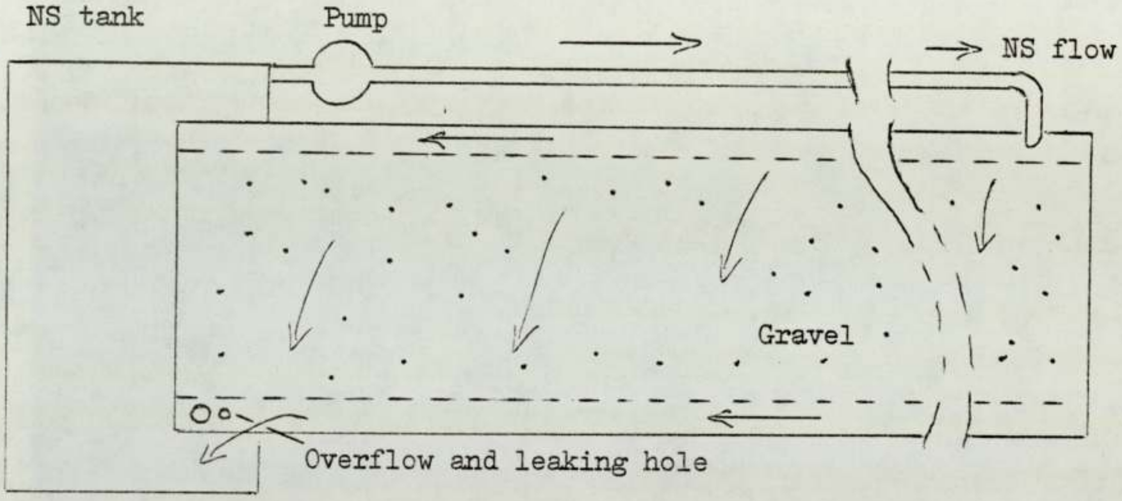
Figure A Typical plan for an outdoor aggregate culture installation



The beds in construction may be as described in Sections 3.1 - 3.3 but in most cases on level or sloping ground the best design appears that of the late H. Filippo (3.4) which enables maximal percolation of the NS through the gravel beds as illustrated in Figure B .

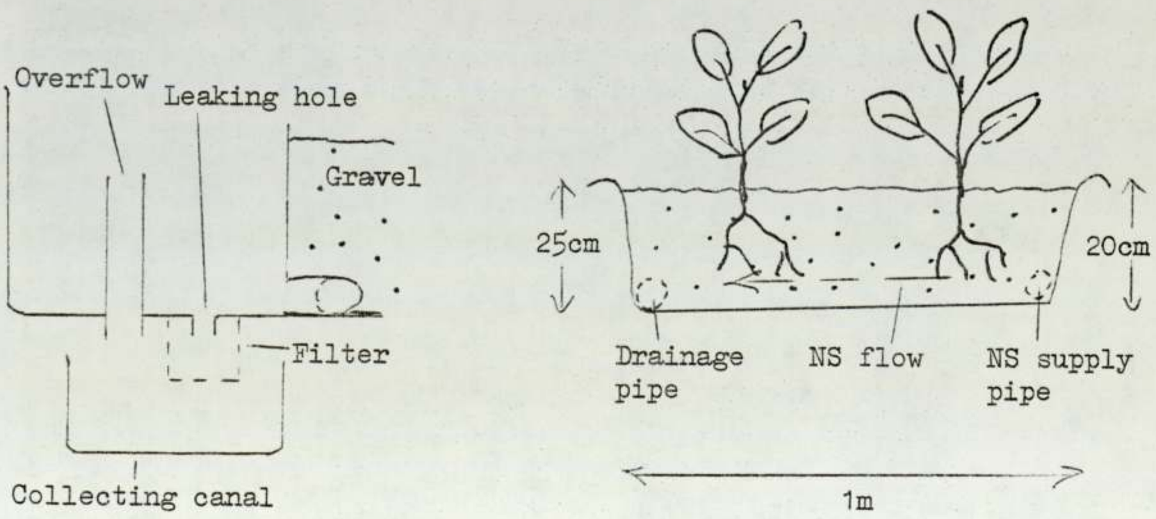
Figure B Filippo's gravel culture system (adapted)

Stylised plan of beds



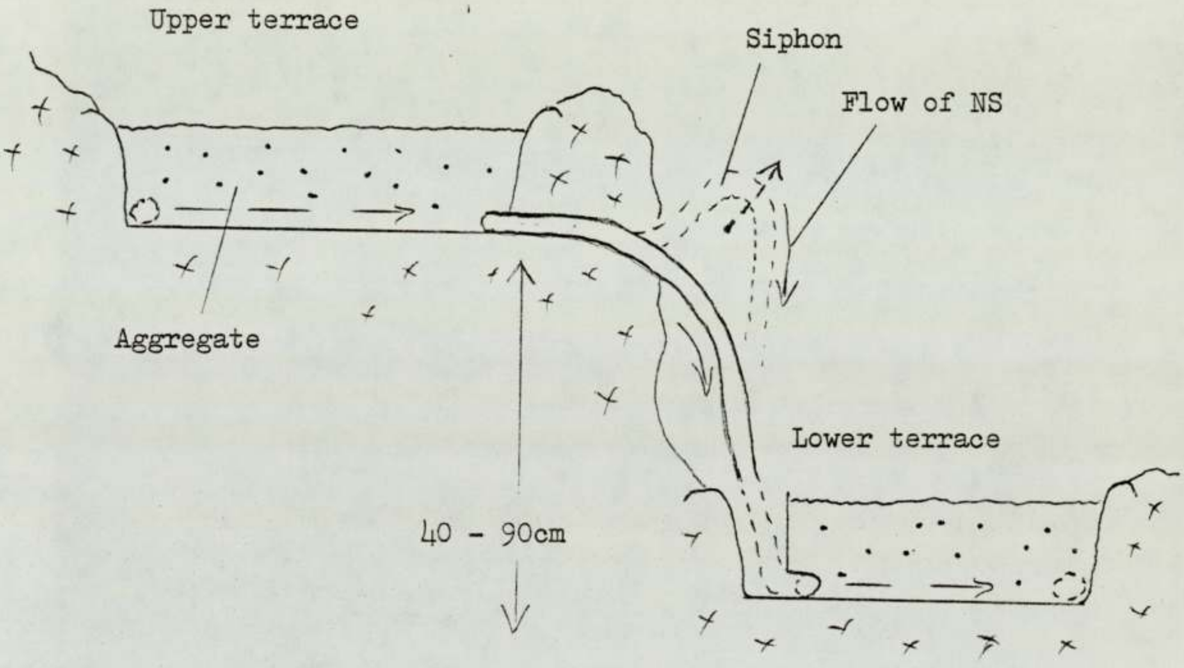
The overflow and and leaking hole

c/s of gravel bed



(b) If the terrain favours it, terracing is advised. The NS is then pumped into the highest bed and flows by gravity to lower beds. An advantage is the use of a smaller tank of which the capacity need only be thirty percent more than that required for the top terrace. We can modify Filippo's system for terracing as in Figure C .

Figure C A terraced Filippo gravel culture system



(c) A third type of layout plan has large beds without provision for cultivation paths. Heavy construction equipment may be required to level the ground beneath each bed which may be lined with asphalt. On-ground irrigation would probably be preferable with drainage tiles below. In this way the maximum growth area is utilized despite an approximate twenty percent loss for walking space, this being a special consideration for greenhouse crops.

Three disadvantages are the need for more gravel, difficulties in arranging trellises and the need to tread on the growth medium. The latter increases the chance of spreading diseases.

System equipment needed

Bed construction

Depending on whether the beds are sunken or raised above ground various materials have been used as listed in Table B.

Table B Possible materials for bed construction

Sunken beds	Raised beds	
Butyl rubber sheeting	Reinforced concrete	plus inert liner e.g. asphalt
Packed earth plus water proofing e.g. asphalt	Prefabricated concrete	
Polyester plastic sheeting	Asbestos cement	
Metal sheeting	Brick and cement	

Fibreglass

Depending on the temperature variance, the raised beds require expansion joints, as would any solid (sunken) bed. An advantage is therefore gained by a flexible bed liner laid in a trench, especially if the aggregate removed can be used, possibly after processing, as part or all of the culture medium. This policy may be feasible in semi arid countries such as Saudi Arabia where suitable aggregate may be accessible.

Pumps

Electric pumps are recommended because automatic control is more easily arranged than with petrol or diesel machines. If mainline electricity is not available then a generator (probably diesel) will be required.

To ensure continued irrigation of the valuable crop a standby pump for the NS is recommended. The pumps should be filled (primed) and ready for action. Submersible pumps may always be filled but they can be difficult to service. For this reason an exterior pump situated adjacent to the bottom of the tank is often preferred. Furthermore, all parts of the pump in contact with the NS should be inert. Centrifugal pumps appear preferable to vertical pumps the NS being more isolated from corrodible moving parts. In addition, air may be more easily added after the pump to improve oxygenation. A tough, inert impeller material such as bronze would be preferred.

The pump's capacity is determined by the growing area and height to which the NS must be raised. For beds on level ground it can be estimated that one horsepower is sufficient for 100m^2 of gravel growing area, supplying 6 - 7.5m^3 every 15-30 minutes. It is the latter requirement that necessitates a good service facility for one pump whilst the other is operating.

Tanks

A storage tank able to contain all the NS required for one irrigation is usually situated at the lowest point on the site. To facilitate complete drainage from the gravel, the tank's upper level should be 10-20cm below the bottom of the lowest bed. The tank size is an important cost and management factor and hence a system is preferred which keeps the return NS at a steady and minimal volume, i.e. the terraced Filippo system.

The means of containing the NS has variations (3.12) involving other cisterns with ball cocks, including the use of a header tank for incoming make-up water. For ease of cleaning, tanks with rounded corners are preferred. Large tanks can be of concrete plus coating, resistant metals or polymers. The latter are probably better for the sunken tank at least; butyl sheeting can be adapted to this purpose successfully.

Pipework

Where a limiting factor of pressure does not apply most pipes used now are of polymer material. Aluminium, asbestos, cement, iron or steel pipes and fittings can be used where suitable, but galvanised and copper pipes should be avoided. The latter two can release phytotoxic concentrations of zinc and copper respectively. Terraced beds or a centrally placed storage tank can reduce the pipework necessary.

Note: The equipment for NS make-up which in the case of automatic control can consist of small pumps, tanks, pipework and electronics is discussed in the section on the NS.

Known commercial installations

Apart from those installations cited in Section 3.2 the majority of commercial growing systems are gravel rather than sand cultures. The approximate areas judged to be under various hydroponic cultures are listed in Appendix D. This section cites in brief detail some gravel culture farms. Steiner (3.4) estimates that ninty percent of all gravel installations are of the American type (see Section 3.1) although there are many variations.

North America

Perhaps the largest single hydroponic bed to exist was that of Flager Hydroponics Inc. Miami in the USA (3.1) which covered 1,000m^2 in the 1950's for tomato growing. At Glendale in Arizona, Hydroculture Inc. have a 5 ha complex which produces about 3,500 tonnes of tomatoes annually, with units let out to individual growers.

In Utah, growers use both gravel and sand cultures for tomatoes which were reported (3.23) to command a premium price in markets because of their superior quality and flavour to soil or peat grown fruit. Some of the large tropic variety weighed in at 16-20oz each.

In 1970 Maas and Adamson (3.23) reported that there were some 7ha of aggregate cultured tomatoes, mainly under glass in the Victoria area of British Columbia. Some thirty five percent of the units were employing a 3 : 1 fine sand-sawdust growing medium.

In Colorado, J. Hanan (3.23) reported that commercial production of carnation blooms equalled 1,000/m^2. The system employed demanded any inert aggregate with particle sizes ranging from 2.0 - 0.03cm with a moisture holding capacity, at a depth of about 17cm, varying between 15 and 25 litres/m^2. He listed the advantages of a good hydroponics system as stability and uniformity, a root medium unaffected by saline water, standard NS's, complete automation, prevention of soil borne diseases, and no risk of over-watering.

Israel

Because of constraints on water use hydroponics has been taken up to a greater degree by Israel than by most other countries. Schwarz (3.24) of the Negev Institute has found promising results with commercial scale tomato crops using high saline NS's. A total NS salt concentration of 4,000 - 8,000ppm was used with gravel culture under cover. The CO_2 levels in the atmosphere were up to 8,000ppm but it was not yet clear what mode of growth promotion may have been operating.

Germany

Reporting on ten years of carnation gravel culture trials, F. Penningsfeld has obtained yields 10-30% higher than the best soil grown ones (3.23). The technique employed was sub-irrigated aggregates of broken bricks then gravels with sand on top. He always advised that it was better to put coarser growing media underneath with a layer of fine inert material above. The beds were made of plastic sheeting and hot water pipes were laid in the aggregate to supply warmth in winter.

Country	Ranking	Total rating	Population	Population growth	G D P per capita	G D P per capita growth	Food imports per capita	Sensitivity of food imports to G D P growth	Oil production per capita	Years of oil reserves	Climate	Land area	Cultivatable land not cultivated	Political stability
BAHRAIN	7	36	1	3	4	5	5	2	2	2	1	5	3	5
EYGPT	12	28	5	2	2	2	2	4	1	3	2	2	2	2
IRAN	7	36	5	2	4	4	4	5	1	4	2	2	3	1
IRAQ	4	42	4	3	3	4	4	5	1	4	2	4	5	3
JORDON	11	33	2	3	3	1	1	5	1	1	2	5	4	2
KUWAIT	1	44	2	4	5	3	3	3	5	5	1	5	1	5
LEBANON	10	35	2	3	3	3	3	3	1	1	3	5	5	1
OMAN	6	37	1	3	4	5	5	3	2	3	1	5	1	4
QATAR	3	43	1	3	5	5	5	2	5	4	1	5	2	5
SAUDI ARABIA	5	40	3	3	5	5	5	3	4	4	2	1	1	5
SUDAN	15	23	4	2	1	1	1	4	1	1	2	1	2	3
SYRIA	7	36	3	3	3	4	4	3	1	4	3	4	4	1
U A E	1	44	2	5	5	5	5	2	5	4	1	5	1	4
YEMEN	12	28	3	3	1	2	2	1	1	1	3	4	5	3
YEMEN PDR	12	28	2	3	1	1	1	3	1	1	3	4	5	3

Source: DIS NB: A rating of 5 is most favourable - highest total rating gives rank 1.

Appendix D1 Countries, populations and total production (protected + field) of selected crops

Source : FAO 1977

Country	Population m	Tomatoes 000t	Lettuce Increasing: +	Cucumbers Decreasing: -
U.K.	55.9	179 -	197	42 -
Holland	13.8	360 +	120	330
Belgium/Luxemburg	9.8	145 -	126	49
Denmark	5.0	22 +		17
Ireland	3.0	26 +		
West Germany	61.6	34 +	74	84
France	53.2	639 -		82
Greece	9.0	1,250	45	109
Italy	56.0	3,000	777	110
Spain and Portugal	50.0	2,800		240
Norway	4.0	10 +		8
Sweden	7.9	12 +		23
Switzerland	5.5	19 +		41
Australia	15.0	171 +		13
U.S.A.	210.0	7,000		815
Canada	18.0	424		71
Saudi Arabia	9.2	305 +		
Kuwait	1.2	3		
Nigeria	36.0	240 +		
Egypt	38.4	2,100 +	230	224
Israel	2.8	237		52
Sudan	18.9	142 +		

N.B. Brackets imply similar climates, growing seasons and methods.

APPENDIX D2 - Greenhouse acreages in Europe 1977-78, mid year-unless indicated by W = winter

COUNTRY	ACRES	% HOT/COLD	TOMATOES		CUCS	LETTUCE		PEPPERS	OTHER VEG	ORNA-MENTALS	MONOCROPPING		REMARKS
			HOT	COLD		HOT	COLD				CROP	ACRES	
England & Wales	5,023 (incl. plastic 276)	Semi: 75/25 Full: 55/45	1,354	832	564	250 W:936	240 W:496	95	283	1,405	H. Tom C. Tom Cucs H. Let C. Let	680 300 200 200 200	AYR chry = 164 Carnations = 126
Scotland (approx)	265	Full: 45/55	70	30	30	30	10	10	70	15	H. Tom C. Tom Cucs H. Let	40 20 20 20	
Eire (approx)	470	Full: 45/55	100	100	60	40	50	15	87	18	H. Tom C. Tom Cucs H. Let C. Let	70 50 30 30 30	
Guernsey	917	Full: 79/21	550	55	0	0	0	8	11	293	H. Tom C. Tom	505 41	Mono roses = 86 Fresias = 116
Jersey	114	Full: 78/22	79	10	0	0	0	4	4 -	17	H. Tom C. Tom	75 6	
Belg/Lux (approx)	3,688	Full: 70/30	500	400	450	300	250	60	1,100	638	H. Tom C. Tom Cucs H. Let C. Let	350 200 200 250 200	Other veg includes 1086 acres fruit - mainly grapes
France (approx)	3,730 (incl. plastic 865)	Full: 40/60	400	600	350	200	350	150	670	1,010	H. Tom C. Tom Cucs H. Let C. Let	100 300 150 180 300	
W. Germany	5,808	50/50	300	278	487	200	306	100	457	3,680	H. Tom C. Tom Cucs H. Let	100 50 200 150	Other veg incl. Kohlrabi = 300 ac. Cauliflower = 140 ac.
Denmark	1,409	60/40	157	100	109	100	35	15	60	833	H. Tom C. Tom Cucs H. Let	100 30 30 70	Other veg incl. melons = 25 ac.
Holland	19,187	Semi: 86/14 Full: 70/30	5,681	900	2,322	S. Total W. Total	35 2,400	474	148	8,009	H. Tom C. Tom Cucs H. Let Peppers	600 100 350 50 150	Other veg mostly endives Ornamentals incl.: Roses = 1,549 ac. Carnations = 1,114 ac. Pot plants = 1,215 ac.

continued.../

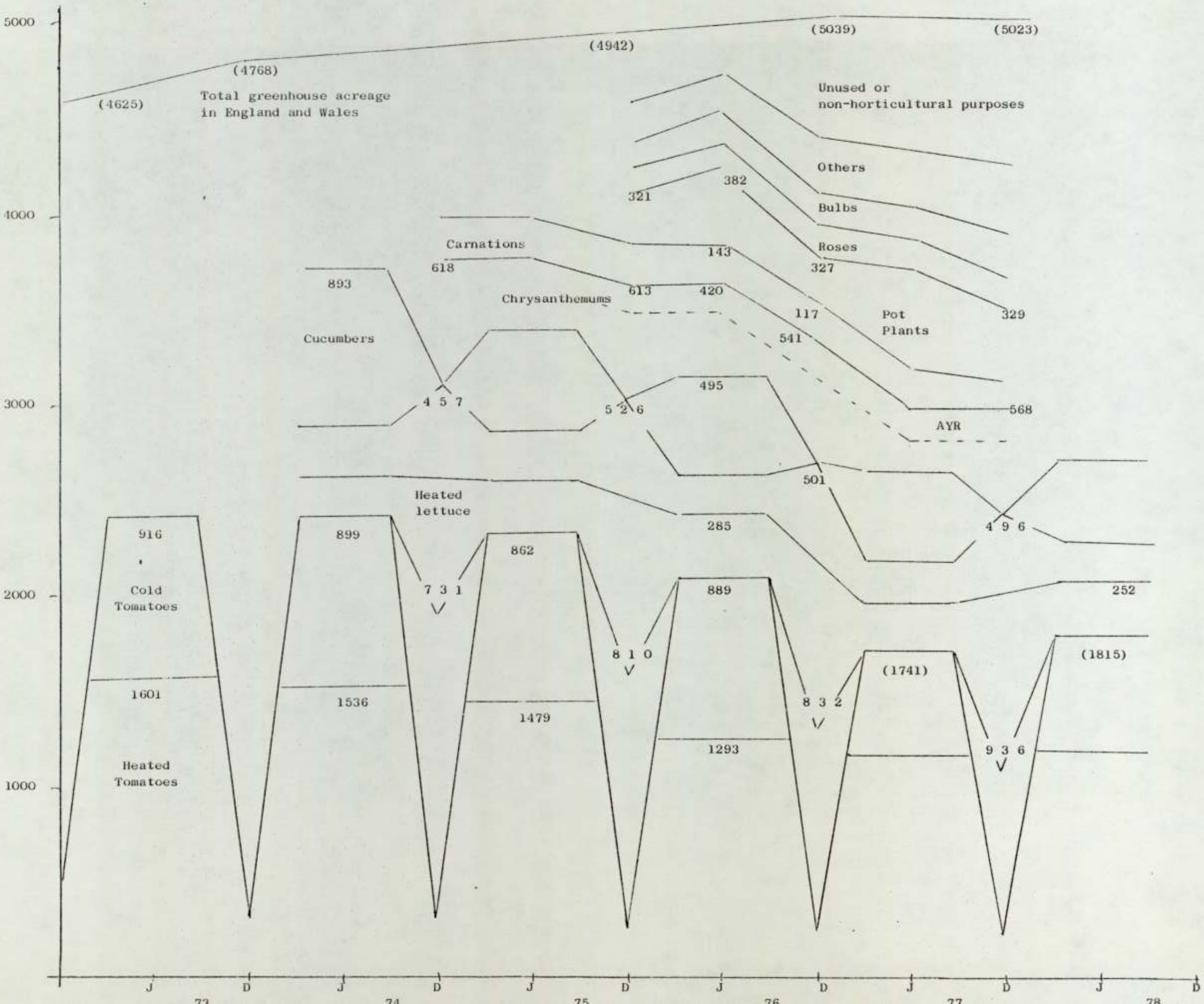
Appendix D2 cont.

COUNTRY	ACRES	% HOT/COLD	TOMATOES		CUCS	LETTUCE		PEPPERS	OTHER VEG	ORNA-MENTALS	MONOCROPPING		REMARKS
			HOT	COLD		HOT	COLD				CROP	ACRES	
Norway (approx)	470	90/10	80	-	20	50	10	10	107	293	H. Tom H. Let	40 40	
Sweden (approx)	954	90/10	150	10	50	120	30	15	23	556	H. Tom H. Let	50 80	
Finland (approx)	754	90/10	150	-	60	150	40	20	23	307	H. Tom H. Let	50 100	
USSR (approx)	16,055	77/23	7,000	1,500	3,000	1,000	500	400	1,855	800	H. Tom C. Tom Cucs H. Let C. Let Peppers	4,000 500 1,500 500 100 100	There is a plan to greatly increase the greenhouse area. Present expansion 1300 ac/annum.
Poland	2,500	70/30	1,000	250	500	100	50	50	-	550			
Hungary) Bulgaria) Romania)	8,800	60/40	4,000	1,000	500	400	100	300	2,000	500			East European countries (including E. Germany) are increasing their plastic greenhouse acreage.

COUNTRY	TOMATOES	CUCUMBERS	LETTUCE	PEPPERS	OTHERS	REMARKS
Spain	11,633	3,818	22	1,321 See capsicum	Capsicums 5,955 Strawberries 1,768 Egg plant 1,102 Melon 22,128 Water melon 9,556	Protected structures are usually plastic and fairly crude with little or no heating. Yields under half that of UK greenhouses.
Italy	12,127	753	655	5,397	Celery 291 Aubergines 1,697 Courgettes 2,433 + ornamentals	As above with about a quarter glass.
Australia	17,450	2,350	4,250	-	Asparagus 4,500	Most of these crops are in the open with yields between third and half that of UK greenhouses Yield as tons/acre: Tomatoes Cucumbers Lettuce 7.1 3.2 5.3 11.5 4.2 7.6 5.1 4.0 7.9 16.7 20.7 8.6 14.1 5.9 9.8 Acreage under hydroponics (NFT) is reported to be approximately 30 and increasing.
States						
NSW	5,681	545	1,885			
Victoria	5,878	291	1,968			
Queensland	6,000	1,454	686			
S. Australia	1,052	111	496			
W. Australia	543	274	420			
Tas.	100	-	250			
North	50	-	-			
Act	50	-	-			

UK trends in greenhouse cropped acreages

APPENDIX D3



Source:
MAFF (2.3)
adapted

Appendix D4 UK Greenhouse cropped holdings in regions at June and December 1976

			Northern		Yorks & Lancs		E. Midlands		W. Midlands		Eastern		S. Eastern		S. Western		Wales		England & Wales	
			No	Acres	No	Acres	No	Acres	No	Acres	No	Acres	No	Acres	No	Acres	No	Acres	No	Acres
< ¼ acre	June toms	H	160	19	401	70	390	48	240	10	280	60	480	70	360	48	81	10	1300	336
		C	171	13	800	96	399	48	350	48	350	90	605	92	460	45	170	15	3400	482
	June cucs		62	2	200	12	190	10	137	9	210	27	350	11	260	10	58	3	1600	90
	Dec lettuce	H	40	3	240	40	114	13	102	11	103	15	140	28	105	12	41	5	1110	152
		C	49	3	301	55	180	18	145	18	230	30	430	53	280	28	60	7	1700	220
	TOTAL		280	47	1050	244	990	72	640	52	1160	192	1200	102	1005	35	240	30	6800	1175
¼<2½ acres	June toms	H	8	7	134	132	29	20	47	43	101	99	98	99	65	60	8	7	492	469
		C	7	7	107	87	24	19	25	22	57	88	64	43	18	14	8	6	300	252
	June cucs		2	3	30	30	0	0	5	6	102	90	9	8	7	8	1	1	150	157
	Dec lettuce	H	3	3	109	107	8	6	23	22	31	30	50	52	19	15	1	1	244	237
		C	2	1	71	67	7	5	16	15	38	37	43	35	11	10	5	5	194	180
	TOTAL		35	34	363	354	190	175	178	170	485	491	498	492	194	183	47	40	1990	1941
2½<10 acres	June toms	H	2	10	18	67	0	0	4	19	13	68	9	40	4	15	0	0	50	222
		C	1	3	7	25	2	6	3	15	3	8	1	6	1	6	0	0	18	43
	June cucs		0	0	19	112	0	0	0	0	10	33	3	11	1	4	0	0	33	40
	Dec lettuce	H	1	7	44	205	0	0	1	2	8	32	4	11	0	0	0	0	58	260
		C	0	0	3	13	1	7	1	5	3	15	2	7	0	0	0	0	10	45
	TOTAL		4	23	71	319	11	42	14	62	61	254	61	257	21	84	4	14	147	1057
10+ acres	June toms	H	0	0	2	21	2	26	1	19	2	32	3	148	0	0	1	19	11	265
		C	0	0	0	0	0	0	0	0	5	103	1	23	0	0	0	0	6	125
	June cucs		0	0	3	55	0	0	0	0	0	0	2	47	0	0	0	0	5	104
	Dec lettuce	H	0	0	5	87	1	14	0	0	3	45	2	29	1	13	0	0	12	190
		C	0	0	0	0	0	0	0	0	3	53	0	0	1	10	0	0	4	63
	TOTAL		0	0	6	105	2	52	2	31	10	264	11	329	2	44	2	31	35	816
All	June toms	H	170	36	155	380	421	94	292	81	396	259	590	257	429	123	90	36	2543	1293
		C	179	23	914	114	425	73	378	85	415	289	671	163	479	61	178	21	3724	889
	June cucs		64	5	252	207	190	10	142	15	322	150	364	76	268	22	59	4	1788	495
	Dec lettuce	H	44	11	398	439	123	33	126	35	145	122	196	120	125	40	42	6	1424	285
		C	51	4	375	135	188	30	162	38	274	135	475	95	292	40	65	12	1908	232
	GRAND TOTAL		335	102	1523	986	1332	432	918	398	1664	1198	1897	1312	1103	453	299	119	9071	4989

Appendix D5 <u>Greenhouse cropped acreages in Holland</u>

	1974	1975	1976	1977
Tomatoes	7,807	7,146	7,149	6,381
Cucumbers	3,092	3,191	3,137	2,322
Winter Lettuce	2,464	2,669	2,276	2,400
Endives	990	1,215	968	≃ 950
Total Vegetables	14,353	14,221	13,530	12,053
Roses	1,517	1,606	1,658	≃ 1,700
Carnations	995	1,057	1,114	≃ 1,150
Pot Plants	1,020	1,116	1,200	≃ 1,400
Other Flowers	3,441	3,750	4,050	≃ 4,050
Total Ornamentals	6,973	7,529	8,022	≃ 8,300

<u>Trend in holding sizes</u>

		< ½ acre	½-1½ acre	1½-2½ acre	2½-5 acre
Vegetable :	1970	5,259	3,628	3,510	770
	1976	3,222	2,084	2,748	1,040
Flower :	1970	4,799	1,436	711	141
	1976	3,980	1,798	1,829	642

APPENDIX D8

REGION	GLASS	POLY	FIBRE G	TOTAL GREENHOUSE	TOMS	CUCS	LETTUCE	OTHER VEG	ORNAMENTAL	HYDROPONIC	REMARKS
New England	66	123	10	199	22	2	1	99	75	1	Semi-protected plastic and cloth houses are approx another 2,874 acres.
North Atlantic	181	401	17	599	31	1	6	7	554	2	
Middle Atlantic	37	50	22	109	7	1	1	2	98	1	72% of fresh tomatoes in USA are produced on 36,000 acres in California.
South East	37	457	127	631	125	1	1	47	457	27	
South Central	64	213	47	324	17	1	12	30	274	5	USA open cucs crop approx 19,000 acres.
North Central	682	342	73	1,097	331	18	140	5	603	9	USA open lettuce crop approx 59,000 acres.
Great Plains	17	73	42	132	11	2	12	25	82	8	
South West	55	130	83	268	59	3	0	68	138	98	Rising costs of energy, labour and materials keep heated greenhouses to small acreage, mainly in Ohio and North Carolina.
Mountain	39	49	66	154	17	0	1	10	126	6	
North West	10	30	19	59	5	3	1	18	32	6	
California	47	31	64	142	17	49	0	14	62	50	From 1971-77 the hydropinic acreage remained fairly static but in the past year some growers are known to be using NFT.
Pacific	1	48	21	70	11	1	0	16	42	1	
U.S.A.	1,236	1,947	591	3,774	553	82	175	1,231	2,543	215	

APPENDIX E

Horticultural Economics

E1 This is intended to show the comparative sales value of greenhouse crops in recent years. It can be seen from Appendix D3 that the vegetable section has declined in favour of ornamentals as a result of worsening margins. Prices are unsteady and increasing overall only at about 8%. The MAFF price indexes for these 3 years were:

Calendar Year	Tomatoes	Lettuce	Cucumbers	Total
1976	189.1	163.3	182.7	183.0
1977	207.9	204.5	194.5	204.5
1978	221.7	228.6	193.6	228.6

E2, E3, E4 The seasonal price patterns show the sources of produce. Off season demand filled by imports from southern countries not requiring very expensive winter heating.

E5, E6, E7 The breakdown of costs show that early season heating is very significant. This and labour costs account for much of the decreasing margin when the market prices are relatively static.

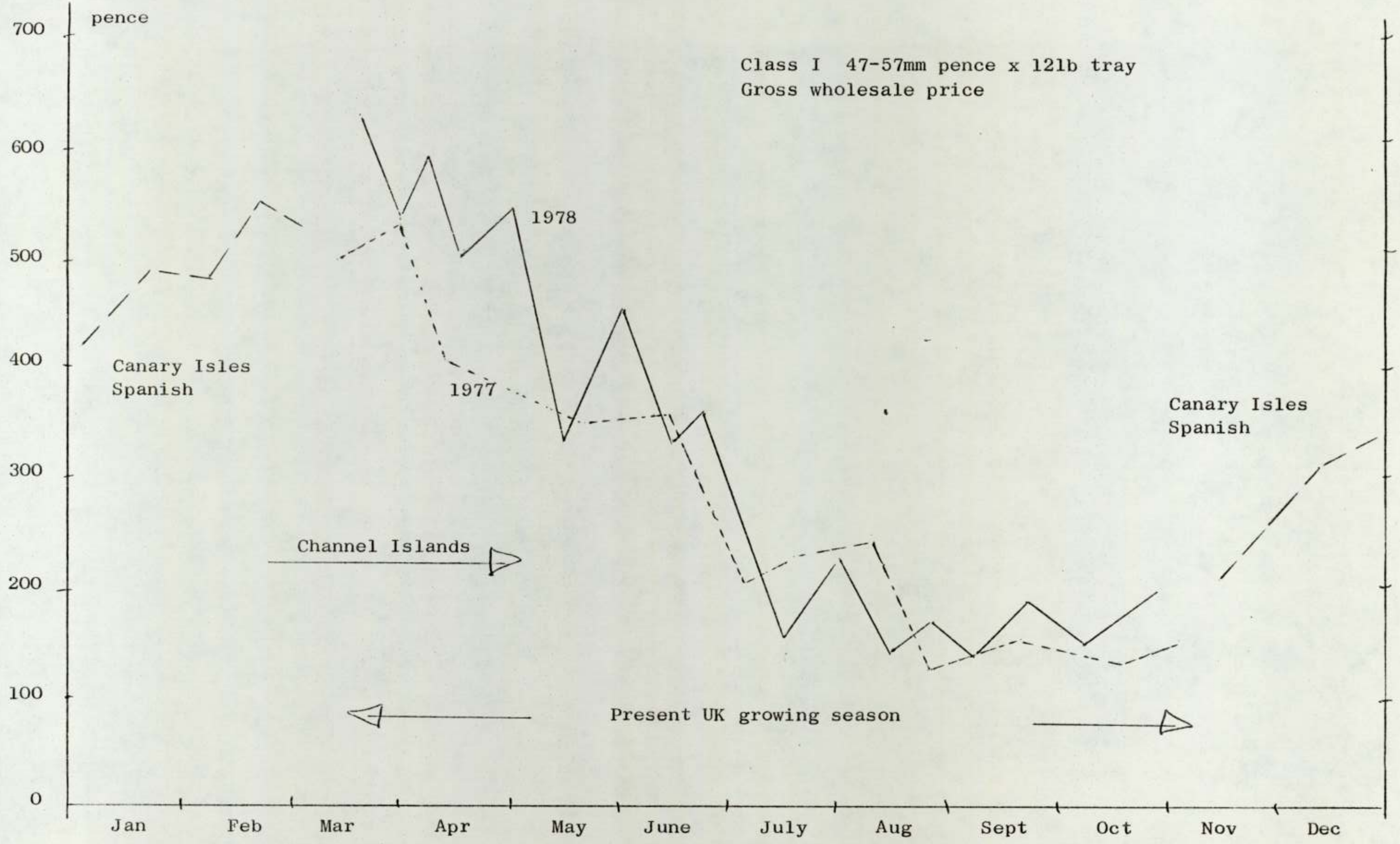
Channel Island production has a large marketing element, much of this being freight charges.

Appendix E1 UK Greenhouse vegetable output

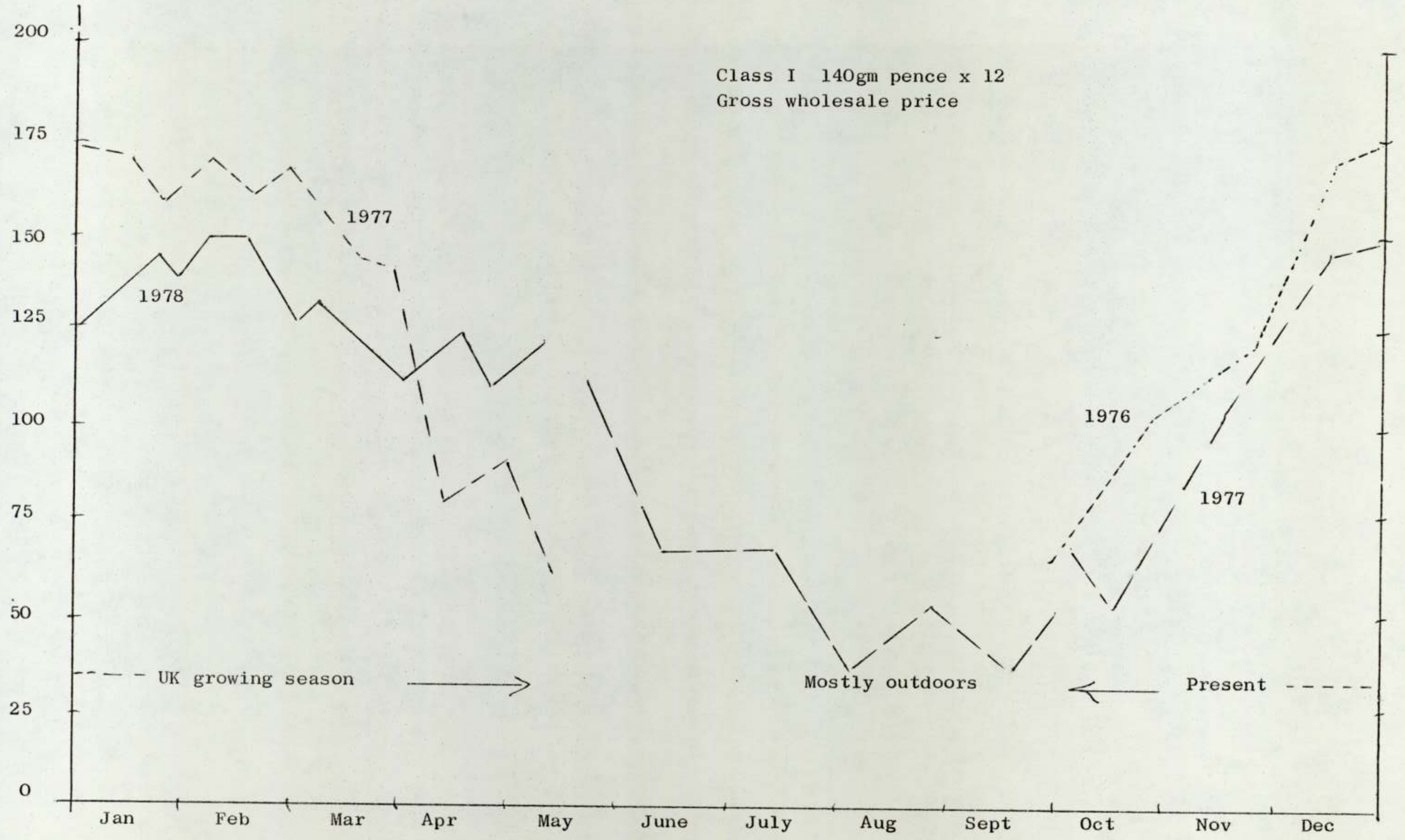
(Source : MAFF (2.3) adapted)

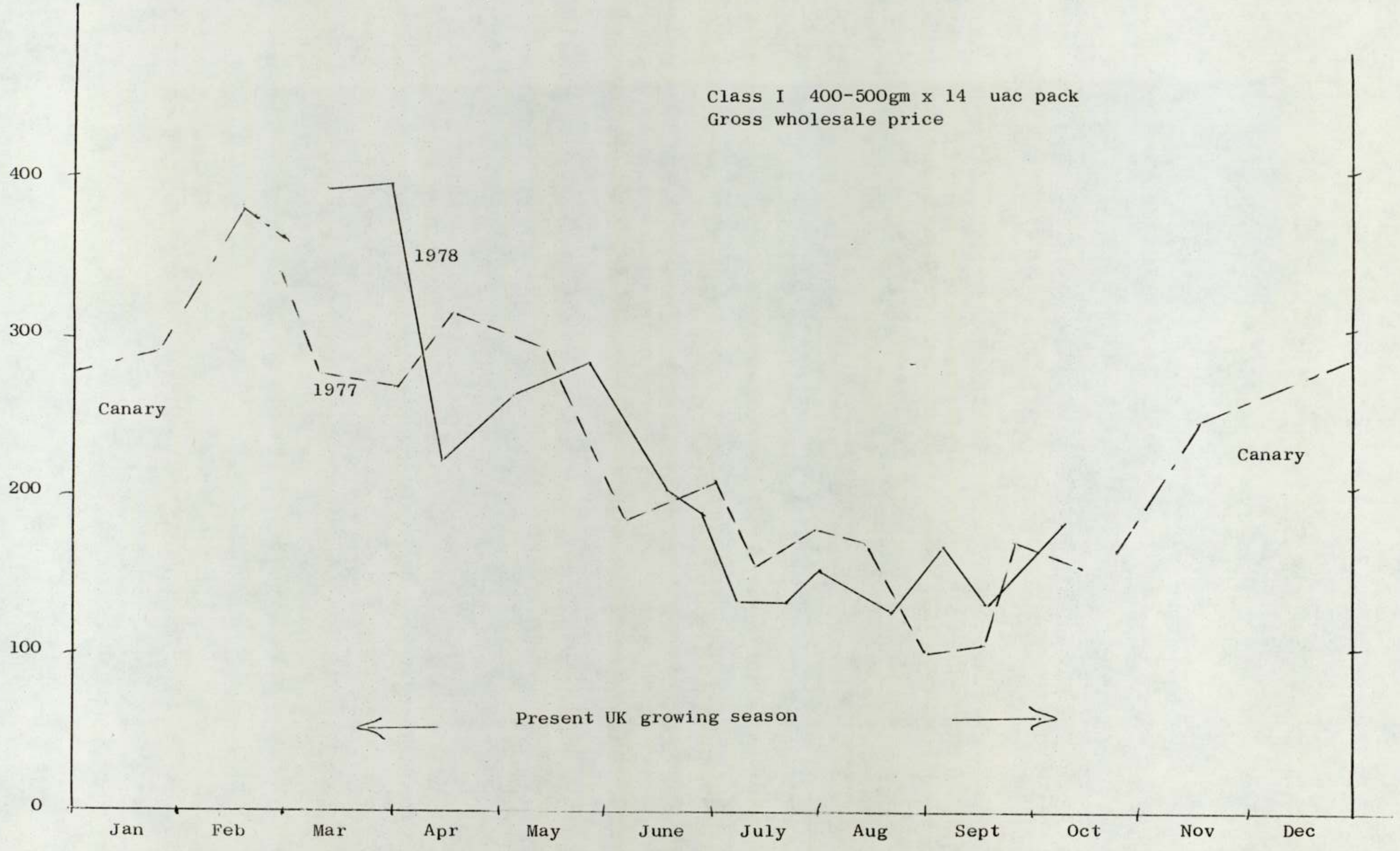
	1975			1976			1977			1978 (Forecast)		
	000t	£m	£/t	000t	£m	£/t	000t	£m	£/t	000t	£m	£/t
Tomatoes	121.6	33.0	271	127.7	40.9	320	123.2	46.4	377	133.4	52.8	397
Lettuce	35.1	16.3	466	30.1	17.4	578	35.7	21.0	588	35.1	22.3	635
Cucumbers	46.9	9.6	205	51.9	13.6	262	51.0	13.2	259	55.8	13.6	244
Others	7.6	2.4		9.7	3.3		11.9	4.3		12.8	4.5	
(Ornamentals)		39.5			43.8			48.8			54.3	
TOTAL		100.8			119.0			133.7			147.5	

Appendix E2 Tomato prices 1977 and 1978



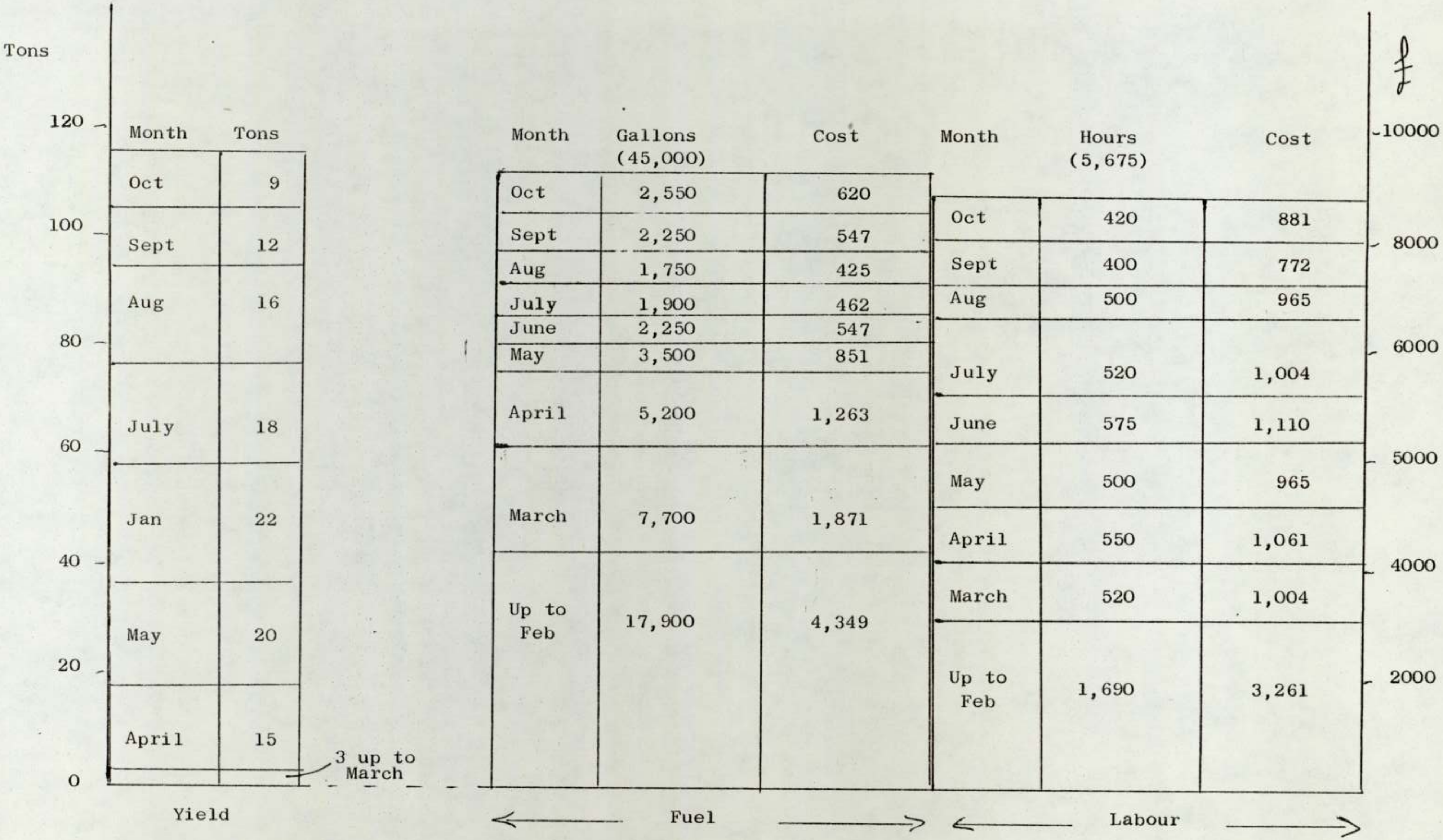
Appendix E3 Greenhouse lettuce prices 1976 - 1978




Class I 400-500gm x 14 uac pack
Gross wholesale price
400
300
200
100
0
1978
1977
Canary
Canary
Present UK growing season
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec

Appendix E5 Monthly yields plus fuel and labour costs for 1978

A heated tomato crop - source: the 'Grower'



Month	Tons
Oct	9
Sept	12
Aug	16
July	18
Jan	22
May	20
April	15

Month	Gallons (45,000)	Cost
Oct	2,550	620
Sept	2,250	547
Aug	1,750	425
July	1,900	462
June	2,250	547
May	3,500	851
April	5,200	1,263
March	7,700	1,871
Up to Feb	17,900	4,349

Month	Hours (5,675)	Cost
Oct	420	881
Sept	400	772
Aug	500	965
July	520	1,004
June	575	1,110
May	500	965
April	550	1,061
March	520	1,004
Up to Feb	1,690	3,261

Appendix E6 Fully heated tomatoes

A greenhouse grower's cost structure

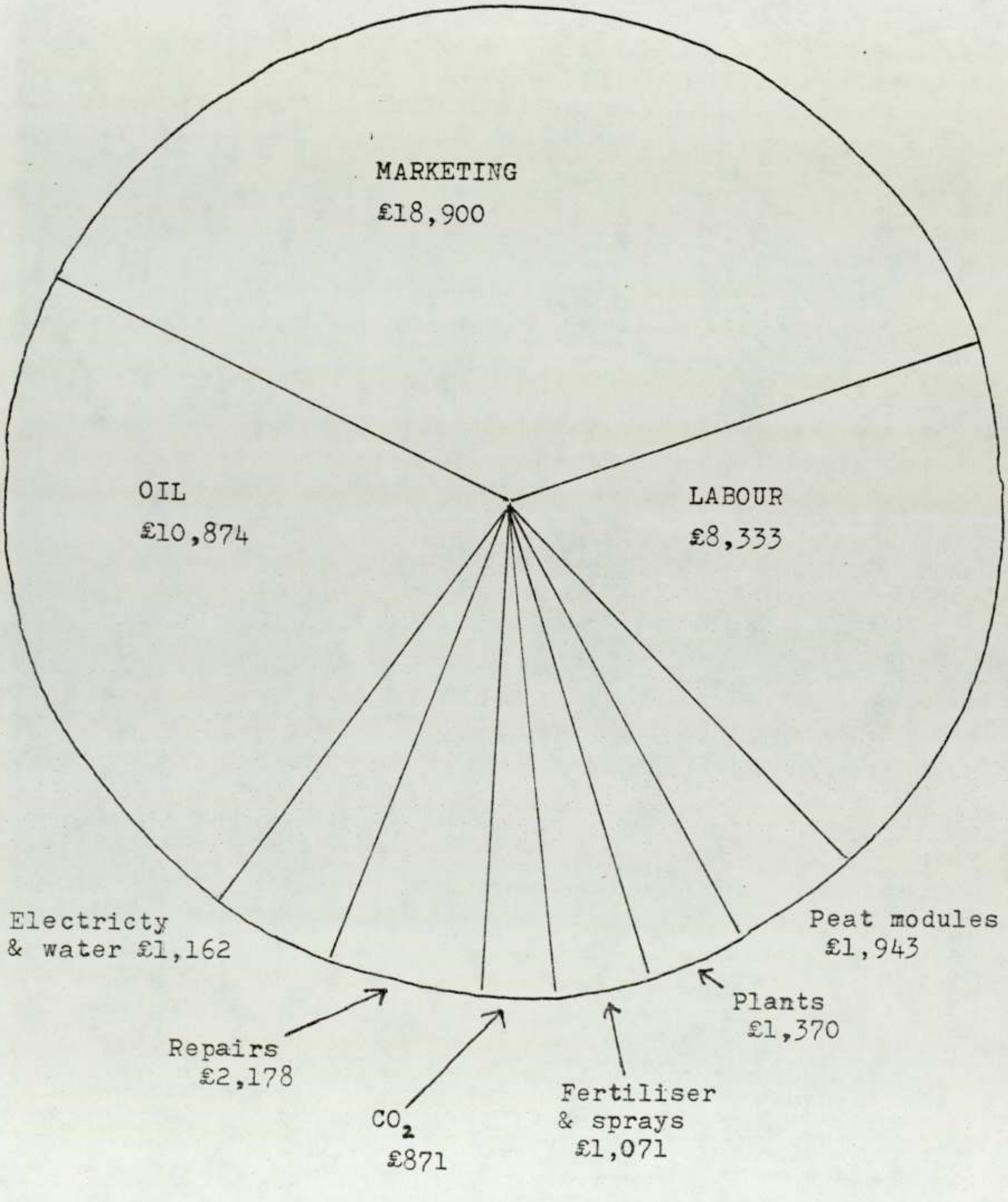
Averaged 110t/acre between March and October

Southern England	1976		1977		(Estimate) 1978	
	£	%	£	%	£	%
Returns	46,000	100	50,000	100	55,000	100
Marketing Costs						
Packing	1,748	3.8	1,850	3.7	2,145	3.9
Haulage	782	1.7	1,250	2.5	1,925	3.5
Net Returns	43,470	94.5	46,900	93.8	50,930	92.6
Variable Costs						
Seasonal Labour	2,400	5.2	2,500	5.0	3,250	5.9
Plants etc.	4,370	9.5	4,900	9.8	5,335	9.7
Fertilizers	1,334	2.9	1,550	3.1	1,760	3.2
Sprays etc.	368	0.8	400	0.8	440	0.8
Heating Fuel	8,900	19.3	10,300	20.6	10,800	19.7
Gross Margin	26,098	56.7	27,250	54.5	29,345	53.4
Fixed Costs						
Regular Labour	8,500	18.5	9,900	19.8	10,900	19.8
Machinery, Fuel Costs	3,036	6.6	3,000	6.0	3,245	5.9
Depreciation and Repairs	2,300	5.0	2,500	5.0	2,750	5.0
Rent and Rates	598	1.3	600	1.2	770	1.4
Business Overheads	2,300	5.0	2,500	5.0	2,750	5.0
Net Margin	9,364	20.4	8,750	17.5	8,939	16.3
Salaries	2,000	4.3	2,200	4.4	2,420	4.4
Man and Inv Income	7,364	16.1	6,550	13.1	6,519	11.9
Tenants Capital	60,260	131	65,500	131	72,050	131
(Note : figure for capital invested is an approximation)						
Return on Inv	15.6%		13.4%		12.4%	

Sources : (2.20), (2.24), (2.25), (2.26), (2.27), and the Grower.

Appendix E7 Costs of production for tomatoes in relation to cost of marketing per acre

(Estimated by States of Guernsey HAS)



APPENDIX F

Firms marketing hydroponic equipment and/or services

The UK

		Equipment/services
Soil-less Cultivation Systems Limited, 46 Birchett Road, Aldershot, Hants.	Tel. 310100	A range of equipment and services for NFT.
T.H. Baggaley Limited, Zephyr House, Waring Street, London.	Tel. 01 670 2258	NFT control panal.
R. Crane and Co. Limited, Abbotts Ann, Andover, Hants.	Tel. 355	NFT control panal.
Imperial Chemical Industries Limited, Plant Protection Division.		Proprietary NFT feed Consultancy service.
Fisons Limited, Horticultural Division.		Proprietary feed.
Interlates Limited, Gladden Place, Skelmersdale, Lancs.	Tel. 33535	Proprietary feed NFT channels.
ISC Irrigation Limited, 5 Finchan Close, East Preston, Littlehampton.	Tel. 3835	Range of equipment and services for NFT.
Marfani Agricultural Limited, Dalton Street, Manchester.	Tel. 061 205 4333	Offered a range of NFT equipment and services.
Nutriculture Limited, (a division of Chandos Limited), Sandy Lane, Maudesley, Ormskirk, Lancs.	Tel. Rufford 822536	Range of NFT equipment and nutrients.

Appendix F cont.

Nutrient Film Cultures Limited, 109 Gloucester Place, London.		NFT consultancy service.
F.D. Stapley Limited, High House Farm, Kenardington, Ashford, Kent.	Tel. Ham Street 2006	Range of NFT equipment and services.
Rossell Fluid Control Limited, Mead Lane, Lydney, Gloucs.	Tel. 2190	Range of NFT controls, tanks and pipework.
Polybuild Limited, Bayfield House, White Hart Street, Aylsham, Norfolk.	Tel. 4155	Offered a range of NFT equipment.
Telcon Plastics Limited, Farnborough Works, Green Street Green, Orpington, Kent.	Tel. F. 55685	Offered a range of NFT equipment.
Universal Packaging Limited, Bulwer Avenue, St. Sampson, Guernsey.	Tel. 46273	Bilaminate polythene sheeting used for NFT channels.
Hago Products Limited, Shripney Road, Bognor Regis, Sussex.	Tel. 3131	A variant NFT channel.
Trough Track Systems Limited, Mead Lane, Lydney, Gloucs.	Tel. 3024	A pot plant NFT system.
Le Huray Limited, Jersey.		A range of NFT equipment and services.
Wilco Heating Limited, Manchester Street, Hull.	Tel. 28892	Are interested in offering a range of NFT equipment and services.

There are several small UK firms marketing domestic hydroponic units.

Appendix F cont.

The USA and Canada

Ball Agricultural Systems Inc., P.O. Box 1034, Boulder, Colorado.	Range of aggregate equipment and services.
Canadian Hydrogardens Limited, 411 Book Road West, Ancaster, Ontario.	Range of aggregate and NFT equipment and services.
Hothfield Investment Inc., 65 King Street, Lindsay, Ontario.	Range of aggregate and NFT equipment and services.
Hygroponics Inc., 3935 N. Palo Alto Avenue, Panama City, Florida 42305.	Range of NFT equipment and services.
General Electric Co., Court Street, Syracruse, New York.	NFT growing rooms and factories.
General Mills Inc., Golden Valley, Minnesota.	NFT growing factories.

In addition there are several commercial growing companies with a capability to provide NFT equipment and services.

Appendix F cont.

Australia

Hygro Hydroponics,
Nerang,
Queensland.

Equipment supplies.

Glencairn Hydroponics,
RSD Huntly,
Nr. Berdigo,
Victoria.

Equipment supplies.

There are several commercial growers which may be interested in equipment and service supplies.

Holland

Rockwool Lapinas,
Industrie Weg 15,
Roermond.

Rockwool suppliers and consultancy.

Austria

Industrieanlagen fur Pflanzerbau,
Rotenturmstrasze,
Wien.

The ISOSC list of members includes possibly another 100 firms in Europe, America and Australia who are seeking equipment and service sales.

Appendix G

Report to management discussing the order processing system of SCS Ltd

Objective:

To identify restrictions in the order processing system and make recommendations to overcome these.

Summary:

Restrictions occured in technical information flow from the quotation stage to the calling-up and purchasing stages. Other restrictions of costing, cash flow, transportation and installation are mentioned.

Contents:

REPORT TO DUNLOP MANAGEMENT DISCUSSING THE ORDER PROCESSING SYSTEM OF SCS LTD.

1. Systems Within SCS Ltd. Until November 1978

1.1 Key costs and resources of SCS Limited

Costs

It was evident that some cost areas were causing concern, notably:

(i) Stock levels were inadequately controlled. Over 500 parts were required for the systems available to the customer

(ii) Travelling and transport expenses mounted quickly for collection, delivery, servicing, installation and co-ordination. Motor vehicle hire became costly.

(iii) Casual labour and sub-contracting costs accumulated.

(iv) Costs allocated to R & D were large.

(v) 'Invisible costs' derived from the inadequacies of the premises, notably the poor warehousing space and lack of a suitable loading wagon which often meant double handling.

Management time spent adjusting the situation drew attention from other priorities. Ensuring that order requirements met deliveries from suppliers was a prime concern and that these agreed with received invoices.

Adequate control and allocation of costs to each order was time consuming and hence mark-up judgements for the selling price could not accurately reflect the true cost of sales.

Competitive bids from other supply companies and the desire to ensure that the customer would not buy direct from manufacturers selected components of the NFT systems influenced the final invoiced delivered.

The lack of a full time accountant who understood the business hence largely prevented the company from achieving the desired profit.

Resources

It was not underestimated how important the hard work, flexibility, innovative design and management abilities of the staff were in achieving a successful completion of various NFT systems.
The fact that customers included ICI, Fisons and important prestigious installations reflects SCS's edge over their present competitors.

The remainder of this chapter details more usefully the lessons learnt from the most recent selling season. It is important now to add that items such as pricing decisions, improved cost control and the re-siting of premises are being acted upon in the 'quiet period' from April to July this year.

1.2 Existing design, quotation and order processing methods in 1978

Design

Apart from small domestic 'Hydropod' systems each 'commercial project' demanded a site survey so that specifications of equipment type could be drawn up. Visits by M.A. Anselm/C.J. Long to the grower/manager served also a sales function essential in the early stages of NFT acceptance.

Each project was tailored to the individual grower which meant no two projects were the same. The difficulties caused by modifications in design for order processing were recognised and standardisation for some items, e.g. pump manifolds were being sought.

To improve design drafting by V. Stent a 'Technical Information Analysis Report' was devised by SCS in December 1978. This form itemised project requirements under the following sections.

(i) General details
(ii) NFT greenhouse spec
(iii) NFT crop spec
(iv) Services - water
(v) Services - electrical
(vi) Services - nutritional
(vii) Design and equipment spec
(viii) Delivery
(ix) Installation
(x) Maintenance contract.

In addition a sketch layout and comments could be added.

The formal recording of project information is essential to provide a common/master working document which can afterwards be filed.

Equipment drawings and schedules were until 1978 composed for each project absorbing man hours and creating a library of part specifications. Hence, a catalogue of 'part sub-assemblies' or 'PSAs' were being compiled; examples are shown in Appendix H.

With each 'working document' (described under 'order processing') was to be enclosed, photocopies of the relevant PSAs in addition to a copy of the 'quotation' (or order), plus a 'progress sheet'.

Quotations

This document was the only one sent to the prospective customer. It was carefully laid out into several sections which summarized the equipment to be used and quoted a price for each section. Most quoted customers accepted the package in full indicating the success of this method.

The quotation sections are linked to Section 7 of the TIAR form (see 'Design') and fall into:

1. Hydrocanal and accessories
2. Pumps and manifolds
3. Nutrient pipework
4. Monitoring and dosage equipment
5. Central control console

6. Delivery
7. Installation.

When required alternative specs. (denoted by A) were added. A contingencies section for terms of payment (usually third on order, third on installation, third in two weeks) may be added.

Order processing

This involves the implementation of the functions needed to turn the quoted design into the completed hardware. Many complex orders necessitate a systematic follow up where possible. To avoid confusion between staff on different orders, part description etc. an efficient and effective administration is required which was still evolving in SCS through the most recent selling season.

A flow chart had been prepared by C.J. Long in October 1978 to show the decision process required in progressing an order (see Appendix H). Around this framework an operable staff function and administrative system can be created. Section 2 attempts to identify the requirements and problem areas experienced by SCS in order processing.

2 Order Processing

2.1 Introduction

Initial attempts by the author to progress existing orders met with several difficulties some of which could be expected by any newcomer to SCS and order processing. An understanding had to be built up of the individual staff, products, suppliers and environs of the firm.

On retrospect the author can identify several functions which required rationalizing within SCS. Rather than providing simply a narrative account of the business operations of SCS, first the requirements of each function is examined (Section 2) and then the problem areas are discussed (Section 3).

The more effective the control function is, the lighter should be the load on the order processor. Hence it is implicitly evident that control mechanisms were needed in SCS, and therefore recommended on three levels i.e. administration, accounting and verbal, summarized in Section 3).

2.2 Stock control

Over 500 parts may be called for in the various designed NFT systems. In addition swimming pool hose and electrical conduit in a range of sizes was stocked for sale during the 'slack summer months' to boost revenue. Warehouse space was no greater than 3,000 square feet; parts were often stacked up to 9 feet high.

A stock card system had been tried and abandoned. Staff relied on memory and visual assessment.

During November 1978 every stocked part was itemised onto stock cards as exampled in Appendix H in an attempt to gain a better foundation from which requisitions could be made. Additionally costing of stock levels and turnover could aid the audit, accounting, and management functions. It was hoped to pre-empty future shortages of parts for the assembly of orders by improving the purchasing function.

Tight cash flow meant that no parts were ordered for stock and only for orders on hand until early 1979. Staff shortage had further inhibited this process.

Stock was divided for convenience into 17 sections but could not be adequately tially separated. About 30 parts took much of the warehouse space and high value small parts such as electrical and UPVC fittings were stored upstairs where possible. However, these and other items could not be adequately allocated to work in progress without a full time stock controller. It proved too much to expect assemblers to stop their work to provide accurate written records (on stock cards or notepads provided).

A major difficulty was that the description of parts by different individuals varied. A code system was considered but believed inoperable in the on-going situation; this compounded by the necessary design variations. 'Incomplete' lengths of pipe etc., dimension ranges and part deliveries are other problem variables.

Because parts for orders could not be spatially separated until immediately prior to despatch the 'complicated' stock card (exampled in Appendix H) was in use. Spatial separation would enable the straightforward 'in-out' card system which experience proves highly desirable. A greater turnover expected warrants a 'bin system' for small parts, e.g. UPVC fittings.

Great effort is justified to reduce (and standardise) the number of part specifications even if occasionally it incurs extra equipment costs. The latter would be recouped in man hours plus the improved order processing, base stock levels and discount possibilities.

2.3 Requisition and procurement

During the most recent selling season this proved a major bottleneck. Prior to November 1978 there was no formal requisition form and hence apart from the purchase orders no record of parts requisited. A notebook of SCS order numbers and a brief note of each order's content was used to 'back-check'.

This created problems when a purchase order included parts allocated to several projects, if amendments to purchase orders had been made or possibly if the notebook was mislaid.

The warehouse assemblers used an'ad hoc' system of reminding management that purchases for individual parts were necessary, or if they had been purchased that they had not, or only in part, been delivered to SCS. Delivery advices were not utilized effectively so that the book-keeping function was inhibited.

Individual requisition sheets appeared unwanted since detailed part descriptions would have to be written out again (i.e. in addition to the quotation, drawings and schedules). Other information necessary for procurement would be needed ideally to make a document which would be truely 'working' and from which not only the purchaser but also a responsible secretary could understand the 'state of procurement'. This could finally be filed for management reference purposes alongside the project TIAR (see Section 1.2).

As an essential aid to order processing the 'progress sheet' was replaced by the 'requisition/procurement' sheet in November 1978 (Appendix H). The principle was for the designer/assembler or order processor to list the parts schedule from the project's inception. Common PSAs could be briefly identified since copies of these should be readily available (i.e. secured to the notice board) in the warehouse office and assembly area.

The R/P sheet plus further necessary drawings then forms the working documents filed on a bring forward basis on the warehouse desk. Brief management meetings here would allocate project responsibilities to the warehouse staff and help 'iron out' problems.

The stock control function could then indicate in adjacent columns whether parts were in fact to be purchased. Order processing could ensure correct purchasing plus checking that deliveries to SCS had been made, (in full or in part, and on time) and who would be the people associated with the project.

Duplication of schedules and requests for modifications or purchases should be drastically reduced if the R/P sheet was treated with import. A modified version (see Appendix H) was introduced in February 1979.

Delivery advices when checked against goods received and purchase orders (including reference numbers) on the R/P sheet will serve as a much needed stock control, order processing, purchasing and book-keeping tool respectively.

A total list of parts derived from the stock cards can also be used for management accounting, designing and 'call off' purposes.

2.4 Fabrication and assembly

This and Section 4.2.5 comprise the hardware implementation function. In November 1978 there were only two full time 'warehouse staff'. The functions required of them were basic toolroom skills and the flexibility to arrange transportation and manage on-site installation from specifications. This therefore included hard work and the uncommon skills of co-ordinating 'in-house' assembly to overcome problems 'in the field'.

By January 1979 an electrician, MW, (originally contracted in by SCS to wire-up control consoles in November 1978) was employed on a full time basis. This enabled specialist attention to an increasingly important product and services area.

Hired labour during the peak selling season was directed to straight-forward assembly, driving and installation tasks which created some over-timing difficulties. Because each project had important, if small, modifications one of the two warehouse technicians or suitably informed staff werealways required. Misunderstandings could be reduced by ensuring the working documents are amended.

The Hydrocanal folding machine was troublesome and expensive (in man hours, waste, heating) to operate. Additionally, imported 1500 gauge black and white plastic had to be prepared (cut) and triple handled. Although expected to last 3-5 years, some slitting problems were encountered after only one season in the greenhouse.

Particularly on large projects the site foreman needs to arrange the priority of installation which could usually be as follows.

Table A <u>Priority of installation for a 1 acre ground (150) NFT (Hydrocanal) system</u>

1. Ensure adequate access to the site for lorry and/or direct delivery by suppliers and storage.
2. Ensure (a) ground levelling; (b) tank and catchment trenches.
3. Install mains and/or nutrient header facilities.
4. Install (a) catchment tank; (b) catchment pipes.
5. Ensure water and electrical supplies.
6. Install (a) pumping system; (b) control console.
7. Install nutrient supply pipework.
8. Install gravel or concrete if used.
9. Layout canal system in line with overhead wires, heating system and paths.
10. Install (a) catchment connectors; (b) supply pipettes; (c) slide end caps.
11. Start up and commission.

The commissioning agreement can include visits (servicing) by SCS staff and be linked to the terms of payment and an after sales analysis, advisory and supply service.

Layflat NFT canals cost a quarter so the heavy gauge Hydrocanals will be phased out except for specialist uses overseas, e.g. high u/v levels.

The management and assembly of metal and plastic fittings should be recognised as a vital skilled function with the increasing system complexity. With increasing turnover this prime responsibility should be that of one person.

2.5 Delivery and installation

During the recent selling season about 60% of the equipment was delivered to the customer by van or lorry hire. About 39% was sent by standard freight or post whilst very little (1%) was collected by the customer. (However SCS collected possibly 25% of the incoming equipment from suppliers.)

Dimensions and weights of packed goods should be recorded on the freight documents and referenced with the order number on the R/P sheet. When equipment is delivered 'loose' to site for installation the R/P sheet should be used as a checklist and the customer asked to sign a delivery advice referenced to the quotation (with any amendments). Such administration should reduce chances of incorrect supply and unaccounted (paid for) journeys. It may also reduce the need for lengthy 'conditions of sale'.

Installation charges by SCS must be conditional on the customer having suitably prepared the site to agreed specifications. Prime examples from experience are those of ground levelling and water/mains supply.

Unless elevated, the preparation of an adequate slope can be labour and time consuming if machinery cannot be used (because of greenhouse obstructions). Additionally trench and tank preparation should be surveyed carefully for each site. These three items could comprise a third of the total project cost.

3 Recommendations for problem areas

3.1 Order processing system

Directional, checkable and feedback systems are sought which are tailored to the unique business of turnkey NFT systems. With a turnover of possible £5 million SCS may be considering a computer aided information system which could be built on an existing manual administrative system. A 'directional management information system', i.e. 'working documents' can be based on the R/P sheet proposed in Section 2.3 and exampled in Appendix H.

Additional information may be added to the R/P sheet, e.g. man hours spent on fabrication. The prime concern of the reviewed order processing system presented in Appendix H is to promote accurate completion of the hardware NFT systems on time. It can be the practical and simple 'cybernetic' basis for an expanding turnkey operation.

3.2 Cost of sales

Section 1.1 identified some high cost items for SCS all of which could not be directly apportioned to any particular projects or overhead requirements. They are however accounted for as 'overheads' rather than variable (direct) costs which, more specifically, they are.

It has been argued that some costs, particularly in man hours per order (project), could be reduced by implementing a revised order processing system. A R/P sheet could give additional information for allocated the reduced variable (and possibly direct) costs to items of sale. In other words the true cost of sales could be more accurately extracted than by the existing estimates.

Although not every order will warrant a thorough cost analysis, it is argued that sample cost of sales exercises could be an effective management, design and accounting control measure, particularly with increased turnover. (Such a measure could be extrapolated to check-up against the annual audit.)

An estimated cost structure was built up by SCS staff in early 1979 and is summarized in Table B . According to the Profit and Loss account however variable costs if apportioned would probably have absorbed all the contribution at that time.

Table B. An estimated cost structure for 1 acre of NFT systems by SCS Limited in early 1979

	Ground		Elevated	
	Disposable	Non Disposable	Disposable	Non Disposable
Best current cost	3,512	4,707	10,313	11,508
Direct labour cost	292	388	292	388
Direct cost of sales	3,804	5,095	10,605	11,896
Selling price	6,037	7,750	16,980	18,693
Contribution £	2,233	2,655	6,375	6,797
Contribution %	37.00	34.26	37.54	36.36
% mark-up	58.7	52.1	60.1	57.1

A buying exercise is underway and the sales prices are being reviewed in 1979.

3.3 Suppliers

Some of the suppliers mentioned in Section 2.2 produced problems of late delivery and in a few cases, where SCS was solely dependent on tailor made equipment, orders were held back. Two areas, those of special plastic fitments and electrical control equipment would be candidates for in-house fabrication. The first is already under review and the second is the topic of Section 2.4.

Volume purchase orders appear desirable for reasons of delivery, discount and more suitable equipment. An important latter case is that of the nutrient supply pipework. At present some of the system is over specified because purchase orders for 'thinner' pipes would have to be of a certain minimum volume. Additionally, cheaper 'fir tree' fittings could then be used.

Early requisition and purchase orders when an order is received will cut down the 'lead time' before fabrication and assembly can begin; this is one purpose of the R/P sheet. Additionally it required that purchase invoices received can be matched to purchase orders and then cleared through accounts; in the last selling season delay in payment of suppliers (cash flow problems) hindered incoming deliveries.

3.4 Customers

A lengthy 'conditions of sale' has been drafted by the company to help overcome some of the difficulties which have arisen when the customer accepts (partly or in full) a quotation. Examples have been those of handling and storing fragile equipment or amendments, guarantees and services to the system or before or after commissioning.

In several areas suggestions for improved communication with the customer and after sales service are applicable.

- A checklist, i.e. the R/P sheet plus the TIAR will be a valuable reference.
- Amendments and significant communications are added to the working documents, dated and initialled.

Appendix H1. Summary valuation of allNFT parts (as at 31st December 1978)

Section	Sub Totals
Hydrocanal and accessories	4,869.96
Metalwork	921.05
Pipework	3,558.25
Pumps	1,591.70
Tanks	633.55
Ball cocks etc	1,006.12
Feeds and supplies	436.42
FIP parts (UPVC fittings)	2,509.76
Other UPVC parts	395.35
GF parts (UPVC fittings)	318.22
Durapipe paets (UPVC fittings)	51.00
Electrical fittings	3,949.74
Timber and miscellaneous	1,438.85
Swimboy	6,439.34
Electroflex	1,657.62
Garden hose	483.22
Total stock value on the stock cards	£30,290.13
Appendix items not on stock cards (Redundant stock)	384.88
Total value of NFT parts on premises	£30,675.01
Work in progress (approximately)	£ 1,518.00

N.B. This was the result of a systematic stock audit.

Appendix H2 Sample NFT part list in the SCS Ltd. warehouse

(as on the stock cards)

	Qty	Unit Price	Valuation
Hydrocanal and Accessories			
Hydrocanal plastic rolls (416mt 9") uncut	0		
HC 1500g plastic 9" variable lengths 200-235mm	41	63.72	2612.52
HC 1500g plastic slit 6" variable lengths	0		
HC formed 9" (standard profile 2") 70-90mt plus	1	20.00	20.00
HC formed 9" (standard profile 2") variable lengths 30-70mt	12	15.00	180.00
HC formed 9" (low profile 1") variable lengths 90 coils	0		
HC formed 9" (low profile 1") VL 70-90mt coils	1	20.00	20.00
HC formed 9" (low profile) 40-70mt coils	1	15.00	15.00
HC formed 6" (standard profile 2") 102mt	34	20.00	680.00
V/W 600g layflat (width 12") variable gusset (180mt)	0		
HC black gusseted 12" width	2	10.00	20.00
HC black gusseted 600g width 9" variable gussets (180mt)	10	8.00	80.00
HC black gusseted 600g width 4" 200mt	6	6.00	36.00
Capillary mat 9" 50mt	202	2.80	565.60
Capillary mat 6" 50mt	7	2.00	14.00
Tie fasteners boxes of 4300	12	14.40	172.80
Tie fastener guns	6	14.25	85.50
Tie fastener needles - industrial	1	0.50	0.50
C. slide end cap 9"	150	4.4p each	6.60
C. slide end caps 6"	10	4.4p each	44
Supply end black polyprop 9"	70	1.20	84.00
Supply end black polyprop 6"	0		
Catchment end black polyprop 9"	15	1.40	21.00

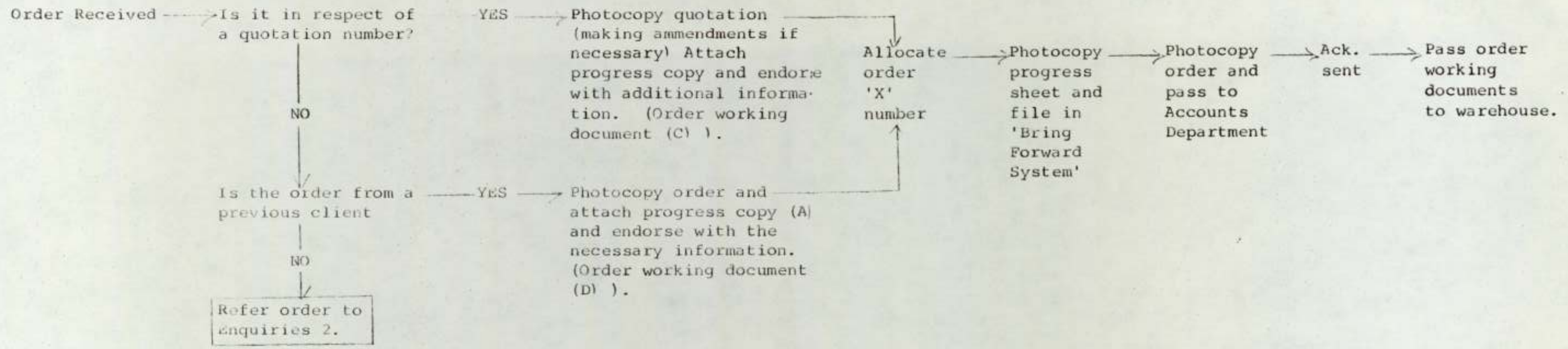
Appendix H3. Two example stock card systems (see Section 2.2)

Example 1. Stock is assigned to individual orders.

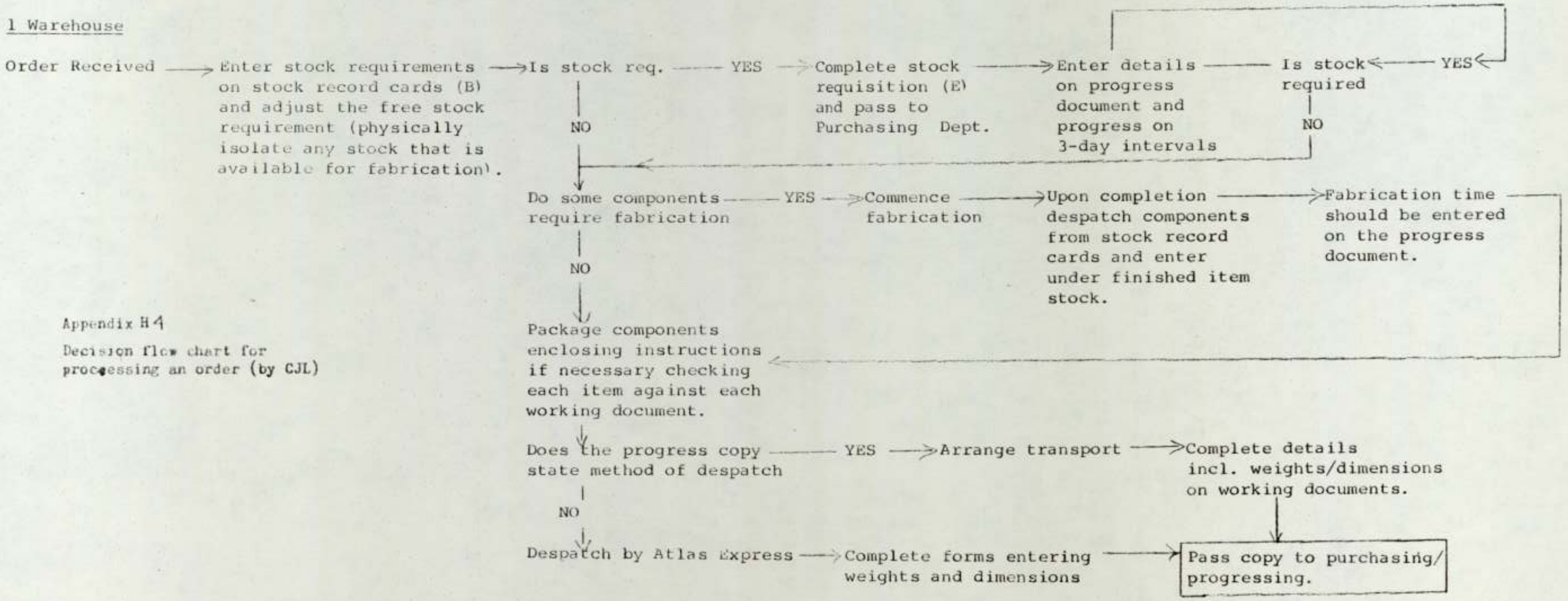
DATE	REFERENCE	O/QTY	DES.DATE	STK.IN	FREE	DESPATCH	PHYSICAL

Example 2. A simple stock record system used when there is little lead time On components.

DATE	REF.	IN	OUT	BALANCE	DATE	REF.	IN	OUT	BALANCE



1 Warehouse



Appendix H4

Decision flow chart for processing an order (by CJL)

Appendix H5 The "R/P sheet"

Order No./Name:

Requisition by:

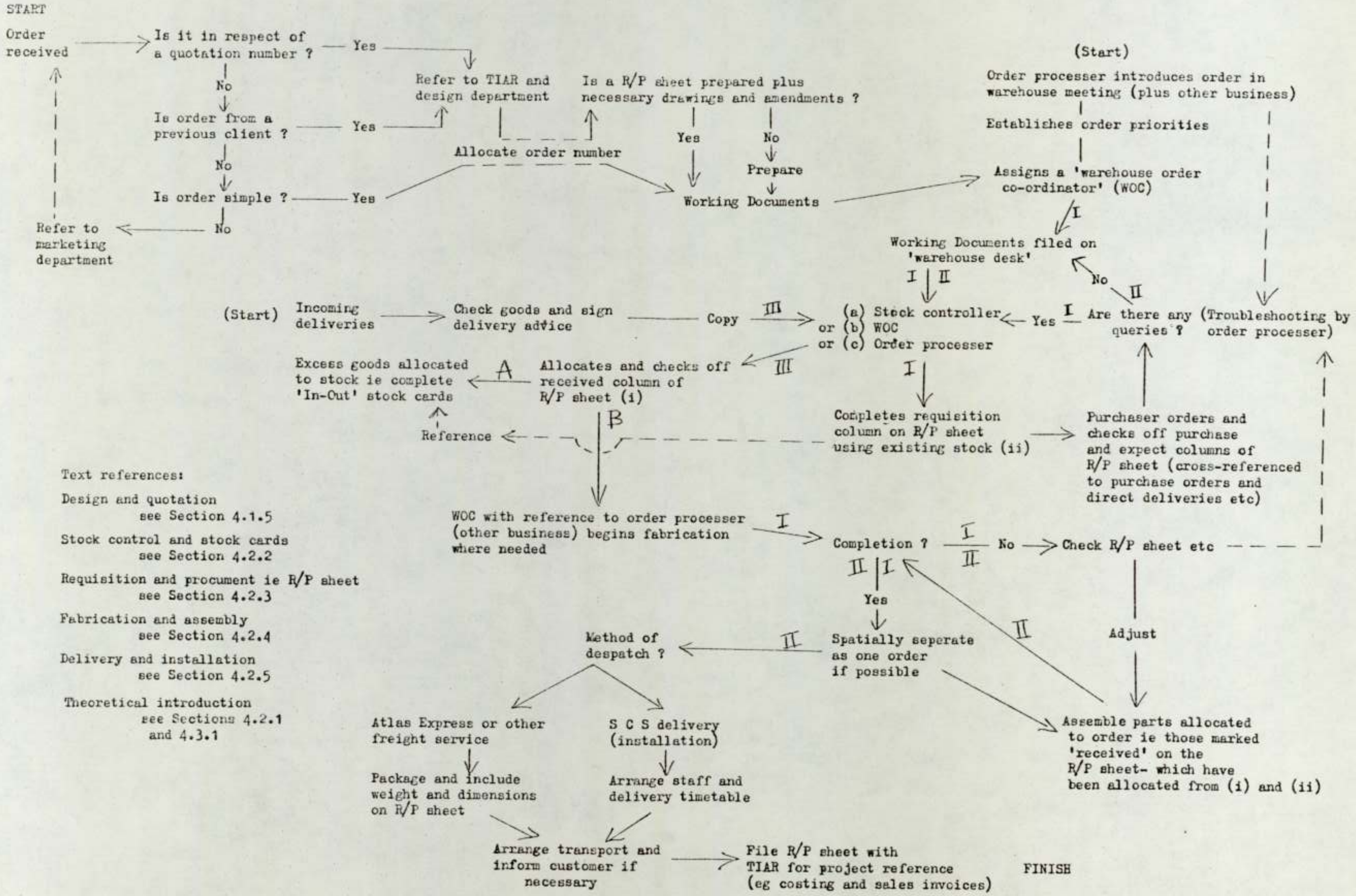
Procurement:

Date of Req.	Quantity	Description/Specification	Supplier (if known)	Date Needed	Confirmed		Purchase Order			Expect Date	Received	
					By	Date	Nº	Date	By		Date	By

Can be continued.

Appendix H 6

REVISED AND COMPREHENSIVE ORDER PROCESSING SYSTEM FOR S C S LTD (JSW)



Text references:

Design and quotation
see Section 4.1.5

Stock control and stock cards
see Section 4.2.2

Requisition and procument ie R/P sheet
see Section 4.2.3

Fabrication and assembly
see Section 4.2.4

Delivery and installation
see Section 4.2.5

Theoretical introduction
see Sections 4.2.1
and 4.3.1

APPENDIX I

A SUMMARY WORLDWIDE SEGMENTATION OF 'COMMERCIAL N.F.T.' AND ITS ACREAGE POTENTIAL OVER 10 YEARS

PARAMETER Y

Micro-environment

Regions mapped in Appendix I

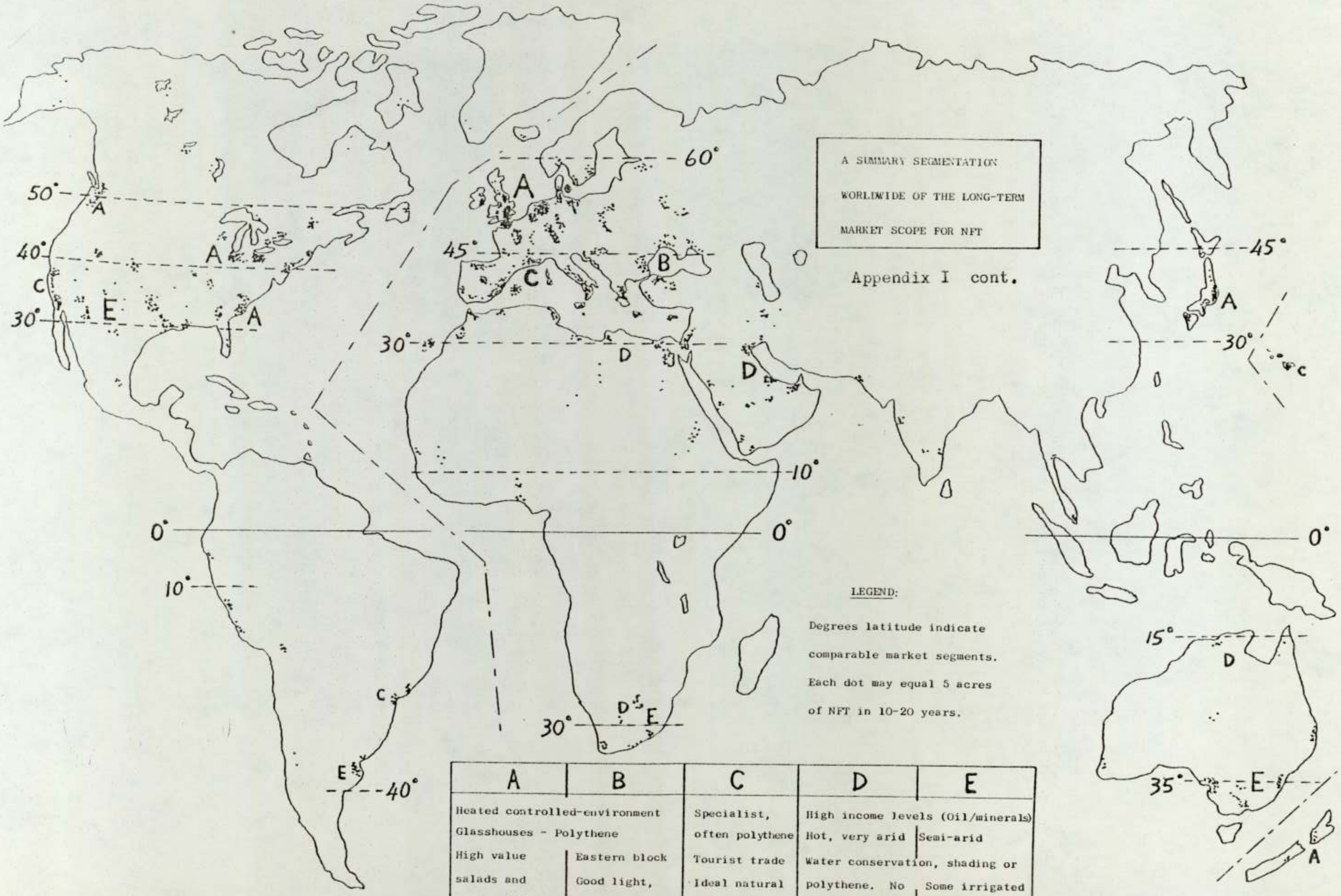
			A (B)	C	E	D		Approx. capital invested (at UK prices) per acre £
Totally enclosed CEH	Oil/mineral rich e.g. Alaska 25	E.g. E. Canada N.Sea oil rigs 20	E.g. N.USA Japan 30	-	-	UAE, Kuwait 5	-	200K
Glass-house CEH	Double-glazed 5	E.g. Scandinavia, N. Great Lakes 300	N.W.Europe 1500 USA Japan 400 300?	-	-	-	-	110K
Polythene CEH	-	20	NW Eur. (East) 300 (200) USA Japan 200 300?	Specialist 200	Water conserving, shading USA Austral. 400 400	Mid-E. 500	-	60K
Polythene	-	-	-	Tourist & Export 500	With irrigated agriculture 100	-	Specialist 20	45K
Semi-protected	-	-	-	Best climates 50	50	-	-	30K
Outdoor	-	-	-	Best Climates 10	-	-	-	20K
PARAMETER X	Frozen	Scandinavian	Temperate	Mediterranean	Hot semi-arid	Hot - arid	Hot - wet	10K

Macro-environment of climate

Increasing light levels ⟶

A SUMMARY SEGMENTATION
WORLDWIDE OF THE LONG-TERM
MARKET SCOPE FOR NFT

Appendix I cont.



LEGEND:

Degrees latitude indicate comparable market segments. Each dot may equal 5 acres of NFT in 10-20 years.

A	B	C	D	E
Heated controlled-environment Glasshouses - Polythene		Specialist, often polythene	High income levels (Oil/minerals)	
High value salads and ornamentals.	Eastern block Good light, variable temp.	Tourist trade Ideal natural climate.	Hot, very arid	Semi-arid
			Water conservation, shading or polythene. No agriculture.	Some irrigated agriculture.

BIBLIOGRAPHY

Section 1 Business studies

1.1 Kotler, Philip
Marketing Management, Analysis, Planning and Control - third edition.
Pub: Prentice/Hall 1976 515p

1.2 Chisnall, Peter M.
Effective Industrial Marketing
Pub: Longman 1977 289p

1.3 Ward, E. Peter
The Dynamics of Planning
Pub: Pergamon Press 1970 323p

1.4 Elliot, K and Christopher, M.
Research Methods in Marketing
Pub: Holt, Rinehart and Winston 1973 180p

1.5 Manual of Industrial Marketing Research
Edited by Rawnsley, Allan
Pub: John Wiley and Sons 1978 196p

1.6 Harper, W.M.
Management Accounting - second edition
Pub: MacDonald and Evans 1977 390p

1.7 Whitehead, Geoffrey
Book-keeping Made Simple
Pub: W.H. Allen 1978 432p

1.8 Diversification via acquisition: creating value
Pub: Harvard Business Review June 1978 22p

Section 2 Background and market references

2.1 Vipond, Stanley and Withers, Bruce
Irrigation, Design and Practice
Pub: Batsford 1974 306p

2.2 Borgstrom, George
World Food Resources
Pub: Intertext 1974 237p

2.3 Ministry of Agriculture, Fisheries and Food
Statistical Information Branch
Epsom Road, Guildford.

2.4 States of Guernsey
Horticultural Advisory Service
St. Martin's, Guernsey.

2.5 Wall, E.T.
The greenhouse industry: a time for reflection on equipment and management
XIX International Horticultural Congress
Warsaw 11-18/9/74 Vol 2 pp 285-294

2.6 Nisen, A.
Glass and plastic greenhouses
XIX Int. Hort. Con. Vol 2 pp 277-284

2.7 Jacobs, J.M. and Meijaard, D.
Economic prospects of protected cultivation
Acta Hort. 1975 No. 51 pp 349-355

2.8 Sheard, George F.
Energy and the future of the glasshouse industry
Presented at British Growers Look Ahead Harrogate 21/2/78 12p

2.9 Driesprong, Cornelius et al
The position of British Horticulture in Europe
BGLA Harrogate 21/3/78 4p

2.10 Hastings, M.R. and Edmond, J.B.
Spreading your labour more thinly 6p
plus,
Watson, R.W.
Labour legislation 11p
BGLA Harrogate 22/2/78

2.11 Cavanagh, R. and Thackeray, D.A.
Altitudes to work training and education in glasshouse crop production.
ATB Research Dept. Report 1977

2.12 Plant tissue culture for the horticulturalist
Several papers presented by Gibco Bio-cult Limited at
Hilton Hotel, Stratford-upon-Avon 23/3/78

2.13 Rice, B.J.
Gas installation shown promise in Efford trials
Commercial Grower 19/6/70

2.14 Wilson, P.N.
Energy inter-relationships in agriculture
Presented at British Association for the Advancement of Science
at Bath University 1978 42p

2.15 Owen, T.A.
Horticultural notes - wind breaks
Gloucestershire and North Avon Farmer Vol. 29 No. 8
August 1978 pp 34-36

2.16 Yaneske, P.P.
A preliminary study for a wind powered glass house heating system
Scientific Horticulture Vol 29 No.4 Summer 1978 pp 158-167

2.17 Richards, Tim
Power on tap from the earth's care
Farmers Weekly 25/8/78 pp (viii)-(ix)

2.18 Holland, M.B.
The CME Energy File
(a) Power from the sun, January 1978 pp 26-32
(b) Sunlight to electricity, March 1978 pp 96-102
Chartered Mechanical Engineer, Special reports.

2.19 Farming may share in £25m energy grants
Farmers Weekly 23/6/78 p 58

2.20 Sheard, G.F.
Overview - Intensive Greenhouse Horticulture in W. Europe
Report from GCRI, England 1977 9p

2.21 Grower Reference Special
Pub: Grower Books 1978

2.22 Turpin, John
Article on peat bag usage
Commercial Grower 13/6/75 pp 1125-1128

2.23 Attenburrow, Derek
Bags are here to stay
Commercial Grower 5/9/75 pp 343-346

2.24. Nicholson, J.A.H.
The Tomato Industry Situation
Wye College 1977 95p

2.25 Hinton, W.L. and Housden, W.C.
Economic results from horticulture 1976 harvest year
University of Cambridge, February 1978 29p

2.26 Fifth symposium on horticultural economics
Acta Hort. No. 77 January 1978 45 papers

2.27 Keeping in touch
A newsletter produced by West Sussex Growers' Association
October 1978

2.28 Sullivan G.H. and Robertson J.C.
Production, marketing and economic trends in the greenhouse
tomato industry 16p
Research bulletin No. 908 June 1974 Purdue University

2.29 Greenhouse Update 1977
American Vegetable Grower special report
November 1977 13p

2.30 McElroy R.G. et al
Economics of greenhouse tomato production in the south east 21p
Economics, statistics and co-operatives service
U.S. Dept. of Agriculture March 1978

2.31 Schippers P.A.
Hydroponics is the Answer
American Vegetable Grower
Vol. 27 No. 2 February 1979

2.32 The new salad factories
Business Week 29/1/79

2.33 Microelectronics: a Scientific American book compiled from
11 articles Pub: W.H. Freeman 1977 142p

Section 3 General Hydroponics

3.1 Douglas, James Sholto
Advanced Guide to Hydroponics
Pub: Pelham 1976 333p

3.2 Woodward, John
Thoughts and experiments on vegetation
Philosophical transactions of the Royal Society of London 1699
Vol 21 pp 193-227

3.3 Gericke W.F.
Aquaculture, a means of crop production
American Journal of Botany 1929 Vol 16 p 862

3.4 International Working Group on Soil-less Culture
Proceedings 1976 at Las Palmas
40 papers
Pub: The Secretariat IWOSC 1977 394p

3.5 Pitcairn, Alan
They're re-making the beds
Farmers Weekly 916178 pp vi - vii

3.6 Zurbicki, Z.J.
Plant nutrition in hydro and aeroponic conditions
Acta Hart 1974 No. 37 pp 2032-2037

3.7 Davtyan, G.S.
The productivity of medicinal, essential oil and condiment
plants grown under open air hydroponics
Hort. Abstracts, Review 1976 Vol 46 No. 8 pp 619-629
(128 references)

3.8 Hill, Jack
Hydroponic vegetables in the Antartic
World Crops May/June 1969 pp 95-98

3.9 Douglas, J.S.
Beginner's Guide to Hydroponics
Pub: Pelham Books 1976 145p

3.10 Thompson, Peter
Vegetable production development in Japan
Paper presented at BGLA, Harrogate 22.2.78

3.11 Seagrave, J.R.
Aquaculture
J. Agriculture in Pakistan 1965 Vol. 16 pp 257-280

3.12 Schwarz, Meir
Guide to Commercial Hydroponics
Pub: Israel Universities Press, Jerusalem 1968 130p

3.13 Schwarz, M and Vaadia, Y
Limestone gravel as a growth medium in hydroponics
Plant and Soil 1969 Vol 31 No.1 pp 122-128

3.14 Stark, J.R. et al
Peat, bark compost and brown coal as a growing medium for greenhouse tomatoes
Acta Hart 1975 No.51 pp 2028;2031

3.15 Beel, E.
Application of artificial substrates for pot plants and azalea
Acta Hart 1975 No.51

3.16 Stern, J.H. et al
Trickle irrigation of chrysanthemum morifolium ramat
Acta Hart 1975 No.51

3.17 Adamson R.M. et al
Amount and kind of growth media in soilless production
Hort Science 1976 Vol.11 No.3 pp 212-213

3.18 Fontes, Miguel R.
Controlled environment horticulture in the Arabian desert at Abu Dhabi
Hort Science 1973 Vol.8 No.1 pp 13-16

3.19 Fontes, M.R.
Controlled environment agriculture in desert regions
Acta Hart 1975 No.51 pp 49-50

3.20 Eisa, Hamdy M. and Jensen, Merle H.
The use of calcareous sand in Abu Dhabi as a growing medium in the sand culture system.
Acta Hart 1975 No.51 pp 89-102

3.21 Qabazard
Report on hydroponic nutrition trial
Ministry of Public Works, Kuwait 1972

3.22 Kharg Environmental Farm
Paper 8p Unknown author or source c 1973

3.23 Douglas, J.S.
World hydroponic congress
World Crops March/April 1970 pp 102-107

3.24 Douglas, J.S.
International Congress on soilless culture
World Crops Jan/Feb 1974 pp 46-53

3.25 Schwarz, M.
Hydroponics pays off
New Scientist 23.6.66 pp 782-784

3.26 Douglas, J.S.
Hydroponic layflats
World Crops March/April 1976 pp 82-87

3.27 Cooper, Allen J.
Nutrient Film Technique of Growing Crops
Pub: Grower Books 1976 33p

3.28 Robinson, Jean
Soil - a thing of the past ?
Gardeners Chronicle 23.7.76

3.29 Furlong, Patrick
A flexible system
Gardeners Chronicle and Horticultural Trade Journal
29.4.77 pp 24-27

3.30 Making NFT commercial
World Crops May/June 1977 pp 125-126

3.31 Maher, Michael J.
Hydroponics for glass house crops
An Faras Taleutais, Kinsealy Research Centre, Malahdie Rd., Dublin
Jan 1977

3.32. Douglas, J.S.
Grass factories for farm and ranch
World Crops Jan/Feb 1970 pp 140-144

3.33. Verwer, F.L.J.A.W.
Cutting and cropping in artificial media
Institute of Agricultural Engineering (IMAG)
Wageningen, Holland, Research report
Jan 1975 7p

3.34 Verwer, F.
Research and results with horticultural crops grown in
rockwool and nutrient film
IMAG, Wageningen September 1977 7p

3.35 Verwer, F.
Grodan information
Rockwool Lapinus Limited, Roermond, Holland
Information leaflet March 1978 11p

3.36. Voogt, S.J. et al
Komkommerteelt op steenwol
Experimental Station for Glasshouse Crops, Naaldwijk, Holland
Information booklet October 1977 38p

3.37 Brooking, I.R.
Soilless potting media for controlled environment facilities
New Zealand J. of Exp. Agr.
Vol.4 1975 pp 203-208

3.38 Orchard, Brian
The Guernsey attitude
Paper presented at the Larch Foundation, Lane End, England
11.4.78 12p

3.39 Rubinstein, Ellis
The engineered tomato
Inst. of Electrical and Electronic Engineers
'Spectrum' January 1978 pp 76-77

3.40 Clarke, John C.
NFT: the effect of solution temperature on the growth and
development of the tomato
Bath University thesis June 1977

Section 4 Horticultural practices

4.1 Epstein, Emmanual
Roots
Scientific American May 1973 pp 48-58

4.2 Fogg, G.E.
The Growth of Plants
Pub: Pelican 1975 290p

4.3 Sutcliffe, J.F. and Baker, D.A.
Plants and Mineral Salts
Pub: Edward Arnold 1974 58p

4.4 Clarkson, D.A.
Ion Transport and Cell Structure in Plants
Pub: Macgraw Hill 1975

4.5 Ware, G.W. and McCollum, J.P.
Producing Vegetable Crops
Pub: Interstate, Illinois 1975 590p

4.6 Mastalerz, John W.
The Greenhouse Environment
Pub: Wiley 1977 629p

4.7 'Greenhouse Crops'
American Vegetable Grower
March 1977

4.8 Shoji, Kobe
Drip irrigation
Scientific American January 1978

4.9 McNeill, E.
Drip for growth and uniformity
Irrigation Journal July/August 1977 pp 26-28

4.10 Bailey, B.J.
Reducing glasshouse heat losses by internal blinds of different materials
National Inst. of Agr. Eng.
Research report 1976

4.11 Electric Growing (and succeeding booklets)
Pub: CEGB March 1972 90p

4.12 Symposium on production of protected crops in peat and other media
Acta Hart No.82 April 1978
30 papers

4.13 Symposium on more profitable use of energy in protected cultivation
Acta Hart No.76 July 1978
50 papers

Section 5 <u>Grower journal of 49 Doughty Street London</u>

(in chronological order. Where an author is not cited the article is produced by the Grower staff.)

5.1 Cooper, A.J.
Rapid crop turn - round is possible with experimental nutrient film technique
5.5.73 pp 1048-1051

5.2 Cooper A.J.
Rapid progress through 1974 with NFT trials
25.1.75 pp 186-118

5.3 Lauder, Kenneth
NFT work at GCRI covers many other crops besides tomatoes
24.1.75 pp 167-171

5.4 Cooper A.J.
NFT culture : Incalculable potential
14.2.76 pp 37-44

5.5 NFT water losses, rose yields and cucumber yields
27.10.77 pp 855-860

5.6 Swings and roundabouts for cucumber costs - Dutch study in rockwool
27.10.77 p 860

5.7 Getting NFT slope right
17.11.77 p 1015

5.8 Lowater, NFT pioneer, crops 120 tons of superb quality
29.12.77 p 1275

5.9 About £$\frac{1}{4}$m to establish a ha of heated glass in Holland
29.12.77 p 1274

5.10 Reducing the size of the fertiliser bill for NFT
plus : Uniform slope gives even film in NFT
12.1.78 p 71

5.11 Dutch rockwool growers use blocks to propogate cucumbers
19.1.78 pp 117-119

5.12 Israeli system has potential to revolutionise field crops - with tissue culture
19.1.78 p 121

5.13 Adams, Peter
How cucumbers respond to variation in nutrition
26.1.78 pp 197-201

5.14 Staunton W.P.
Rapid disease spread fears unfounded in NFT
26.1.78 pp 201-203

5.15 26.1.78 Supplement to journal
pp 1-5 Mulder G. & Boon J.C.
World's vegetable garden

plus

5.16 pp 6-7 Kruyk, Peter
Change in the face of Dutch glass

plus

5.17 pp 8-9 Lawson, Geoff
Computer crops

plus

5.18 pp 11-12 Lawson, Geoff
Dutch use fewer man hours

5.19 Big turnout at LSA Newent open day
2.2.78 p 217

5.20 Minor crop chemicals - what does the future hold ?
2.2.78 pp 239-240

5.21 NFT: Two Jerseymen are committed
2.2.78 p 247

5.22 Part 1 Interview with Gavin Strang, Parliamentary Secretary
16.2.78 pp 330-331

5.23 Lowater, Peter
Disease and NFT
16.2.78 p 372

5.24 Supplement to journal 16.2.78
pp 1-5 Sheard, George F.
A look ahead at the glasshouse industry

5.25 p 13 Where next for tomatoes ?

5.26 23.2.78 p 386
No future for heated glass without new fuel sources
BGLA told by George Sheard

5.27 23.2.78 p 409 Price, D.
Root disorders in NFT tackled by regular fungicide doses

5.28 23.2.78 p 431
Part 2 Interview with Gavin Strang

5.29 16.3.78 p 558
Report puts glass return at £70,000 + per ha

5.30 23.3.78 p 646
Efford aim for NFT 'blueprint'

5.31 23.3.78 p 647
Thermal screen economics

5.32 23.3.78 p 665
Waste heat work

5.33 30.3.78 pp 697-699
Guernsey firm offers new package deal in NFT

5.34 6.4.78 p 735
Up to 20% more cucumbers in rockwool

5.35 13.4.78 p 793
Most glass under 12 years old

5.36 13.4.78 pp 851-854 Accati, E.
Ideal climate, no labour costs, make Kenyan flowers boom

5.37 20.4.78 p 878 Norman, Bob
NFT dropped for rockwool by Yorkshire EHS for cucumbers

538 20.4.78 p 880
Water quality vital for NFT success

5.39 27.4.78 p 937
Tomatoes not right as distillery crop

5.40 27.4.78 p 941
Dutch glass vegetable area up

5.41 27.4.78 p 943
Dutch export more winter lettuce than ever before

5.42 27.4.78 pp 973-975
No doubt about value of thermal screens

5.43 27.4.78 pp 977-979
Growers getting to grips with laboratory production with tissue culture

5.44 27.4.78 p 981
Tomato crops one ton down on last year

5.45 4.5.78 p 995
Gas heating economics look attractive for the moment

5.46 4.5.78 p 1004 Norman, R.O.
Begging the NFT question

Note: From May to December 1978 there were over 50 articles in the Grower discussing NFT and related topics.