SPACE OPTIMIZATION OF GREENHOUSE POTTED FLOWERS IN QUEBEC: A LINEAR PROGRAMMING APPROACH

BY

IBRAHIM TABCHE

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CANADA

ABSTRACT

Space Optimization of Greenhouse Potted Flowers in Québec: A Linear Programming Approach

By Ibrahim Tabche, M.Sc.

Department of Agricultural Economics
Advisor: Dr. Randall Westgren

A linear programming (LP) model is formulated to reflect economic, climatic conditions, and cultural practices followed in the pot flower industry of Québec. The objective is to determine the optimal crop mix that maximizes net returns and optimizes space usage given production and marketing constraints. Decision variables are composed of nine major pot flower varieties with several pot sizes produced for different marketing periods during the year. Data are collected from producers in the Montreal area in 1990, and is supplemented by interviews with ornamental counsellors and citations of governmental publications.

Results have shown that the use of LP as a design tool can be of benefit to ornamental producers and managers in decision making. Increasing the amount and quality of available information to producers can lead to improved decisions that increase production efficiency and space productivity, and thus lead to a more competitive industry.

RESUME

Optimisation de l'Espace pour les Potees Fleuries dans les Serres du Quebec: Une Méthode de Programmation Lineaire

Par Ibrahim Tabche, Maitrise

Département d'Agro-économie
Consultant : Dr Randall Westgren

Un modèle de programmation lineaire tenant compte des conditions economiques, climatiques et pratiques culturales utilisées par l'industrie des fleurs a pots au Quebec est developpe. L'objective est de determiner la combinaison des plantes qui permet de maximiser le revenu net et d'optimiser l'espace utilisee compte tenu donnees des contraintes de production et de commercialisation. Les variables influençant la prise de décision sont composees de neuf varietes de fleurs produites dans des pots de differentes grandeurs pour des plusieurs periodes de commercialisation durant l'annee. Des donnees ont ete collectees aupres de producteurs dans la région de Montreal en 1990 ainsi qu'aupres de consultants en horticulture ornamentale et par des informations provenant des publications gouvernementales.

Les résultats de cette etude montrent que l'utilisation de la programmation linéaire comme methode de planification s'avère un outil efficace prise de decision par les producteurs de fleurs ornamentales et les gestionnaires. La disponibilite d'informations de qualite amene le producteur à prendre de meilleurs decisions qui augmentent l'efficacite de la production le rendement par unite de surface et qui de fait ameliorer la competitivité de l'industrie.

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LIST OF ABBREVIATIONS

Word	
Kg.	Kilogramme
Lit.	Liter
LP	Linear Programming
Qsb	Quantitative Systems for Business Software
/	Per

CHAPTER 1

INTRODUCTION

1.1 Background

The greenhouse industry is relatively new in the province of Québec. Started 20 years ago, it involves about 1200 producers occupying a total area of 195 ha. of production under glass and plastic. Of those producers, 650 are involved in the production of ornamental plants and occupy 41% of the total area covered with greenhouses in Quebec (Carrier, 1988).

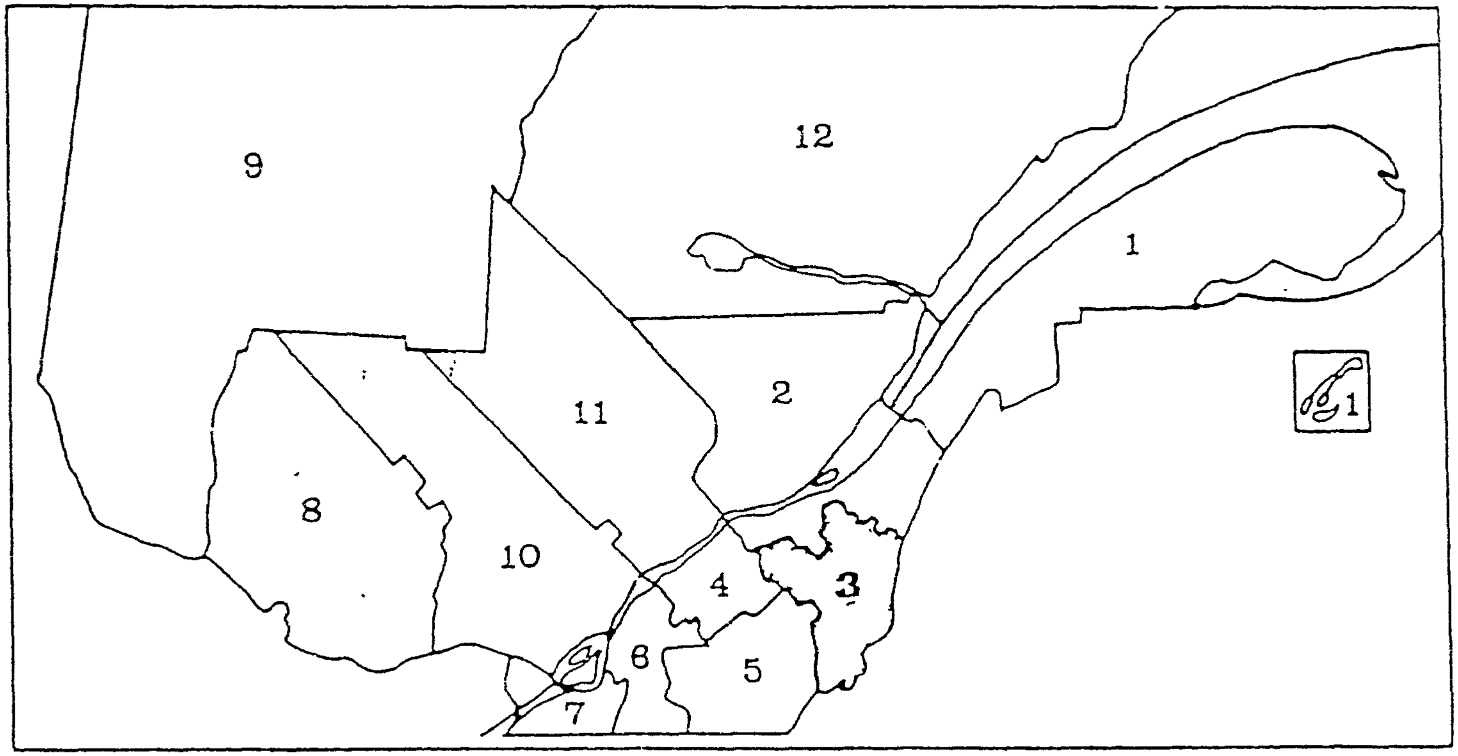
Most of the ornamental production in the province of Québec is concentrated in the area of Montreal, in designated regions 6,7,10 where about 70% of the production area exist (Carrier, 1988). Central Quebec (regions 4,5,11) has 15% of the production area. The agricultural regions of Quebec are shown in Figure 1.1.

Ornamental greenhouse production is divided into several categories: annual (bedding plants), potted flowers, cut flowers, house plants, and bulbs. Annual flowers have the largest covered greenhouse area, whereas potted flowers, with 300 full and partial production enterprises, use a total covered area of 97,000 square meters (Carrier,1988).

In a study published by Agriculture Canada in 1984, titled " La Rentabilite des Productions Serricoles au Québec", the problems facing greenhouse producers were quoted by Lebeau (1984a) as follows,

> **"I consciously simplify the problems of greenhouse producers into three main points : 1) Weak plant productivity per unit area, 2) Very high global consumption of labor, 3) Very high heating costs." (Lebeau, Universite Laval, 1984, p.384)**

In addition to the above mentioned problems, producers



1-Bas Saint-Laurent, Gaspésie,
Iles de la Madeleine
Saint Laurent
2-Rives Nord et Sud du
Saint Laurent
3-Beauce, Dorchester, Mégantic,
Frontenac

4-Nicolet
5-Les Cantons de L'Est
6-L'Est de Montreal
7-Sud-Ouest de Montreal
8-Region Agricole de l'Outaouais
9-Le Nord-Ouest Québécois

10-Rive Nord du Fleuve
Saint Laurent
11-La Mauricie
12-Saguenay Lac St. Jean

Figure 1.1: AGRICULTURAL REGIONS OF QUEBEC

Source: "Les Régions Agricoles du Québéc". By Michèle Dumas-Rousseau. MAPAQ.Undated.

also face strong competition from products imported from areas with lower production costs such as the United States, Latin America, and Europe.

These and other problems threaten the future progress and development of this important industry which generated, according to the "Federation Interdisciplinaire de l'Horticulture Ornementale" (FIHOQ), 650 million dollars in total sales and services in 1984 (Anonymous, 1989). As profitable production depends on both technical and managerial skills, improving technical knowledge and the decision making ability of managers and owners could insure long run profitability and business growth.

In other words, some of the possible solutions to industry difficulties include, in addition to the use of improved production techniques and technologies, the application of better managerial skills to improve the quality of decisions. Production decisions include varieties to plant, quantities, pot sizes, and timing of production. These decisions should be driven by the context of market demand, acceptable profit margins, and available production skills. Market demand involves three factors: 1) the plant variety desired for certain holidays and occasions, 2) consumer preference for type, pot size and color, 3) and prices.

The development of the theory and tools of operations research in general, and mathematical programming in particular, have brought a useful and powerful set of decision aids to agricultural production. Coupled with the availability of advanced computer hardware and software, this development has enhanced the ability to solve complex models in decision making. Linear programming, a technique widely used in agriculture, could form the basis for a decision support system for improved decision making in the pot flower industry.

1.2 Hypothesis

It is hypothesized that it is possible to formulate a linear programming (LP) model that simulates the economic conditions and cultural practices followed in the pot flower industry in the province of Québec. The use of the LP model in production design will lead to inferences about production efficiency, optimal product mix, and lower costs.

1.3 Objectives of the Study

The objective of this study is to construct several computer models using linear programming which simulate cultural, climatic, and economic conditions facing greenhouse pot flower producers in the province of Québec. These models will be used to determine the optimal production plan and distribution of greenhouse space among several varieties and pot sizes of potted flowers to maximize profits for different periods during the year including the major holidays. In addition to the optimal production plan, the analysis will include a sensitivity analysis for varying production constraints and prices.

1.4 Scope of the Study

The study is based upon data collected from greenhouse producers in the area of Montreal in 1990. The study concerns the following potted flower plants: African Violet, Azalea, Begonia, Chrysanthemums, Cyclamen, Easter Lily, Geraniums, Hydrangea, and Poinsettia.

A number of single period linear programming models will be built, each representing a different set of production and marketing constraints. Production constraints include availability of labor and space, while marketing constraints include pot size and holiday quotas. Other minor models will include the development of optimum production plans for specific occasions.

1.5 Overview of the Québec Pot Flower Industry

It will be useful to discuss two issues, the effect of climate on practices and market conditions, to reach a comprehensive understanding of the background of the pot flower industry of Quebec. It should be noted however, that although this section will focus on the pot flower industry, most of the discussions would apply to other ornamental production in Québec.

1.5.1 Climate Effect on Production

The cold weather prevailing in the region of Montreal and the province of Quebec in general, relative to the United States and other parts of Canada like Ontario and British Columbia, has discouraged some practices and favoured the adoption of others. Of those practices we can note the following:

1-The production season has been limited or reduced to certain periods of the year of moderate temperatures, since producers were reluctant to provide products at times of year when production costs are high due to high heating costs while imported products, from the United States and other parts of Canada, had easy access to the market.

2-The production of some plant varieties with a long production season like Cyclamen, which requires a period of about eight months, were discouraged for their high heating costs. Consequently, plant varieties with less heating requirements or short production seasons such as Geranium and others, were more popular.

As a consequence of these problems, producers have resorted to the following practices:

1-Several producers have been importing semi-finished plants of several varieties including Azalea and Hydrangea and finishing them in Québec.

2-Producers have delayed their planting dates until early spring to reduce heating costs.

3-Producers grow smaller pot sizes in order to maximize the number of pots per greenhouse unit area. This divides the cost over a larger number of plants.

4-Increasing numbers of producers are using higher levels of mechanization to decrease total operating costs. Production costs will be discussed in more detail in section 3.3.

1.5.2 The Market Conditions

Although few studies have been done on the market capacity to absorb production of potted flowers in Québec, this market is characterized by some distinctive features which affect market size.

1-Season-specific demand : This is shown in the large increases of volume demanded for holidays in comparison to other parts of the year. In fact, several producers have indicated that the demand level at these times, which accounts for 4 to 5 times the regular demand level, exceeds supply and therefore has to be supplemented by imports.

2-Product-specific demand : Demand is for specific products. Some plant varieties are more in demand than others at particular occasions, for example, Poinsettia for Christmas, Lilies for Easter, etc.

Those factors do not lead to stable production and marketing plans.

1.5.3 Market Potential

Several ornamental counsellors interviewed in 1990 believed that the market was not well exploited and that there are two opportunities that need to be further developed. The first is the need to market pot flowers outside holiday periods especially Mums, Poinsettias, and African Violets. This practice is more common in Europe where pot flowers are marketed all year round. The second point stresses the importance of fulfilling the demands of the ethnic communities of Montreal. The presence of these communities which have different tastes and holiday dates, could provide an additional market where producers could fill the demand gap.

1.5.4 Trends in Production Management

As a consequence of the above mentioned climate and market conditions, producers have realized that any effort to increase production has to be coupled with an increased level of efficiency. This could be achieved by two means: the use of advanced cultural techniques and/or by improved management practices. In this manner, several producers have resorted, on a small scale, to advanced technologies such as the application of hydroponic methods, use of thermal blankets, application of carbon dioxide enrichment, and environmental computer control. Such cultural advances have helped to extend production periods and reduced operating costs.

In order to improve their management, producers have resorted to practices that could either reduce costs or increase returns. Some of the practices currently used include continuous production during the summer season even when profit is low. This is justified since it would help to recover some of the winter's high heating costs, maximize the use of fixed cost inputs (plastic cover), and maintain a steady operation inside the greenhouse. The rule, however, is to maintain operation as long as there was a break-even in recovering variable operating costs.

Most producers have realized the importance of improving their decision making ability. The use of computers in the planning and design process, appears to be an attractive option. In the United States and Europe, several researchers have developed decision support systems for production planning in the pot plant nurseries (Gortzig, 1976; Basham and Hanan, 1983; and Saedt and Annevelink, 1988). In Québec, however, computer usage in nurseries, has been limited to word processing and database operations.

Despite the current problems, several producers interviewed were optimistic about the potential of Quebec producers to export to other parts of Canada and the United States with proper management. However, the chances to compete internationally can only occur with an increase in efficiency and productivity.

1.6 Organization of the study

Chapter 2 will present the review of literature on economic studies and linear programming models in the field of ornamental horticulture. Chapter 3 which is composed of 3 sections, will describe the methodology used in the analysis. The first section will discuss the data collection process and calculation of input parameters. Section two will examine the calculation of input production costs. Section three will present a detailed description of the linear programming methodology and will discuss the structures of the models which include the decision variables and constraints. Chapter four will then illustrate and discuss the results of the models described in chapter three. Finally, chapter five will present a summary of the study with concluding remarks and some recommendations for further research.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

This section will discuss the relevant literature related to the pot flower industry in Quebec. The review will be divided into two sections. The first section will review previous economic studies and will describe the conditions of the industry, market capacity, and some previously suggested solutions to the present problems. The second section will cover earlier applications of the linear programming technique in the pot flower industry.

2.2 Economic Studies of the pot flower industry in Quebec

Lebeau (1984a) has indicated that previous economic studies performed by governmental agencies have shown the greenhouse production sector in Canada, and Quebec in particular, to be facing precarious financial conditions. In a study performed to evaluate the profitability of greenhouse production under various floral and vegetable production systems (traditional and modern), using several fuel types, Lebeau concluded that modern production systems using techniques such as hydroponics, artificial lighting, carbon dioxide enrichment, and mechanization of production processes, yielded positive returns in contrast to traditional production practices which were followed by the majority of greenhouse producers in Quebec. The latter practices did not enable producers to repay their initial investment. Furthermore, floral production was more profitable than vegetable production as it has more production options and faces less domestic competition. Improving productivity was the most important factor influencing the recovery of invested capital, even when considering savings made by less expensive fuel types and more efficient fuel systems (Lebeau, 1984a). Traditional greenhouse producers have to rely on external sources of income, whereas dynamic and innovative producers, who use more efficient production techniques, will have a better structured commercial production with lower costs.

Carrier (1984), reported that a study performed by the "Direction des etudes economiques du MAPAQ" in 1982, showed that 56% of producers interviewed attribute problems facing the greenhouse sector to production, while 32% believed that marketing was the main obstacle. Production problems include the high costs of heating and labor which made up 85% of total variable costs. Furthermore, greenhouse workers are characterized by low productivity as they are mostly non-specialized. The harsh working conditions combined with low salaries and seasonal employment did not promote interest in greenhouse jobs, preventing greenhouse workers from reaching optimum efficiency (Carrier, 1984). Marketing problems, on the other hand, varied according to the product type and region. These problems stem from the absence of product quality standards, lack of joint action by producers as only 15% belong to marketing syndicates, and poor dissemination of price information. Solutions include better grouping of producers to maintain a stable product supply with higher concentration levels. Grouping can also reduce the negative effects of imports and unfair competition and practices among producers, produce unified standards in production and packaging, and enhance promotion.

2.2.1 Market Capacity

Carrier (1988) states that although the market is not very large, self sufficiency has not been attained. The degree of self-sufficiency varies for different varieties of pot flower. For example, in 1983 it ranged from a high of 96% for African Violets, and 92% for Geraniums to as low as 31% and 16% for Azaleas and Easter Lilies respectively. Cheap imports, however, might not be the solution. In fact, Carrier reported in 1984 that imports, in many cases, did not respond to the specific quality requirements of the local market. Consequently, a local specialized production would respond better to that.

2.2.2 Suggested Solutions

Several solutions have been suggested to increase the efficiency of greenhouse producers. Carrier (1984), has stressed the need for a better orientation of research in several aspects of cultural practices and technological advances to reduce production costs. However, this has to be coupled with better information and communication among counsellors, researchers, and producers. Increased mechanization, and the use of computers as a decision aid might be an attractive option especially to large enterprises.

Carrier (1984) contends that there would be a future to expand production of several pot flowers such as Geranium, African Violet, Begonias, and others. In 1988, Carrier urged producers to pursue innovations in production and marketing techniques which could lead to expand consumption. In this manner, producers should follow the change in consumers' tastes, or work on consumers attitudes by developing new preferences. This include new colors, pot sizes, and new varieties. In brief, Carrier (1988) believed that, in the pot flower industry, there would always be a future for moderately sized and priced products.

In summary, the literature has indicated that high input costs, perishable nature of the product, and the short and specific marketing periods combined with lack of sufficient expertise, and under-utilization of the greenhouse have led to low productivity in the greenhouse industry. Proposed solutions to increase productivity include the use of increased levels of mechanization and introduction of innovative production and marketing techniques.

2.3 Linear Programming Models

It is essential to start with a brief introduction of linear programming (LP) before discussing previous models. A detailed description of the methodology will follow in the methodology chapter.

2.3.1 Linear Programming: Introduction and Importance

Heady and Candler (1958) have described linear programming as :

" A procedure which provides *normative* answers to problems so formulated. By normative we refer to the course of action which ought to be taken by an individual business unit, area, or other economic sector when (a) the end or objective takes a particular form, and (b) the conditions and restraints surrounding the action or choice are of a particular form." (Heady and Candler, 1958, p.8)

Hazell and Norton (1986) have defined linear programming as " a method of determining a profit maximizing combination of farm enterprises that is feasible with respect to a set of fixed farm constraints." (Hazell and Norton, 1986, p.10). Agrawal and Heady (1972) reported that linear programming falls under the broader category of mathematical programming which also includes nonlinear programming and dynamic programming. However, linear programming has been the simplest and most widely used technique in agriculture. It was developed after the second world war to deal with complex planning and investment problems.

Agrawal and Heady (1972) reported that linear programming has been used in agriculture since its very inception. Heady, in 1954, was the first to apply linear programming in the field of farm management and agricultural economics (Gortzig, 1976). Barker (1964), concluded in a study on the use of linear programming in farm management, that it assists the farmer in decision making by providing quantitative estimates of returns for specified alternatives and levels of resource use. King (1953) reported that linear programming has proven to be one of the most powerful tools for analysis of resource allocation choices at the firm and sector level.

Linear programming is applicable to almost all fields of agriculture where the individual farm is the unit of observation. This includes minimizing cost of feed rations for livestock, and farm planning (optimizing crop rotation plans, machinery use and others). Farm planning was initiated by Heady and Love in 1954 (Agrawal and Heady, 1972). Further applications of linear programming to farm management can be found in Agrawal and Heady (1972), and Rae (1977). Moreover, LP has been used on a macro level to solve problems in agricultural marketing, spatial analysis, and transportation models.

Hales (1972) believed that LP was a valuable technique in horticultural crop production management due to the nature of horticultural businesses, which is characterized by a large number of enterprises, and complex labor and marketing operations. However, Gortzig (1976) reported that LP has been more extensively applied in general agriculture than in commercial floriculture management.

2.3.2 Established LP Models in the Pot Flower Industry

An extensive search of the literature did not reveal any established LP models used in ornamental production in Canada. However, the situation was different for the United States and Europe.

Gortzig (1976) reported that few applications of LP have been developed for floriculture production management in the United States before 1976. Besides some applications by several cooperative extension agents and university centers (Mississippi State and Pennsylvania), the author referred to a single publication by Vaut et al. (1973) who simulated a small family operated flower production enterprise.

This assessment of few applications was shared by Sowell et al. (1982) who referred to an additional model done by Boyd et al. (1982). However other works published after 1982, have been identified. This includes, in addition to the works of Sowell et al. (1982), Basham and Hanan (1983), Lippert (1983), Weston and Schumacher (1983), and Sabota et al. (1987).

In a study on the economics of pot flower space allocation, Sowell et al. (1982) applied linear programming to optimize production management decisions for commercial flower production in North Carolina. Specifically, the intent was to demonstrate the usefulness of the technique as a research tool to examine alternative management schemes. The model included three sets of crops: Chrysanthemums, Easter Lilies, and bedding plants. These crops given different varieties and marketing dates, constituted a total of 881 different decision variables. Resource limitations included availability of skilled and unskilled labor, space availability, market restrictions such as plant type and color preference, and market quotas which included minimum and maximum limits on production as required by contracts and market absorption for both color and type.

Weston and Schumacher (1983) reported that linear programming has a significant future in the floriculture industry due to it's flexibility in accommodating different crops, time periods and market restrictions. A linear programming design was presented to illustrate the application of the technique for a glasshouse production plan. The model focused on how formulation of LP proceeded in both a single and multiple product case. However, the expanded model, containing ten products, assumed that the greenhouse had three physical areas with different night temperatures. The model had to find the optimum crop mix to satisfy temperature restriction and plant movement between the glasshouse compartments along the production year. Weston and Schumacher (1983) believed that the value of the model was in its ability to model crops grown as a function of the night-time temperature and production periods within the year.

Lippert (1983), reported that production planning in pot plant nurseries is often difficult to estimate due to the broad number of production alternatives. Moreover, the problem becomes more complicated if financial consequences of the planning are considered. However, LP had proved to be an efficient tool for solving complex planning problems in pot plant nurseries. Lippert (1983) illustrated briefly the principles of LP and described an example, and concluded that in order for the LP planning to be widely used, it was essential to **"have a good pre-program to build up the matrix, and a post-program so that the LP solution is practical to work with." (Lippert, 1983, p.121)**. In other words, the process of data input and reporting of results should be easily accessible to farmers and other users. Commenting on the work of Lippert, Bloch (1983) concluded that for a production plan to be successful it is necessary to look upon it as an integrated part of the whole farm management plan and not as an isolated part.

Basham and Hanan (1983) found that greenhouse producers specializing in potted plants have one of the most complex scheduling problems in agriculture. Therefore, the use of LP and computer systems is essential for the design of an operating schedule for such enterprise. Basham and Hanan (1983) applied LP to allocate space within a greenhouse to a range of crops so as to maximize profits. They concluded that successful application of this practice depends on the close cooperation between the decision maker and the analyst.

Sabota et al. (1987) concluded that **"successful nurserymen must continually re-evaluate and develop more efficient production methods." (Sabota et al., 1987, p.506)**. In this manner, LP can improve the decision making ability of managers by providing more information to make better informed and up to date decisions. The authors developed multi-period models for three different sizes of nurseries to determine the optimum product mix plan to maximize profits. Constraints included equipment, materials, and labor.

Gortzig (1976), applied the LP technique to study a series of management decisions concerning alternative cropping systems to find optimal crop mixes that maximize profits subject to input availability. Various systems studied included, in addition to pot flowers, single crop systems with several production options for each of Carnations, Snapdragons, Chrysanthemums, Geraniums, and poinsettias. Other systems included cut flowers specialization, bedding plants, and a diversified crops program. It was concluded that the potted crop specialization model ranked second in profitability to the diversified crop program.

Saedt and Annevelink (1988) have reported that a decision support system has been developed in the Netherlands, for pot plant nurseries. This system, which constructs or modifies the production plan by simulation or optimization using LP, is being used by a number of nurseries. The system was considered an adaptive planning system since it takes into consideration changing space requirements, variations in selling prices, occurrences of plant diseases, and delays in inputs supply. Saedt and Annevelink (1988) concluded that the system still had some weak points which included long decision intervals (4 weeks), and other structural issues.

In summary, previous literature has indicated that the use of LP to optimize space use for floricultural products and pot flowers has been an effective tool for the planning process. Moreover, it can increase production efficiency and productivity in the greenhouse industry.

Based on this conclusion, data will be collected to formulate a single period model that will simulate economic conditions and cultural practices followed in the pot flower industry in Quebec. The followed methodology which include the data collection process and the model's components, will be discussed in the next chapter.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This chapter will be divided into four sections. The first section will discuss procedures used to estimate the input data as well as the process of data collection. The second section will present the methodology and assumptions used to evaluate the costs of production which include fixed costs, and variable costs such as labor, heating, and materials. The third section will describe the technical coefficients and assumptions used to build the model, while the fourth section will describe the technique of linear programming (LP) with a detailed description of the pot flower LP model and it's components.

3.2 Estimation of the Input Data

3.2.1 Data Collection

The data required to build the model includes prices, constraints, and other technical coefficients, which were partially obtained from census reports and other costs of production reports prepared by governmental agencies. Supplemental data were obtained from discussions and interviews with marketing specialists and horticultural counsellors from the "Ministere de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec", (MAPAQ) and other related research centers (Institut de Technologie Agro-Alimentaire (ITA), and Institut Quebecois du Developpement de l'Horticulture Ornementale (IQDHO). Additional information was acquired through a questionnaire sent to several representative production firms in regions 6,7, and 10.

The questionnaire, listed in Appendix A, aimed to gather detailed information regarding the costs of production, in addition to other related information such as specific cultural practices followed, market demand and constraints, common pot sizes, and spacing requirements for the plants under study. Data published by the CREAQ, MAPAQ, Statistics and Agriculture Canada were cited for additional references.

3.2.2 General Procedures

The data collected were used to simulate economic and cultural practices for a model greenhouse, located in the area of Montreal. The modelled greenhouse, with a bench area of 2000 square meters, is made up of several gutter-connected houses, and is covered with a double polyethylene layer. The planting area represents about 80% of the provincial average greenhouse size in 1988 (Statistics Canada, 1989).([1])

The model greenhouse is irrigated with a drip irrigation system and heated using a bi-energy system, which uses both electricity and number two oil, in a 40:60 proportion. It should be noted that the data were collected in 1990 and reflects the production costs incurred in 1989.

3.3 Production Costs

Production costs depend on many factors which differ between production firms. Such factors include location, size, managerial skills, time of the year, greenhouse type and age, facilities available, crops produced, production plan, and others. Several assumptions were made concerning the production costs and cultural practices followed. The discussion of these cultural practices, presented in section 3.3.1, will help to outline the production costs.

The production costs, which are composed of both fixed and variable operating costs, are discussed in sections 3.3.2 to 3.3.3.3.

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[1] Statistics Canada has reported that the average size of greenhouses operated in the province of Quebec for the year 1988, averaged 2557 square meters.

3.3.1 Plant Cultural Practices

Cultural practices and production scheduling vary tremendously among producers due to different management skills, experience, greenhouse location, and facilities available. It is beyond the scope of this study to outline such exact production schedules and practices. However, those data would be needed to outline labor hour requirements, heating costs, and spacing associated with the plants under study. For this reason, cultural practices followed for these plants will include some general or common practices that will be followed for all the plants, and other specific practices, that vary from one plant to another. The general practices include the frequency of irrigation, and the application of fertilizers, pesticides and growth regulators. Other specific practices associated with the production of these potted flowers, such as pruning, pinching, lighting or shading, and others will be mentioned in the production practice schedule.

3.3.1.1 General Practices

A detailed description of the general practices followed for all the plants are listed as follows :

1-Frequency of irrigation : The frequency of irrigation depends on many factors such as the plant requirement which vary according to growth stage, climate, pot size, and potting media. In this study, irrigation will be supplied daily through a drip irrigation system except for the first and last weeks of the production cycle where it will be supplied every two days to enhance rooting in the beginning, and to increase hardiness for marketing in the end. Different water requirements due to the above mentioned factors will be accommodated by varying the length of the irrigation cycle to give more or less water. The irrigation system will have check valves to control the water distribution.

2-Fertilizer application : Fertilizer application varies according to various needs of the plants, growth stage, planting media, chemical composition and solubility of the product. In this study it will be assumed that except for the initial fertilizer application that will be incorporated in the soil, a constant feeding through the irrigation system (fertigation) will be followed except for the first and last week. In this manner, a separate fertilizer tank will be connected to different sections of the main water pipes to be distributed to various sections of the greenhouse by different drip networks. It should be noted that no fertilizer name or rate will be mentioned due to the various combinations of chemicals present on the market.

3-Pesticide application : Pesticide application depends on the type of pest (weed, fungi, or insect), propagation method, and growth stage. A pest preventive program that employ the use of fungicides, insecticides, and acaricides, will be applied via the drip irrigation system at 14 days interval. If other problems emerge, specific pesticides will be used and sprayed by a manual sprayer. Care should be taken in order not to spray any pesticides during the flowering stage to avoid injury of the inflorescence. Again, it should be noted that no pesticide name or rate will be mentioned due to the variety of trade names and chemical compositions of products available on the market.

4-Growth regulators : The application of growth regulators depend on the plant vigour and growth stage, the purpose of application (to retard or enhance vegetative or reproductive growth), the production or cultural practices followed, and product concentration. In this manner, specific growth regulators will be applied to different plants at different time intervals as required by the production practice followed. This application will be done manually using sprayers. The main category of growth regulators used will include growth retardants.

5-Pot size : It will be assumed that one final pot size will be used from the beginning of the production cycle until the end. This practice will reduce the labor hours needed to repot the plants. However, plants will be respaced frequently according to the plants' growth stage and requirements. It will be assumed that a 5 cm larger pot will require one additional week of production.

3.3.1.2 <u>Specific Practices</u>

These include the set of cultural practices specific to each of the potted flower plants under study. This will include pruning, pinching, lighting or shading, respacing and others. These practices will be described along with plant requirements. The list of plant varieties used in this study is listed in Table 3.7 (page 44). The schedules of cultural practices will be presented in Appendix D.

<u>1-African Violet</u>

The African Violet (<u>Saintpaulia</u> <u>ionantha</u>) is considered one of the most popular hobby plants. Consumers show a high demand for this flowering plant because it can thrive with minimum care. It has a high tolerance to low light intensity, warm temperatures, and dry atmospheres. For these reasons, the plant is one of the few potted flowers, besides Chrysanthemums, that can be grown for sale on a year round schedule. It is noted, however, that the peak demand of Violets is during the main holidays. In this study Violets will be produced for sale on a bi-weekly schedule through out the year including the major holidays. Some of the cultivars used in Quebec include Optimara, Rhapsodie, and Antoflorens. In Quebec, many producers have found difficulty in the production process. In fact, it is believed that there are only 2 or 3 major producers for this plant in the province.

Producers can start from either seeds, leaf cutting, or seedlings. In this study, imported seedlings will be used. The plant requires an average of 10 weeks of production. This depends on the season of production which could vary the production period between 8 to 11 weeks. In this study, a production period of 10 weeks on average, will be used. African Violets, unlike other plants, seem to grow better with a warmer night temperature and a cooler day temperature. Additional light on short days, plays an important role in flower initiation and plant growth. The planting medium should be loose, well drained, and rich in organic matter to help keep the roots wet. The plant enjoys a good fertility rate, but care should be taken to avoid increasing the salt level since Violets are sensitive to high soluble salt levels. The most important pot size produced for the Quebec market is the 10 cm pot. Those pots are spaced pot to pot for the first 2 weeks after which they are respaced to occupy an area of 0.40 square meters until marketing dates. Table 1 in Appendix D shows the schedule of cultural practices followed.

2-Azalea

Azalea (Rhododendron obtusum) is imported as a semi-finished plant to be forced in Quebec. Azalea cultivars have a large variety of colored flowers with various sizes and shapes. The plant is produced for sale for the four holiday marketing periods. Producers could propagate the plant from seeds or cuttings. In this study, imported pre-budded finished plants will be used. These plants require from 6 to 8 weeks of forcing before marketing. In this study, a production period of 8 weeks will be used.

Since Azalea is a long day plant, light plays an important role in flower initiation. During the winter the daylength must be extended by the use of artificial lights. Other special treatments include the application of growth regulators to enhance flowering. This is done once every week after two weeks from the starting date. Other special treatments include pruning of side shoots to maintain a well branched plant. The planting medium should be porous with a high percentage of organic matter (mainly peat moss 50%-100%). A planting medium with a pH level between 4.5 to 5.5 should be maintained as higher pH levels might cause leaf chlorosis. The plant requires a constant supply of nutrients, but care should be taken to avoid using fertilizers that increase the soil pH and soluble salt level. The most important pot sizes produced for the Quebec market are 15 cm and 17.5 cm. Other less important pot sizes such as 11.25 cm pots are available. The 15 cm and 17.5 cm sizes will be used in this study. Those pots are spaced directly using the final spacing. This is 30 by 30 cm for the 15 cm pots, and 35 by 40 for 17.5 cm pots. Tables 2 and 3 in Appendix D show the schedule of cultural practices followed for Azalea.

3-Begonia

Tuberous Begonia (Begonia tuberhybrida) is considered one of the most versatile of all commercial potted plants. The plant has a tremendous variability in flower size, form, color, and texture. Other Begonia species could be grown as foliage or bedding plants. This classification differs according to the root systems. The plant is mainly produced for the spring season and Easter and Mother's day although it can be produced for Christmas, but producers in Quebec avoid this because of high costs. In this study, Begonias will be produced for sale for Easter and Mother's day. Several varieties are used in Québec, some of which include the Nonstop varieties. Producers could start from either seeds, tubers, or cuttings. In this study, seedlings will be used. The plant requires an average of 10 to 12 weeks before it becomes ready for marketing in spring. In this study, a production period of 10 weeks on average will be used.

Light plays an important role in flower initiation and plant growth. In this manner, additional artificial light have to be supplied to the plants during excessive light reduction in winter which can reduce growth and affect plant formation. On the other hand, tuberous Begonia requires shading from intense light between April and September. The planting medium should be porous and well drained with high percentage of organic matter such as peat moss (25-50%) to help keep the roots moist at all times, since a water shortage might harden the growth and dry the foliage. Care should be taken to avoid increasing the soluble salt level. Ten and fifteen cm pots are the most widely produced for the Quebec market. Those pots are spaced pot to pot for the first 3 weeks after which they are respaced at 20 by 20 cm for the 10 cm pot, and 30 by 30 cm for the 15 cm pots. Tables 4 and 5 in Appendix D show the schedule of cultural practices followed for tuberous Begonia.

4-Chrysanthemum

Chrysanthemums (Dendranthema grandiflorum) are considered to be the most important potted flowers produced in Quebec as far as wholesale value is concerned. This plant is one of the few potted flowers that could be grown for sale on a year round schedule. Although this practice is more common in Europe, several ornamental counsellors interviewed believe that the market is under-exploited in Quebec. Depending on the cultivar's growth characteristics, mums are sold as potted flowers or as cut flowers. In this study, mums will be produced for sale every two weeks through out the year including the major holidays. There are a large number of varieties used in Québec. Those vary according to color, type and growth characteristics. The Yoder Company, one of the major producers of cuttings, classified the demand in North America according to color and plant type. In terms of color it was estimated that demand was 40% for yellow, 27% for white, 23% for pink, and 10% for red/bronze color. As for type, preference is given to decorative plants (68%), where the center bud is pinched, daisy (23%), and 7% for anemones. Most producers could start from rooted or unrooted cuttings. In this study, rooted cutting will be used.

The plant requires an average of 9 to 12 weeks before it becomes ready for marketing depending on the season of production. In this study, a production period of 10 weeks on average will be used. Mums are classified according to their response to temperature and light. In this manner, thermoneutral or thermonegative cultivars, which require a temperature less than 16 Celsius degrees to initiate flower bud development, could save on the energy costs in Québec. Light plays an important role in flower initiation. Short days will enhance the process while long days can be used to enhance vegetative growth and delay flowering. Other special treatments include pinching and application of growth regulators. The former practice is done to control plant height and increase lateral buds and branching, while the latter practice is done to control plant height and growth. In addition to other fertilizers, Phosphorous is particularly needed for proper plant growth. Ten and fifteen cm are the most common pot sizes produced for the Quebec. However, there is greater demand for the 15 cm pot. The 15 cm pots contain five plants per pot, while the 10 cm pots have only two plants. Pots touch for the first 2 weeks of growth after which they are respaced to a 30 by 35 cm for the 15 cm pot, and 20 by 25 cm for the 10 cm pot. Tables 6 and 7 in Appendix D show the schedule of cultural practices followed for Chrysanthemums.

5-Cyclamen

Cyclamen (Cyclamen indicum) is a small plant with an attractive flower. Several ornamental counsellors believe that the development of improved cultivars which have a longer shelf life and fast flowering time, combined with the development of accelerated production techniques, which require a shorter production cycle (8 to 9 months rather than 12 to 15 months), have re-established this plant as an important commercial product. In Europe, Cyclamens are produced year round. But in North America and Quebec, the plant is mainly produced for Christmas. Other less important occasions include spring holidays such as Valentine, Easter and Mother's day. In this study, Cyclamens will be produced for sale at Easter, Mother's day, Valentines, and Christmas.

Producers could start from either seeds, or seedlings. In this study, seedlings will be used. The plant requires an average of 7 to 8 months before it becomes ready for marketing. In this study, a production period of 30 weeks will be used. Since light plays an important role in flower initiation and plant growth, artificial lights will be used during the winter nights to enhance growth. Other special treatments include the application of growth regulators to induce early and more uniform flowering. This is done 1.5 to 2 months before the desired blooming date. The planting medium should be porous with a high percentage of orgainic matter to help retain sufficient water. A planting medium with a pH above 5.5 should be maintained. The plant requires a constant moderate supply of nutrients, but excessive nutrients slow growth. Care should be taken to avoid increasing the soluble salt level to a high extent. The most important pot size produced for the Quebec market is 15 cm although a 10 cm pot is not uncommon. Those pots are spaced pot to pot for the first 10 weeks after which they are respaced at 30 by 30 cm for the 15 cm pot, and 20 by 20 cm for the 10 cm pots. Tables 8 and 9 in Appendix D show the schedule of cultural practices followed for Cyclamen.

6-Easter Lily

Easter Lily (Lilum longiflorum) is the main plant produced for Easter. The most commonly used cultivars in the United States and Canada are Ace and Nellie White (Senecal and Bigras, 1987). Most producers buy vernalized bulbs and finish them in their greenhouses. Since larger bulbs produce more flowers, bulbs are graded according to size (circumference). The plant requires an average of 110-120 days before it is ready for marketing. In this study, a period of 16 weeks will be used for the production cycle.

Special treatments include daylength extension during winter, and the application of growth regulators to obtain a shorter and more uniform products. Planting media should have a pH of 6.0 and allow for a good drainage. The most common pot size produced for the Quebec market is the 15 cm pot diameter. As for fertilization, nitrogen, calcium and phosphorus are the most important elements for this crop. Pots were initially spaced size by size (15 cm by 15 cm center to center) for the first 6 weeks after which they were respaced to 20 cm by 30 cm (0.06 square meters). Pesticide application should not be applied when flower buds start to appear. The schedule of cultural practices of Easter lily is presented in Table 10 of Appendix D.

7-Geranium

Geranium (Pelargonium hortorum) is the plant that is most widely sold for Quebec gardens. It is sold as a potted flower plant or in trays for landscaping. The quantity produced has increased yearly over the last 10 years. The method of production known as "fast crop" is the most profitable and is the most commonly used in Quebec. This method consists of the optimal combination of plant stock variety, medium, fertility level, and temperature manipulation. The geranium is produced for spring, especially Easter and Mother's day. In this study, the geranium will be produced to be marketed at bi-weekly intervals between the period of March 19 and June 18 (eight times). There are a large number of varieties used in Quebec, some of which include Oglevees, Fischer, Kim, Veronica, and Yours Truly. Most producers start from rooted cuttings bought from the local market, however large producers buy mother plants to produce their own cuttings in the spring. In this study, a rooted cutting bought from the market will be used. The plant requires an average of 6 to 8 weeks before it becomes ready for marketing in the spring.

Temperature and light play an important role in the timing of production. Light affects flower initiation, and the plant will not flower until it has accumulated a certain number of light hours. High temperature, on the other hand, has a positive effect on the flower bud initiation and elongation. Other special treatments include the application of growth regulators to control vegetative growth and enhance the development of side shoots. The Geranium can withstand a planting medium which is less porous than other potted plants, but the plant requires an elevated supply of fertilizers. Phosphorous and Magnesium are particularly important. The most important pot sizes produced for the Québec market are the 10 and 15 cm. It is not uncommon for many producers to use a 11.25 cm pot size but the 10 cm was found to be the most common. Other producers tend to use the larger pot size to produce a better quality plant with higher selling price. However, the larger plant requires two additional production weeks. In this study, both the 10 and 15 cm pots will be used. These pots are spaced pot to pot for the first two weeks after which they are respaced to a 15 by 15 cm for the 10 cm pot, and 20 by 20 cm arrangement for the 15 cm pot. Tables 11 and 12 in Appendix D show the schedule of cultural practices for Geranium.

8-Hydrangea

Hydrangea (Hydrangea macrophylla) is a potted plant characterized by a spectacular inflorescence. Flower color can be pink, blue, or white. Several ornamental counsellors believe that the cultivation of this plant is in decline due to it's long season of production and difficulty to conserve the flower for a long period. The color preference in Québec is mainly pink (85%) followed by blue (10%), and white (5%). (Senecal and Bigras, 1986). This plant is mainly produced for Easter and Mothers' day. There are a large number of cultivars grown in Québec, two of the more popular ones include Merritt Supreme, and Rose Supreme. Due to the difficulty and high cost of production, most producers in Quebec buy finished plants from the United States or Ontario and force them in Quebec. In this study, a finished plant will be used. Forcing requires an average of 12 to 14 weeks, depending on the greenhouse temperature, before the plant becomes ready for marketing in spring. In this study, a production period of 13 weeks will be used. Aluminum and pH level are important factors that influence flower color. Flowers have a blue color if aluminum is abundant, and pink if supply is low. PH will control the availability of aluminum which will be more available at lower pH levels. Light plays an important role in flower initiation and long days delay flower formation.

Other special treatments include the application of growth retardants to control plant height. The planting medium should be well aerated with a high water holding capacity since water deficiency severly slows crop growth and damages tissues. In addition to other fertilizers, Phosphorous is particularly needed for proper plant growth. The most common pot sizes produced for the Québec market are the 15 and 17.5 cm pots. Those pots are spaced pot to pot for the first 4 weeks after which they are respaced at 40 by 45 cm, and 45 by 50 cm for the 15 and 17.5 cm pots respectively, for the rest of the forcing cycle. The 17.5 cm pot requires an additional two weeks of production. Tables 13 and 14 of Appendix D show the schedule of cultural practices followed for Hydrangea.

9-Poinsettia

Poinsettia (Euphorbia pulcherrima) is considered the main potted flower plant produced for Christmas. In the United States, it is considered to be the leading potted flower in terms of wholesale value. In Quebec, it ranks second after the Chrysanthemum (Dansereau, 1990). It's popularity has been attributed mainly to the use of improved varieties which keep their leaves and flowers for longer periods of time. However, doubts have risen concerning the profitability of this plant because of the large supply compared to demand on one side, and due to the high heating costs in the production period, on the other hand. The most commonly used cultivars in Quebec are Annette Hegg Dark Red (80%), Pink (5%) and White (5%).

Most producers start from locally produced cuttings purchased in July or August. Cuttings can be bought with or without roots, pinched or unpinched. In this study, we will be starting from a rooted pinched plant. The plant requires an average of 110-120 days before it being marketable in early December. Since Poinsettia are short day plants, light plays an important role in flower initiation. Other special treatments include the application of growth regulators to shorten the plants, strengthen the stem, and intensify the colors of the leaves and flowers. An unpinched cutting should be pinched about 15 days after potting to remove the terminal bud and increase branching. The planting medium should be porous and well drained. The plant needs continuous fertiliza--tion, however, chemicals that increase soil salinity should be avoided due to root sensitivity. The most important pot sizes produced for the Québec market are those of 15, 20 and 25 cm. The 15 cm pots contain one plant whereas the 20 cm may contain 2 to 3 plants and the 25 cm pot has 3 to 4 plants. Pots touch for the first month after which they are moved to a 30 by 35 cm, 50 by 45 cm, and 55 by 60 cm for the 15, 20, and 25 cm sizes, respectively. Tables 15 to 17 in Appendix D list the schedule of cultural practices used for Poinsettia.

3.3.2 Fixed Costs

Fixed costs are the costs incurred regardless of the number of plants or crop varieties produced in the greenhouse. These costs include managerial salaries, taxes, insurance, depreciation, interest on loans, repairs, greenhouse structure, heating and irrigation systems, office expenses, and repairs and maintenance.

These costs differ among various greenhouse firms depending on the production methods followed, managerial skills, styles and preferences, plants produced, as well as the location of the greenhouse as it affects rent, labor wages, and heating requirements.

Moreover, since the calculation of the fixed costs would not affect the results obtained from the optimization procedure, which depends on the variable costs, the fixed costs required for the modelled greenhouse were not specified. Further information on fixed costs of greenhouses, are cited in the publication of "Le Comité de Réferences Economiques en Agriculture du Québec" (CREAQ, 1989a).

3.3.3 Variable Costs

The variable costs are composed of heating, material, and labor costs. These costs were estimated per unit of plant variety produced for a certain occasion. These costs, listed in Appendix C, were estimated and calculated as follows:

3.3.3.1 Heating Costs

One of the major costs in the production of pot flowers in greenhouses under northern climates is maintaining proper temperatures inside the greenhouse. As energy sources have become more costly, heating expenses associated with production have increased.

The total annual heating cost is divided into the system and fuel costs. While the system costs are considered part of fixed costs, fuel costs are added to operating costs.

Fuel costs vary depending on the location of the greenhouse, temperatures required, crops produced, and greenhouse structure. These costs will be included in the variable costs as the cost of heating per plant unit. This was estimated depending on the time the plant was present in the greenhouse and area occupied.

The variable heating costs were based on the heating requirements as tabulated by the "Comite de References Économiques en Agriculture du Quebec" (CREAQ) for the region of Montreal (1987). The method used by CREAQ to estimate the heating requirements takes into consideration meteorological data such as solar radiation, average day and night temperature, fuel type, and greenhouse structure (single or attached).

The CREAQ tables (Appendix B) show the monthly requirements for number 2 oil in liters per square meter needed to achieve a certain night temperature in an attached structure in the region of Montreal. Heating Requirements depend on the required temperature difference between day and night inside the greenhouse. In this case, the modelled greenhouse was kept at 18 degrees Celsius. A conversion table (Appendix B) was prepared by CREAQ (CREAQ, 1987), to change the required energy from oil to other forms of energy including electricity. This is particulary important since a bi-energy system, which depends on oil and electricity in a 60:40 ratio respectively, was used. The price of a liter of oil was calculated to be 22 cents, while the price of a kilowatt-hour (Kw-Hr) of electricity was estimated to be 4.81 cents (D-rate, Hydro Québec, 1990). Based on this data, the heating costs for different periods of the year are calculated and presented in Table 3.1. It is noted that most of the heating costs occur in a few months of the year.

In order to calculate the heating cost associated with the production of one plant unit, the area occupied by the plant was multiplied by the heating costs of both electricity

TABLE 3.1: HEATING REQUIREMENTS & COSTS PER PERIOD AT 18 C NIGHT TEMPERATURE FOR MONTREAL REGION

PERIOD	DATE				ENERGY REQUIREMENT ELECTRICITY (Kwh/m^2)	ENERGY REQUIREMENT Oil (lit./m^2)	ENERGY COSTS ELECTRICITY (cents/m^2)	ENERGY COSTS Oil (cents/m^2)	TOTAL (cents/m^2)
1 st	2 weeks	Jan 8	-	Jan.21	20.1768	3.7394	97.05	82.27	179.32
2 nd	2 weeks	Jan 22	-	Feb 4	19.3144	3.5794	92.90	78.75	171.65
3 rd	2 weeks	Feb 5	-	Feb 18	17.1584	3.1794	82.53	69.95	152.48
4 th	2 weeks	Feb 19	-	Mar 4	15.5976	2.8902	75.02	63.58	138.61
5 th	2 weeks	Mar 5	-	Mar 18	11.6956	2.1672	56.26	47.68	103.93
6 th	2 weeks	Mar.19	-	Apr 1	11.3242	2.0984	54.47	46.16	100.63
7 th	2 weeks	Apr 2	-	Apr 15	6.4960	1.2040	31.25	26.49	57.73
8 th	2 weeks	Apr.16	-	Apr 29	6.4960	1.2040	31.25	26.49	57.73
9 th	1 week	Apr 30	-	May 6	1.6544	0.3068	7.96	6.75	14.71
10 th	2 weeks	May 7	-	May 20	2.7776	0.5152	13.36	11.33	24.69
11 th	2 weeks	May 21	-	Jun 3	2.3765	0.4408	11.43	9.70	21.13
12 th	2 weeks	Jun 4	-	Jun 17	0.3058	0.1680	4.36	3.70	8.05
13 th	2 weeks	Jun 18	-	Jul 1	0.8619	0.1599	4.15	3.52	7.66
14 th	2 weeks	Jul 2	-	Jul 15	0.2912	0.0546	1.40	1.20	2.60
15 th	2 weeks	Jul 16	-	Jul 29	0.2912	0.0546	1.40	1.20	2.60
16 th	2 weeks	Jul 30	-	Aug 12	0.6680	0.1242	3.21	2.73	5.95
17 th	2 weeks	Aug 13	-	Aug 26	0.7308	0.1358	3.52	2.99	6.50
18 th	2 weeks	Aug 27	-	Sep 9	1.7172	0.3185	8.26	7.01	15.27
19 th	2 weeks	Sep 10	-	Sep 23	2.2652	0.4200	10.90	9.24	20.14
20 th	2 weeks	Sep 24	-	Oct 7	4.1293	0.7658	19.86	16.85	36.71
21 st	2 weeks	Oct 8	-	Oct 21	5.9934	1.1116	28.83	24.46	53.28
22 nd	2 weeks	Oct 22	-	Nov 4	7.4322	1.3780	35.75	30.32	66.06
23 rd	2 weeks	Nov 5	-	Nov 18	11.0292	2.0440	53.05	44.97	98.02
24 th	2 weeks	Nov 19	-	Dec 2	12.0854	2.2398	58.13	49.28	107.41
25 th	2 weeks	Dec 3	-	Dec 16	18.4226	3.4146	88.61	75.12	163.73
26 th	3 weeks	Dec 17	-	Jan 7	29.8269	5.5282	143.47	121.62	265.09
							YEARLY SUBTOTAL =		1881.70

and oil, in the assigned proportions, for the period the plant was present in the greenhouse.

As for the fixed system costs, CREAQ reported that the cost of a bi-energy system, which uses both electricity and oil, was estimated to be 55.60 dollars per square meter (CREAQ, 1989a). This value could be multiplied by the total area of the greenhouse, to find the total fixed costs of the heating system. Annual fixed costs could then be determined by dividing the total fixed costs by an estimated life of the system.

3.3.3.2 <u>Labor Costs</u>

Labor costs were measured in terms of the time needed to produce a unit of crop, hence it was necessary to estimate the labor hours involved in the production of a plant unit. However, since most growers interviewed were unable to state with confidence the labor requirements needed (in terms of time) for the production of a plant unit, producers were asked, instead, to approximate the amount of time needed for certain cultural practices such as planting, spacing, pruning, and others. The time required depended on the worker's skills, past experience, available facilities, plant variety, and pot size.

Averaging the producers' approximations with other estimates from consultation with ornamental counsellors and horticultural specialists, the amount of time needed for a certain cultural operation was estimated according to the pot size. This estimation, listed in Table 3.2, was used for all the pot flowers under study. This table lists the time needed to perform certain operations such as potting, spacing, pinching, watering, pesticides and fertilizer applications, harvesting, and other maintenance activities.

Labor requirements for different plant varieties in different periods of the year, were estimated according to the schedule of cultural practices cited in several

TABLE 3.2: LABOR REQUIREMENTS PER TASK FOR DIFFERENT POT SIZES

Operation\Time	10 cm (sec)	15 cm (sec)	17.5cm (sec)	20 cm (sec)	25 cm (sec)
DF: Drench Fungicide	5	6	6 5	7	8
FW Fertigate & Irrigate	3	3	3	3	3
GR. Spray growth regulator	3	4	4.5	5	6
IR: Irrigate	1.5	1.5	1.5	1 5	1.5
PA: Pesticide Application	3	4	4.5	5	6
PKG:Package plant	9	12	13.5	15	18
PG: Place in greenhouse	5	6	6.5	7	8
PMD:Prepare media & fill pot	3	4	4.5	5	5
PP: Plant cutting (rooted)	4.5	6	7	8	10
PI: Pinch or prune	5	7	8	9	10
RS. Respace plants	2	3	3.5	4	5
SA Soak bulb in acaricide	6	6	6	6	6
S&H:Shipping & handling	5	6	6.5	7	8
SH: Shade plants	1.5	2	2.25	2 5	3
US Unshade plants	2.5	3	3.25	3 5	4

ornamental production books and technical references. The schedule of cultural practices used for the studied plants, listed in Appendix D, was discussed in detail in section 3.3.1. A summary of the total time needed per plant unit is listed in Table 3.3. It should be noted that labor wage was estimated at 5.50 dollars per hour.

3.3.3.3 Material Costs

Material costs make up a major part of the variable costs of production. These include the costs of plants, pots, planting media, fertilizers, pesticides, and packaging materials. Material costs were calculated using producers estimation and other published governmental data (CREAQ, 1989b).

Total material costs for the plants under study are listed in Table 3.4. These costs are presented in more detail in Appendix C.

3.4 Model Input Coefficients

This section illustrates in detail the steps and assumptions taken to simplify the construction of the model input coefficients. This will also include the discussion of the plants production practices.

3.4.1 Periods Marketed

The production year was divided into 26 periods each covering a two-week time except for two periods one with one and the other for three weeks. The year was divided in this manner in order for the periods to coincide with the marketing dates associated with the holidays. It was felt that a period of two weeks would be sufficient since a longer period such as one month time would be too long for accuracy while a one week period would lead to a very large matrix. The division of the year into periods was illustrated in Table 3.1. It should be noted that the four major holidays

TABLE 3.3: LABOR REQUIREMENTS IN SECONDS FOR PLANTS IN DIFFERENT PERIODS

Period/Plant	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	9 th 2 wks	Mktng Date *	Total
African Violet,10 cm	0	0	0	0	50.5	47	45	45	37 5	5	230
Azalea,15 cm	0	0	0	0	0	46	61	54	45.5	6	212 5
Azalea,17.5 cm	0	0	0	0	23.5	42	63.5	55 5	30	6 5	221
Begonia,10 cm	0	0	0	0	50.5	47	50	50	37.5	5	240
Begonia,15 cm	0	0	0	38	46	49	53	53	41 5	6	286 5
Cyclamen,10 cm	0	0	40	90 5	90.5	90 5	90 5	92.5	90 5		
			34.5	34.5	34.5	37 5	37.5	34 5	31.5	5	834.5
Cyclamen,15 cm	0	45 5	105.5	105 5	105.5	105.5	108.5	105.5	105.5		
			35.5	35.5	35.5	39.5	39.5	35.5	35 5	6	1049.
Mums,10 cm	0	0	0	0	35.5	102	109	104	37.5	5	393
Mums,15 cm	0	0	0	0	56	126	127	120	41.5	6	473.5
Easter Lily,15 cm	0	62	46	46	53	46	46	46	41.5	6	392.5
Geranium,10 cm	0	0	0	0	0	50.5	53	48	37 5	5	194
Geranium,15 cm	0	0	0	0	41	40	57	50	41.5	6	235.5
Hydrangea,15 cm	0	0	37	48	57	89	123	123	41.5	6	524.5
Hydrangea,17.5 cm	0	0	54	55.5	59	94	131.5	131.5	43.5	6 5	575 5
Poinsettia,15 cm	0	56	53	88	116	120	46	46	41.5	6	572 5
Poinsettia,20 cm	47	41	56	98	131	136	47	47	45 5	7	655 5
Poinsettia,25 cm	67	58	53	152	146	152	48	48	49.5	8	781.5

for the 1989 production year, fell on the following dates: Christmas on December 25th, Valentine's Day on February 14th, Easter on March 26th, and Mother's Day on May 14th. The marketing periods for these holidays were about one week before the holiday date.

3.4.2 Prices

Since most producers sell their products to wholesalers, the value used for the price of the pot flowers was the wholesale price adjusted by a 5% loss factor. The value of loss factor was the average figure reported by producers interviewed. In this manner, the wholesale price was multiplied by a factor of 95% to account for the 5% loss factor. Price data were collected from producers and ornamental marketing unions. Moreover, it was assumed that prices of plants produced for the holidays will be sold at a 5% higher rate than at other times of the year. This price increase was concluded from discussions with counsellors of the marketing unions in Quebec. The adjusted prices are listed in Table 3.5.

3.4.3 Plant Spacing Requirements

Plants require different pot spacings during their growing cycle. Spacing should provide optimum air circulation and light distribution for the whole plant in all seasons.

In this study, plants started from seedlings were kept at pot to pot adjacent spacing and shifted to larger spacings after several weeks. On the other hand, plants which were finished in the greenhouse, were spaced at the final spacing from the beginning. Table 3.6 lists the spacings followed for the studied plants according to age.

It should be noted that a more efficient use of space through close (dense) spacing, could lead to a lower heating cost per plant. However, this would increase space competition among plants and lead to an inferior quality

TABLE 3 4 TOTAL MATERIAL COSTS OF PLANTS PRODUCED IN CENTS PER POT

Plant Variety	Pot Size	Material Cost	Plant Variety	Pot Size	Material Cost
African Violet	10 cm	71 00	Easter Lily	15 cm	191 25
Azalea	15 cm	554 50	Geranium	10 cm	85 30
Azalea	17 5 cm	697 00	Geranium	15 cm	140 00
Begonia	10 cm	68 00	Hydrangea	15 cm	356 50
Begonia	15 cm	123 25	Hydrangea	17 5 cm	375 00
Chrysanthemum	10 cm	78 50	Poinsettia	15 cm	151 25
Chrysanthemum	15 cm	195.25	Poinsettia	20 cm	305 00
Cyclamen	10 cm	98 50	Poinsettia	25 cm	431 30
Cyclamen	15 cm	155 25			

TABLE 3 5 ADJUSTED SALE PRICE OF PLANTS PRODUCED IN CENTS PER POT

Plant Variety	Pot Size	Sales Price (c)
HOLIDAY PRICES		
African Violet	10 cm	131 00
Azalea	15 cm	824 50
Azalea	17 5 cm	1018 50
Begonia	10 cm	194.00
Begonia	15 cm	388 00
Chrysanthemum	10 cm	218 25
Chrysanthemum	15 cm	388 00
Cyclamen	10 cm	218 25
Cyclamen	15 cm	436 50
Easter Lily	15 cm	339 50
Geranium	10 cm	155 20
Geranium	15 cm	339.50
Hydrangea	15 cm	582.00
Hydrangea	17 5 cm	776 00
Poinsettia	15 cm	388 00
Poinsettia	20 cm	582 00
Poinsettia	25 cm	824 50
All YEAR PRICES		
African Violet	10 cm	124 45
Chrysanthemum	10 cm	207 34
Chrysanthemum	15 cm	368.60
Geranium	10 cm	147 44
Geranium	15 cm	322 53

TABLE 3.6 SPACE REQUIREMENTS FOR PLANTS PRODUCED IN SQUARE METERS

PLANT VARIETY	FIRST SPACING	NO OF WEEKS	SECON SPACING	NO. OF WEEKS	TOTAL WEEKS
African Violet,10 cm	0 01	2	0 04	8	10
Azalea,15 cm	0	0	0.09	8	8
Azalea,17 5 cm	0	0	0 14	8 5	8 5
Begonia,10 cm	0 01	3	0 04	7	10
Begonia,15 cm	0 0225	3	0 09	8	11
Chrysanthemum,10 cm	0 01	1	0 05	8	9
Chrysanthemum,15 cm	0 0225	2	0 105	8	10
Cyclamen,10 cm	0 01	10	0 04	18	28
Cyclamen,15 cm	0 0225	10	0 09	20	30
Easter Lily,15 cm	0 0225	6	0 06	10	16
Geranium,10 cm	0 01	2	0 0225	6	8
Geranium,15 cm	0 0225	3	0 04	6	9
Hydrangea,15 cm	0 0225	3	0 18	10	13
Hydrangea,17 5 cm	0 0306	4	0 225	10	14
Poinsettia,15 cm	0 0225	4	0.105	12	16
Poinsettia,20 cm	0 04	4	0 225	13	17
Poinsettia,25 cm	0 0625	4	0.33	14	18

plant with a lower selling price. On the other hand, larger spacings between plants, due to a single large spacing or successive movements of the plants, would increase labor and heating costs per plant unit, but result in a higher selling price due to better quality. This issue represents one of the difficulties in the design of pot flower production.

This compromise in resource allocation and cost distribution depends on several factors such as labor availability, heating costs, plant varieties (late or short season), greenhouse location, market demand and purchasing power, and time of the year.

In this manner, larger spacings could be used when net returns are expected to be high while smaller spacings are used for the reverse case. It should also be noted that larger spacings would reduce the number of plants per unit area. This would affect the expected profitability of the fixed greenhouse space.

3.4.4 Other Assumptions

The following additional assumptions were considered to increase simplicity :

1) The greenhouse temperature was maintained at 18 degrees Celsius for the whole year. In summer, this was achieved by increased ventilation and shading.
2) The study started from an empty greenhouse, void of any ongoing production.
3) The simulated study used a single space layer for plantation in the greenhouse. It should be noted that the use of multiple layers, is not an uncommon practice.

3.5 The Linear Programming Technique

LP problems have three components: an objective function that aims to maximize net profits or minimize costs, decision variables or activities which represent alternative methods to attain the objective, and constraints or restrictions on resource availability and use.

The structure of the LP model has been illustrated by Hazell and Norton (1986) in mathematical statements as follows:

Maximize

$$Z=\sum_{j=1}^{n} CjXj$$

for all j=1 to n

such that

$$\sum_{j=1}^{n} AijXj \leq Bi$$

for all i=1 to m
and j=1 to n

and

$$Xj \geq 0$$

for all j=1 to n

where

Xj = the level of the j th activity, (j=1 to n)

Cj = the forecasted gross margin of a unit of the j th activity (j=1 to n)

Aij= the quantity of the i th resource required to produce one unit of the j th activity, (i=1 to m; j=1 to n)

Bi = the amount of the i th resource available, (i=1 to m)

In other words, this implies that the optimal plan should include a set of activity levels (Xj) to yield the largest sum of gross margins (Z) such that it does not exceed any resource constraint (Bi) or include any negative activity levels. The use of these components in the pot flower model is illustrated in section 3.5.1.

3.5.1 General Structure of the Suggested LP Model

The model consist of the following components: an objective function, 9 sets of decision variables which correspond to the nine plant varieties under study, and production and marketing constraints. The basic matrix contains 128 columns and 52 rows. The model components will be discussed in the following sections.

3.5.1.1 The Decision Variables

The decision variables are those whose values are determined by the linear programming optimization process. In this case, it is the number of plant units of a certain species with several pot sizes, that is to be marketed at specific periods of the year including the holidays.

Table 3.7 summarizes the list of decision variables used in this model, which include the plant varieties, pot sizes, and marketing periods specific to that variety. A detailed listing of the decision variables of the model is found in Appendix E.

3.5.1.2 The Objective Function

The objective function in the pot flower model reflects the aim of maximizing the difference between the market value or the selling price of the crops produced minus the sum of the operating costs associated with those crops, within the production and marketing constraints.

Gross margin can be defined as the net returns to

TABLE 3.7: LIST OF DECISION VARIABLES

PRODUCTION OPTIONS	POT SIZES (cm)	MARKETING DATES	PLANTING MATERIAL	COUNT
AFRICAN VIOLET	10	All year including VV,EE,MD,XX	Seedling	26
AZALEA	15,17.5	VV,EE,MD,XX	P.F.Plant (1)	8
BEGONIA	10,15	EE,MD	Bulb	4
CHRYSANTHEMUM	10,15	All year including VV,EE,MD,XX	R.Cutting (2)	52
CYCLAMEN	10,15	VV,EE,MD,XX	Seedling	8
EASTER LILY	15	Easter	Precool Bulb	1
GERANIUM	10,15	Spring (19 Mar.–18 June) + V,E,M	R.Cutting (2)	18
HYDRANGEA	15,17.5	VV,EE,MD,XX	P.F.Plant (1)	8
POINSETTIA	15,20,25	Christmas	R.Cutting (2)	3
			TOTAL :	128

VV: VALENTINES, EE: EASTER, MD: MOTHER'S DAY, XX: CHRISTMAS

(1) : Prefinished plant

(2) : Rooted cutting

overhead, management, capital investment and marketing. It may also be considered the income which the manager/owner receives beyond his salary compensation for his management skills.

The linear programming objective function is stated mathematically as follows :

$$Max\sum_{n=1}^{9} GMn_{ik}=\sum_{n=1}^{9} TRn_{ik}-\sum_{n=1}^{9} TVCn_{ik}$$

for all i=1 to m
and all k=1 to 26

where

$\sum_{n=1}^{9} GM\, n_{ik}$ = the summation of the gross margins from all units of plant variety n of pot size i produced for market in period k, for all plant varieties.

$\sum_{n=1}^{9} TR\, n_{ik}$ = the summation of the total returns from all units of plant variety n of pot size i produced for market in period k, for all plant varieties. Total returns (TR), is equal to the weighted selling price of one plant unit of variety n of pot size i produced for period k times the number of plant units of that variety.

$\sum_{n=1}^{9} TVC\, n_{ik}$ = the summation of the total variable costs from all units of plant variety n of pot size i produced for market in period k for all plant varieties. Total variable costs (TVC), is equal to the sum of labor, heating, and material costs of one plant unit of variety n of pot size i produced for period k times the number of plant units of that variety.

In other words, the objective is to maximize the sum of net returns which is equal to the sum of weighted selling price per pot for all plant varieties times the number of pots produced minus the sum of total variable operating costs per pot times the total number of pots produced. A detailed listing of the equation of the objective function of the model is found in Appendix E.

3.5.1.3 Constraints

Constraints are restrictions imposed on the set of allowable alternatives due to limited available resources or restrictive decisions. Constraints in the linear programming model are of different types. Some represent limited production resources such as planting area, greenhouse space, and labor hours, while others represent market restrictions such as quotas and maximum market absorption rates. In this manner, the presentation of the constraints identifies two groups as follows:

A- Total Available Resources: Labor and area.
B- Marketing Constraints: Pot size and holiday quotas.

A-Total Available Resources

This group of constraints includes available labor hours, and greenhouse planting area. It insures that the total amount of labor hours and space utilization required for all the crop varieties in all periods do not exceed the amount available for that period.

1-Available labor Hours

Labor requirements can be filled from two sources: 1) full time employees who work 40 hours per week, and 2) part time employees that could be hired in rush periods (February to the end of May) and could work up to 40 hours per week. The available hours include 3 full time workers, and an additional 2 part time workers, working 40 hours per week during the periods extending from February 5th to June 3rd, and from October 22nd to December 16th. Since the year is divided into 26 marketing periods, there are 26 labor constraints, each corresponding to a period.

The mathematical statement of this group constraint is stated as follows :

$$\sum_{n=1}^{9} Ln_{ijk} * Xn_{ik} \le \sum_{j=1}^{26} TTL_j$$

for all i= 1 to m
j=1 to 26
k=1 to 26

where

Ln_{ijk} = Number of hours of labor required during period j for production of one unit of plant variety n of pot size i for marketing in period k.

Xn_{ik} = Number of plant units of variety n of pot size i produced for marketing in period k

TTL_j = Total hours of labor available during period j. j = 1 to 26

The detailed listing of this constraint group is found in Appendix E.

2- Available Greenhouse Planting Area

This group of constraints is related to another limited resource, the production area. This group insures that the sum of the space used by the crops in the greenhouse each period does not exceed the total space available in that period (2000 square meters). Consequently, there are 26 constraints in this group corresponding to the number of periods.

The mathematical statement of this group constraint is stated as follows :

$$\sum_{n=1}^{9} Sn_{ijk} * Xn_{ik} \leq \sum_{j=1}^{26} TTS_j$$

for all j=1 to 26
i=1 to m
k=1 to 26

where

Sn_{ijk} = Space area in square meters required during period j for production of one unit of plant variety n of pot size i for marketing in period k.

TTS_j = Total space area in Square meters available in period j. j = 1 to 26

The detailed listing of this constraint group is found in Appendix E.

B-Marketing Constraints

This group of constraints imposes limits on the number of plant units of certain plant varieties produced for various holidays. It includes two sets of constraints: 1) pot size quota which imposes a maximum percentage of plants of pot size i within a certain variety, and 2) holiday quota which controls production distribution among holidays. The estimates of these limitations were calculated from interviews with ornamental counsellors and producers.

1-Pot Size Quota

This constraint insures that the production of a certain plant variety is distributed according to a certain percentage of different pot sizes. This limits the maximum number of plants produced of a certain pot size. Such a distribution reflects the market demand and product absorption rate. Table 3.8 lists the pot size constraints for different plant varieties.

TABLE 3.8: POT SIZE QUOTA FOR ALL PLANTS

PLANT	PERCENTAGES OF POT SIZES			
	10 cm	15 cm	17 5 cm	20 & 25 cm
AFRICAN VIOLET	= 100%			
AZALEA		>= 70%	<= 30%	
BEGONIA	>= 80%	<= 20%		
CHRYSANTHEMUM	<= 30%	>= 70%		
CYCLAMEN	<= 30%	>= 70%		
EASTER LILY		= 100%		
GERANIUM	>= 50%	<= 50%		
HYDRANGEA		<= 15%	>= 85%	
POINSETTIA		>= 75%		<= 25%

= Equal to

>= More than or equal to

<= Less than or equal to

The mathematical statement of this group constraint is stated as follows :

$$\frac{Xn_i}{\sum_{i=1}^{m}(Xn_i)} \geq Pn_i$$

for all i=1 to m
n=1 to 9

where

Xn_i = Total number of plant units of variety n and pot size i produced for the whole year.

Pn_i = The desired percentage of plant variety n of pot size i.

2- Holidays Quotas

This constraint divides the production volume of certain plant varieties among various holidays of the year. This distribution reflects the relative importance of the holiday. In this manner, the production will be distributed among the four main holidays, in the following manner: 40% for Easter, 30% for Mothers Day, 20% for Christmas, and 10% for Valentines Day. However, it should be noted that this distribution, or maximum limit imposed, concerns the plants produced for the four occasions and not the plant varieties produced for one or two occasions such as Poinsettia for Christmas, Easter Lily for Easter and others. The list include African Violet, Chrysanthemums, Azalea, Cyclamen, and Hydrangea.

The mathematical statement of this group constraint is stated as follows :

$$\frac{\sum_{i=1}^{m} Xn_{ik=B}}{\left(\sum_{i=1}^{m} Xn_{ik=VV} + \sum_{i=1}^{m} Xn_{ik=EE} + \sum_{i=1}^{m} Xn_{ik=MD} + \sum_{i=1}^{m} Xn_{ik=XX}\right)} \quad P_B$$

for all i=1 to m
n=1 to 5

where

Xn_{ik} = Total number of plant units of variety n and pot size i produced for marketing in period k.

PB = Production probability for occasion B.

B = Holiday marketing period, VV=Valentines, EE=Easter, MD= Mother's Day, XX= Christmas.

3.5.2 Linear Programming Models

Several models will be formulated in this study. The base model is designed to find the optimal product mix for a full production year as restricted by only two sets of production constraints, labor and space. The ommission of marketing constraints, whose effect is studied in additional models, will be based on the assumption that the production of the modelled greenhouse is small enough so as not to affect the whole market output. Other minor models will simulate increasing factor costs such as heating, labor, materials, and will account for varying sale prices. This will help to show which input cost has the largest effect on total gross margins. In addition to that, optimal plans will be determined for several periods of the year to compare the profitability of various holidays and seasons. This will help to design production plans for the producers with part time operations.

In other words, these models increase available information that can lead to better decisions, and demonstrate the flexibility in modelling to satisfy various objectives. In summary, optimal plans will be determined for three sets of cases as follows: I) various periods of the year, II) varying input and sale prices, and III) marketing constraints.

I. Various periods which include

1-The whole year. (Main model)

2-The 4 main holidays of the year.

3-The spring period which will be divided into 3 parts:

  A-All Spring Holidays: Valentines, Easter, and Mothers Day

  B-Late Spring Holidays : Easter and Mothers Day.

  C-All spring period extending from Valentines to Mothers Day including the holidays.

4-The winter holidays: Christmas and Valentines

5-Single holidays: Christmas, Valentines, Easter, Mothers Day.

II. Varying input costs and sale prices

1-10 to 40% increase in the costs of heating, labor, and materials. This chosen range is believed to be a possible range of variation for the coming five years.

2-10 to 40% increase in the sale price.

III. Marketing constraints

1-Pot size quota.

2-Holiday quota.

3-Pot size and Holiday Quotas.

Over all, there will be 29 model formulations in the simulated pot flower greenhouse. These are illustrated in a flow chart format in Figures 3.1A and 3.1B.

It should be noted that the formulation and solution of the LP model will be performed using the "Quantitative Systems for Business" (QSB) software package.

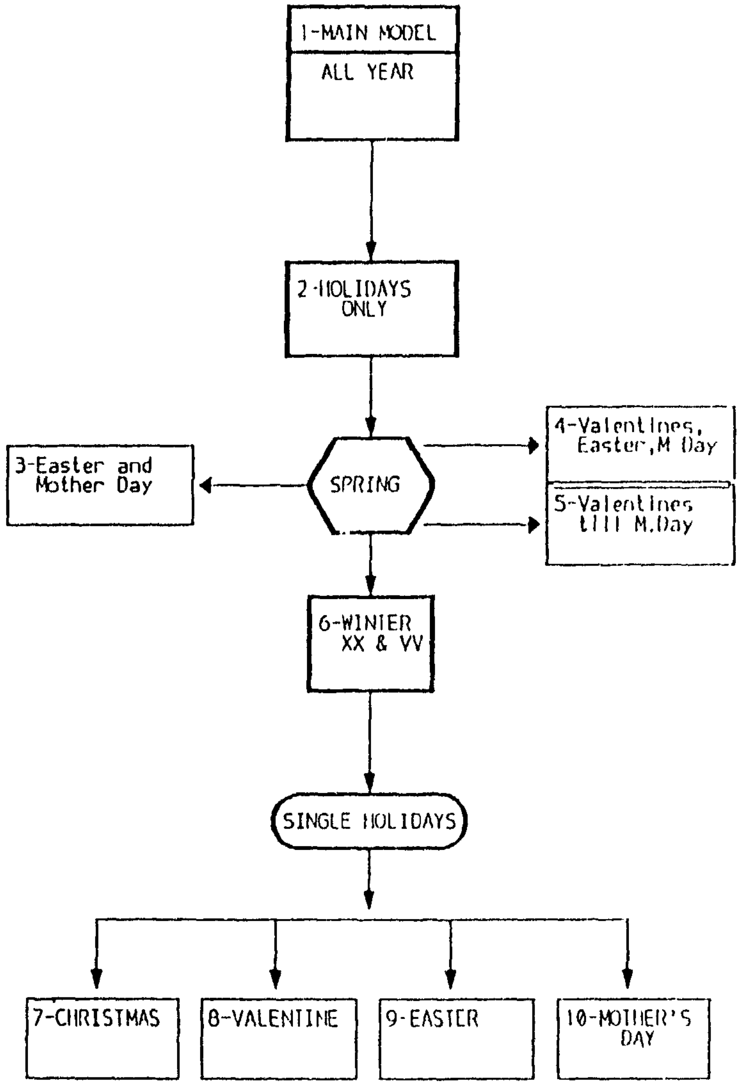


FIGURE 3.1A: FLOW CHART OF OTHER MODELS

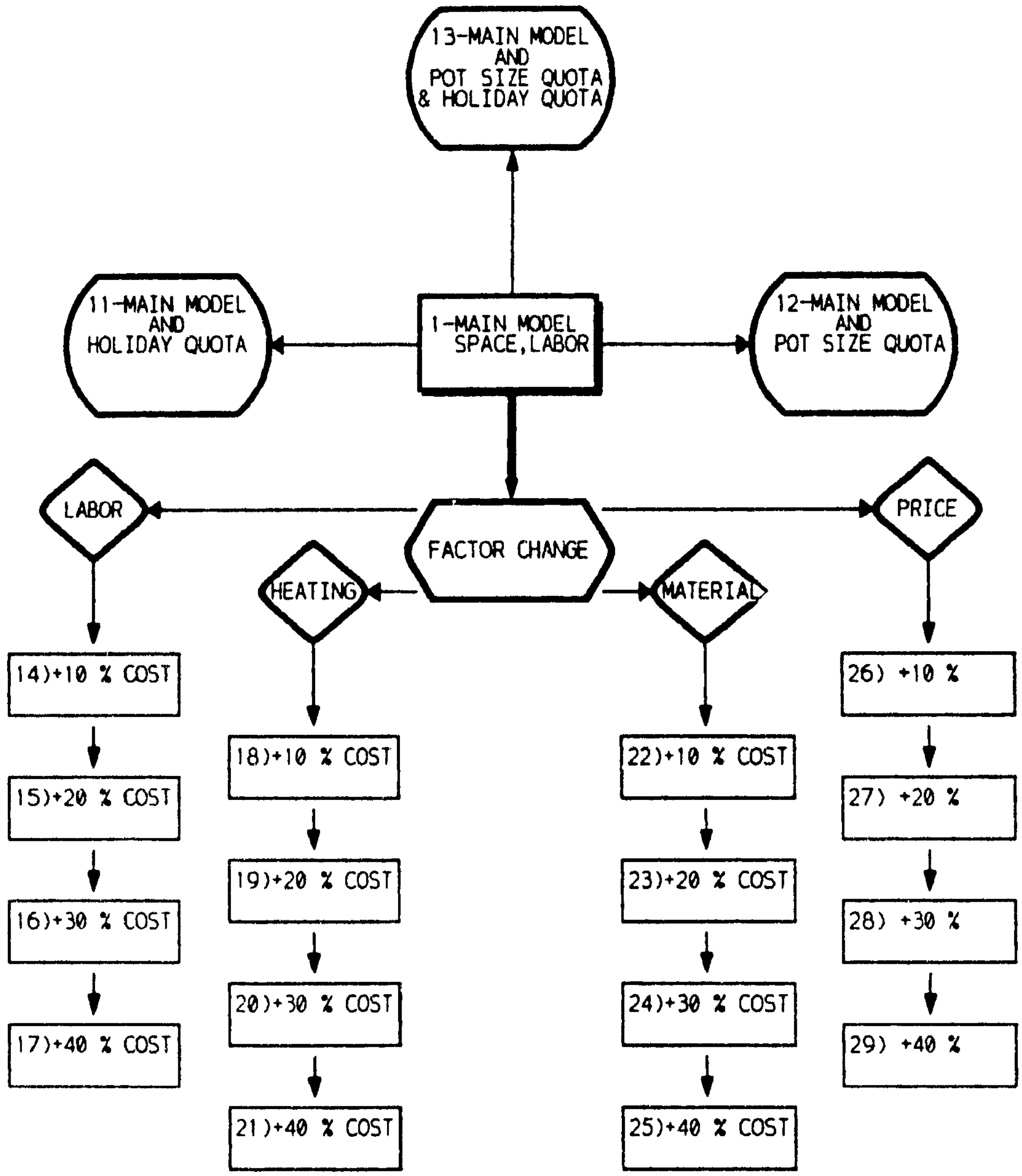


FIGURE 3.1B: FLOW CHART OF OTHER MODELS

3.6 Summary

The simulated model aims to optimize the use of greenhouse space for pot flowers, in order to maximize net profits within the limitations of available space, labor hours, and market restrictions. An optimal production plan will be generated to determine the number of plants of a certain variety and pot size, produced for certain marketing periods. In addition to that, the model will imply some conclusions regarding the following points:

1-The importance of LP as a tool to improve production decisions in the pot flower industry, through a well structured plan, that reflects the level of resource use and productivity. This includes a sensitivity analysis which estimates ranges of net profits and constraint variations that would preserve the optimum plan.

2-The profitability and importance of off-season crops which are produced outside the holiday occasions. This would show whether the market could still be exploited and profits made.

3-The relative profitability of different marketing dates, and production sizes under local conditions.

4-The profitability of pot sizes other than the traditionally demanded ones, which reflects the importance of producing better quality crops, and represents one way of adding value to the crops.

5-The importance of cost accounting which increases the understanding of the factors affecting the profitability equation. This includes a comprehensive knowledge of the input costs involved in production. Such knowledge will reflect inefficiencies, and lead to better control of costs, use of improved production techniques, technologies (mechanization), and marketing practices.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

This chapter will present a discussion of the results obtained from the main linear programming model. This will include the optimum plan of production followed to optimize space use and maximize net returns of pot flowers. In addition to that, a detailed discussion of the plan's sensitivity analysis, which reflects resource productivity, will be presented. Results of other models will be listed and discussed.

4.2 The Optimal Plan of the Main model

The optimal plan shows the optimal combination of plant product mix, to yield the maximum net returns after total variable costs, in the production year.

This plan, listed in Table 4.1, shows the number of plant units produced of certain varieties. However, it should be noted that these figures should be rounded to give complete unit values and not decimal figures, but they were left in this manner for mathematical purposes.

The plan shows that Azalea of pot size 15 cm, produced for Christmas, was the crop with the highest level of production for a single period with 20091 units. On the other hand, Chrysanthemum of pot size 15 cm, marketed in the 23rd period (November 5th) was the plant with the lowest level of production with 101 units. Overall, the plan is composed of three plant varieties with different pot sizes: Geranium, Chrysanthemum and Azalea. Geranium 15 cm, was the plant most widely produced for the year with a total of 37853 units. It was followed by Azalea 15 cm (36048 units), Chrysanthemum 15 cm (16367 units) and 10 cm (3625 units), and Azalea 17.5 cm (3579 units).

The production or sales plan during various periods of

TABLE 4.1: OPTIMAL PRODUCTION PLAN

PLANT VARIETY	POT SIZE (Cm)	PERIOD	QUANTITY (Units)	PLANT VARIETY	POT SIZE (Cm)	PERIOD	QUANTITY (Units)
Geranium	15	3(VV)	8524 55	Chrysanthemum	15	18	4255 51
Geranium	15	6(EE)	8626 19	Chrysanthemum	15	19	1621 74
Geranium	15	8	10532 56	Chrysanthemum	15	21	2135 47
Geranium	15	12	1704 11	Chrysanthemum	15	22	3923 22
Geranium	15	13	8465 08	Chrysanthemum	15	23	100 61
Chrysanthemum	10	24	2453 15	Azalea	15	6(EE)	323 47
Chrysanthemum	10	25	1171 61	Azalea	15	10(MD	15633 88
Chrysanthemum	15	15	3661 21	Azalea	15	26(XX)	20091 08
Chrysanthemum	15	17	669 67	Azalea	17 5	6(EE)	3578 66
OBJECTIVE FUNCTION VALUE = $150,501.10							

VV: Valentines EE: Easter MD Mothers Day XX Christmas

TABLE 4 2: PRODUCTION PLAN FOR DIFFERENT PERIODS

Period	PLANTS (1)					TOTAL (Units)
	Gf	Mt	Mf	Zf	Zs	
1						0
2						0
3(VV)	8524 6					8524 55
4						0
5						0
6(EE)	8626 2			323 5	3578 7	12528 32
7						0
8	10532 6					10532 56
9						0
10(MD)				15633 9		15633 88
11						0
12	1704 1					1704 11
13	8465 1					8465 08
14						0
15			3661 2			3661 21
16						0
17			669 7			669 67
18			4255 5			4255 51
19			1621 7			1621 74
20						0
21			2135 5			2135 47
22			3923 2			3923 22
23			100 6			100 61
24		2453 15				2453 15
25		1171 61				1171 61
26(XX)				20091 1		20091 08
TOTAL	37852 5	3624 8	16367.4	36048 4	3578 7	97471.77
PERCENT	38 83	3 72	16 79	36 98	3 67	100

VV: Valentines EE Easter MD Mothers Day XX Christmas

(1) Gf: Geranium, 15 cm Zf Azalea, 15 cm
Mt: Mums, 10 cm Zs Azalea, 17 5 cm
Mf. Mums, 15 cm

the year is shown in Table 4.2. This table shows the periods with the largest production. In this manner, the Christmas period was the busiest marketing period of the year. Such an illustration could help to allocate the equipments for distribution along with sufficient labor.

The number of plants produced for the optimal plan reflects the relative profitability of those plants, and is also a function of the allocation of available resources and binding constraints during the year. The total net returns of this plan, after subtracting the total variable costs, amounted to 150,501.10 dollars.

This plan will remain valid as long as the values of the objective function, which represent the net returns for a plant unit of a certain variety, remain within the minimum and maximum range as calculated by QSB. The same idea would apply to the range of values of the right hand side, which represent the values of the constraints. The value of these ranges, listed in Appendix E, will be discussed in section 4.4.

4.2.1 Penalty Costs

The computer output, presented in Appendix E, lists the values of the penalty or reduced costs for those decision variables (plant type * pot size * marketing period) which do not appear in the optimal solution. These values represent the amount by which the objective function value would be reduced if the plants were forced to enter the optimal plan. Table 4.3 lists the values of these costs. This table shows that about 44% (48 plants) of the remaining plants (110) would enter the optimum plan if their net returns increase by values up to one dollar (total of the first two columns of Table 4.3).

4.2.2 Costs of the Optimal Plan

The total costs incurred to produce the optimal

TABLE 4 3 VALUES OF OPPORTUNITY COSTS

0-30 cents		31-75 cents		75-150 cents		151-250 cents		251-400 cents		401-700 cents	
Name	Cost	Name	Cost	Name	Cost	Name	Cost	Name	Cost	Name	Cost
Mt 23	0 302	Vt 16	31 18	Mt 1	83 07	Mt 7	152 87	Mt 9	251 45	Hf MD	408 22
Mf 24	1 390	Vt 25	32 95	Bt EE	84 07	Vt EE	154 22	Mf 5	255 14	Hs VV	424 57
Mt 14	2 61	Vt 19	35 45	Zs VV	85 29	Vt 11	158 96	Mf 4	263 30	Cf EE	419 20
Mf 20	6 07	Vt 21	37 31	Gt 8	86 73	Vt VV	163 14	Ct XX	265 35	Hf VV	451 86
Mf 25	7 38	Gf 11	37 58	Vt XX	87 55	Mf XX	174 13	Hs EE	271 50	PNtw	459 42
Mt 22	8 29	M 16	37 65	Gt 12	90 45	PNf	176 69	Mt 11	277 14	Cf MD	531 26
Zs MD	8 49	M 14	38 56	Vt 1	96 27	EL EE	178 76	Mt MD	293 57	PNtf	655 36
Zf VV	9 54	Gt 13	41 21	Vt 2	104 07	Vt 9	180 79	Hs XX	305 29		
Mt 17	9 72	Gt 7	45 79	Bt MD	106 65	Vt MD	180 98	Ct VV	312 01		
Mt 21	9 76	Vt 17	46 00	Vt 5	112 51	Mf 1	187 89	Mf EE	314 06		
Mt 19	12 70	Gf 7	46 47	Vt 8	115 54	Mf 2	190 53	Mf 9	321 03		
Mt 18	15 48	Bf MD	53 26	Gt EE	119 56	Vt 7	191 88	Cf XX	324 68		
Mt 15	16 70	Gf MD	53 47	Gt 11	121 34	Mt 4	198 02	Hf EE	331 52		
Mt 20	19 20	Gf 9	54 74	Vt 4	121 35	Mf 8	200 72	Mf 11	331 79		
Vt 20	23 07	Vt 14	63 28	Vt 13	121 55	Mt 12	206 61	Ct EE	339 33		
Vt 18	23 69	Gt VV	67 78	Mt 13	125 20	Mt 5	209 97	Mf MD	354 07		
Vt 22	24 16	Zs XX	72 27	Mf 13	130 33	Mt EE	230 03	Hs MD	363 28		
Vt 15	26 05	M 2	73 30	Vt 12	130 99	Mf 7	242 40	Hf XX	364 73		
Vt 23	27 60	M XX	73 87	Gt MD	133 96	Mf 12	245 64	Cf VV	387 58		
Vt 24	27 94			Mt VV	134 00	Mf VV	245 75	Ct MD	397 24		
Mf 16	28 52			Mt 8	148 77						
Bf EE	28 87			Gt 9	148 96						
COUNT T	22		19		22		20		20		7

• EXPLANATION OF VARIABLES SYMBOLS

I First letter indicates plant variety

A African Violet	B Begonia	C Cyclamen	EL Easter Lily
G Geranium	H Hyadrangea	M Chrysanthemum	Z Azalea

II Second letter indicates pot size

f Fifteen cm	t Ten cm	s Seventeen & half cm

III Last two letters/digits indicate marketing period

EE Easter	MD Mother's Day	VV Valentines	XX Christmas

IV Other Notations

ELEE Easter Lily for Easter	PNf Poinsettia fifteen cm
PNtw Poinsettia twenty cm	PNtf Poinsettia twenty five cm

TABLE 4.4 INPUT COSTS OF OPTIMAL PLAN PER PLANT VARIETY

(Xi)	QUANTITY (Units)	%	LABOR COST $	% (2)	MATERIAL COST $	% (2)	HEATING COST $	% (2)	NET REVENUES(1) $	% (3)
GI8	10532.56	10.8	3788.56	9.35	14745.59	4.72	1614.64	7.07	13821.88	9.18
GI12	1704.11	1.75	612.97	1.51	2385.75	0.76	94.07	0.41	2403.47	1.60
GI13	8465.08	8.68	3044.89	7.51	11851.11	3.79	319.98	1.40	12086.44	8.03
GIEE	8626.19	8.85	3102.84	7.66	12076.67	3.86	1870.16	8.19	12236.25	8.13
GIVV	8524.55	8.75	3066.28	7.56	11934.37	3.82	2283.73	10.00	11656.47	7.75
MI24	2453.15	2.52	1472.87	3.63	1925.72	0.62	316.46	1.39	1371.31	0.91
MI25	1171.61	1.20	703.43	1.74	919.71	0.29	193.32	0.85	612.75	0.41
MI15	3661.21	3.76	2646.69	6.53	7148.50	2.29	172.08	0.75	3527.94	2.34
MI17	669.67	0.69	484.10	1.19	1307.53	0.42	14.46	0.06	662.30	0.44
MI18	4255.51	4.37	3076.31	7.59	8308.89	2.66	86.39	0.38	4214.23	2.80
MI19	1621.74	1.66	1172.36	2.89	3166.45	1.01	52.54	0.23	1586.39	1.05
MI21	2135.47	2.19	1543.73	3.81	4169.50	1.33	179.17	0.78	1978.94	1.31
MI22	3923.22	4.02	2836.10	7.00	7660.09	2.45	522.18	2.29	3442.63	2.29
MI23	100.61	0.10	72.73	0.18	196.45	0.06	18.96	0.08	82.72	0.05
ZIEE	323.47	0.33	105.00	0.26	1793.64	0.57	164.97	0.72	603.40	0.40
ZIMD	15633.88	16.0	5074.76	12.52	86689.87	27.73	3978.82	17.41	33157.90	22.03
ZIXX	20091.08	20.6	6521.57	16.09	111405.1	35.64	7869.68	34.44	39854.68	26.48
ZsEE	3578.66	3.67	1208.16	2.98	24943.29	7.98	3095.90	13.55	7201.34	4.78
TOTAL	97471.8	100	40533.3	10.8	312628.2	83.1	22847.5	6.1	150501.1	100.0

(1) NET REVENUES = TOTAL REVENUES - TOTAL VARIABLE COSTS

(2) PERCENTAGE IS THE PLANT'S SHARE FROM TOTAL INPUT COSTS

(3) PERCENTAGE IS THE PLANT'S SHARE FROM TOTAL NET REVENUES

EXPLANATION OF VARIABLES SYMBOLS

I First letter indicates plant variety			
G Geranium	M Chrysanthemum	Z Azalea	
II Second letter indicates pot size			
I Fifteen cm	t Ten cm	s Seventeen & half cm	
III Last two letters/digits indicate marketing period			
EE Easter	MD Mother's Day	VV Valentines	XX Christmas

combination of plants, is listed in Table 4.4. This table, which helps to show the cost structure of the optimal plan, is important as it shows the distribution of labor, material, and heating costs among different plant varieties. It was concluded that Azalea 15 cm, produced for Christmas (SfXX), had the higher percentages of input costs and net returns. This could be justified since this plant was the one produced in the largest quantity for a single period.

The same information can be displayed in a different pattern. This is shown in Table 4.5 which presents a financial plan per period for the optimal product mix. This plan shows the distribution of input costs, namely labor, heating, and material costs between different periods. In this manner, it was shown that except for a few periods, material costs constituted the largest share of expenses among input costs in most periods.

Moreover, this plan will help to indicate periods with maximum and minimum total variable input costs and returns. This table shows that the largest percentage (30.5%) of the total input costs was incurred in period 22, which falls between October 22 and November 4, while the lowest percentage (0.3%) was incurred in periods 9, 15, and 21. As for net revenues, the largest figure, 163,560.10 dollars, was generated in the Christmas period (26). This is justified since Azalea 15 cm, the plant with the largest number of units, was produced for that period. It should be noted that the sum of the total revenues, reported in Table 4.5, was 0.16% greater than the value reported in the optimal plan. This was attributed to minor calculation errors which resulted from the process of rounding off at various stages. Figure 4.1 shows the variation of net returns during different periods of the year. The distribution of total input costs in the optimal plan, listed in the last row of Tables 4.4 and 4.5, indicates that material costs comprised the largest share of input costs with a 83.09 % share. This

TABLE 4 5: FINANCIAL PLAN FOR THE OPTIMAL PLAN PER PERIOD

Period	LABOR COST(1)	% (4)	HEATING COST(2)	% (4)	MATERIAL COST(3)	% (4)	TOTAL COSTS	% (5)	NET REVENUES	% (5)
1	1320 00	3 35	1042 16	2 65	37019 95	94 00	39382 11	10 5	-39382 11	-26.2
2	1320 00	26 71	1828 41	37 00	1793 64	36 29	4942 05	1 3	-4942 05	-3 29
3(VV)	1866 41	10 30	1515 14	8 36	14745 59	81 35	18127 14	4 8	10613 72	7 20
4	1632 73	51 44	1541 56	48 56	0 00	0 00	3174 29	0 8	-3174 29	-2 11
5	2200 00	2 42	2078 60	2.28	86689 87	95 30	90968 47	24 2	-90968 47	-60 5
6(EE)	2200 00	54 46	1839 87	45 54	0 00	0 00	4039 87	1 1	64361 75	42 84
7	2200 00	38 85	1077 64	19 03	2385 75	42 13	5663 39	1 5	-5663 39	-3 77
8	2200 00	14 65	961 60	6 41	11851 11	78 94	15012 71	4 0	18957 97	12 62
9	876 24	76 66	266 81	23 34	0 00	0 00	1143 05	0 3	-1143 05	-0 76
10(MD)	1323 69	15 41	120 77	1 41	7148 50	83 19	8593 16	2 3	120308 19	80 07
11	1459 47	89 72	167 18	10 28	0 00	0 00	1626.64	0 4	-1626 64	-1 08
12	1320 00	49 13	59 42	2 21	1307 53	48.66	2686 94	0 7	2809 31	1.87
13	1241 81	12.95	42 17	0 44	8308 89	86 62	9592 87	2 5	17709 55	11 79
14	1320 00	29.26	24 39	0.54	3166 45	70 20	4510 84	1 2	-4510 84	-3.00
15	1294 21	98 64	17 87	1.36	0 00	0 00	1312.08	0 3	12183 13	8 11
16	1320 00	23 86	43 76	0.79	4169 50	75 35	5533 26	1.5	-5533 26	-3 68
17	1320 00	14 60	60 42	0.67	7660 09	84 73	9040.51	2 4	-6572 12	-4 37
18	1320 00	80 49	123 49	7.53	196 45	11 98	1639 94	0 4	14045 88	9 35
19	1320 00	39 07	132 72	3 93	1925 72	57.00	3378 45	0 9	2599 29	1 73
20	1320 00	52 29	284 59	11.27	919 71	36.43	2524 30	0 7	-2524 30	-1 68
21	877 86	73 18	321 67	26.82	0 00	0 00	1199.53	0 3	6671 81	4 44
22	2039 18	1.78	1321.20	1.15	111405.1	97 07	114765 4	30 5	-100304 5	-66 8
23	2200 00	53.01	1950 04	46 99	0 00	0 00	4150 04	1 1	-3779 18	-2 52
24	1743 38	46 51	2005 11	53.49	0 00	0 00	3748 48	1.0	1337 88	0 89
25	2200 00	12 64	3274 60	18 81	11934.37	68.55	17408.97	4 6	-14979.77	-9 97
26(XX)	1186.99	56.77	903 91	43 23	0 00	0.00	2090 90	0 6	163560 09	108 9
TOTAL	40622.2	10.80	23005.11	6.11	312628.2	83.09	376255.5	100	T50254 62	100

1 · LABOR COST DEPEND ON LABOR HOURS USED PER PLANT PER PERIOD

2 · HEATING COST DEPEND ON AREA USED PER PLANT PER PERIOD

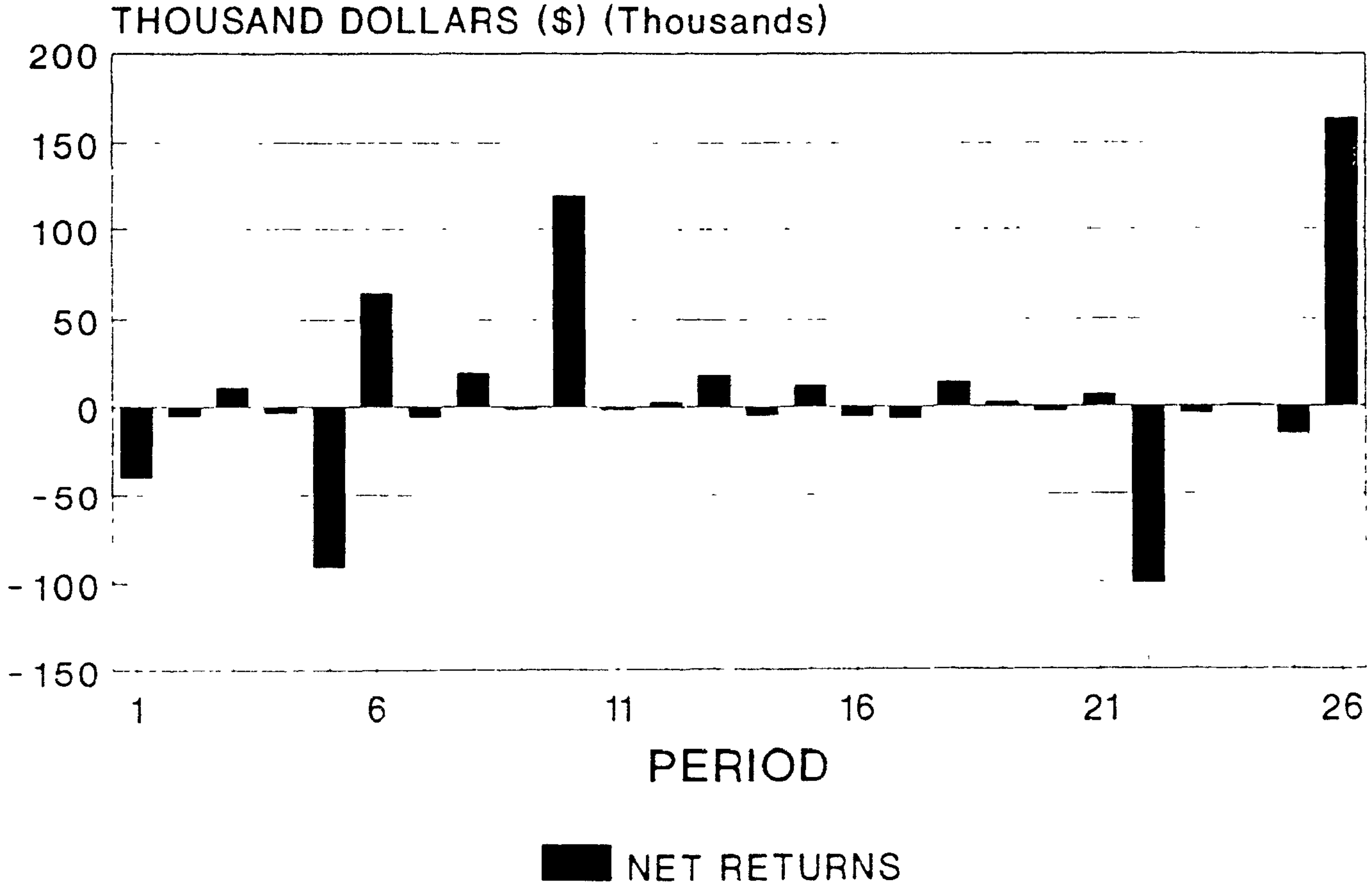
3 · MATERIAL COST FOR EACH PLANT IS TOTALLY ADDED AT PLANTING TIME

4 . SHOWS PERCENTAGE AMONG TOTAL INPUT COSTS PER PERIOD

5 . SHOWS PERCENTAGE OF EACH PERIOD PER TOTAL YEARLY REVENUES

VV: VALENTINES EE. EASTER MD: MOTHERS DAY XX: CHRISTMAS

FIGURE 4.1: NET RETURNS PER PERIOD IN THE OPTIMAL PLAN



was followed by labor (10.8%), and heating costs (6.11%). The distribution of input costs in the optimal plan is shown in Figures 4.2 to 4.4.

4.3 <u>Resource Use and Opportunity Costs</u>

The optimum production plan satisfied the objective function subject to the constraints of available resources and other marketing restrictions for all periods. In this manner, production resources, such as labor and space, were used at various levels for different periods. These levels calculated by QSB, were listed in the model output presented in Appendix E. This is also shown in Tables 4.6 and 4.7. The first two tables show the space area used per period to produce each plant variety included in the optimal plan. This detailed illustration is helpful to show space distribution among different varieties along the year. In addition to that, Table 4.6 presents the total space used per period. This shows that except for few periods (5,22, and 25), the greenhouse space was not fully exploited. This vacant space could be used for other filling plants such as house plants, however, labor availability and costs in addition to material costs have to be taken into consideration since the optimal plan will be changed. It was noted that space was least used in the Christmas and new year period (26th) because this period is characterized by high heating costs.

Table 4.7 show the level of labor hours used per period for the plants included in the optimal plan. This indicated that Azalea 15 cm produced for Christmas, required the greatest amount of labor hours during the year. This amounted to 1185.9 hours and represented 16.06% of the total labor hours used during the year. On the other hand, Chrysanthemum 15 cm, produced for the 23rd period, used the least number of labor hours at a rate of 13.32 hours which represented 0.18%. It was also observed that the available labor hours constraint was binding in more periods than the available

FIGURE 4.2 : HEATING COSTS PER PERIOD IN THE OPTIMAL PLAN

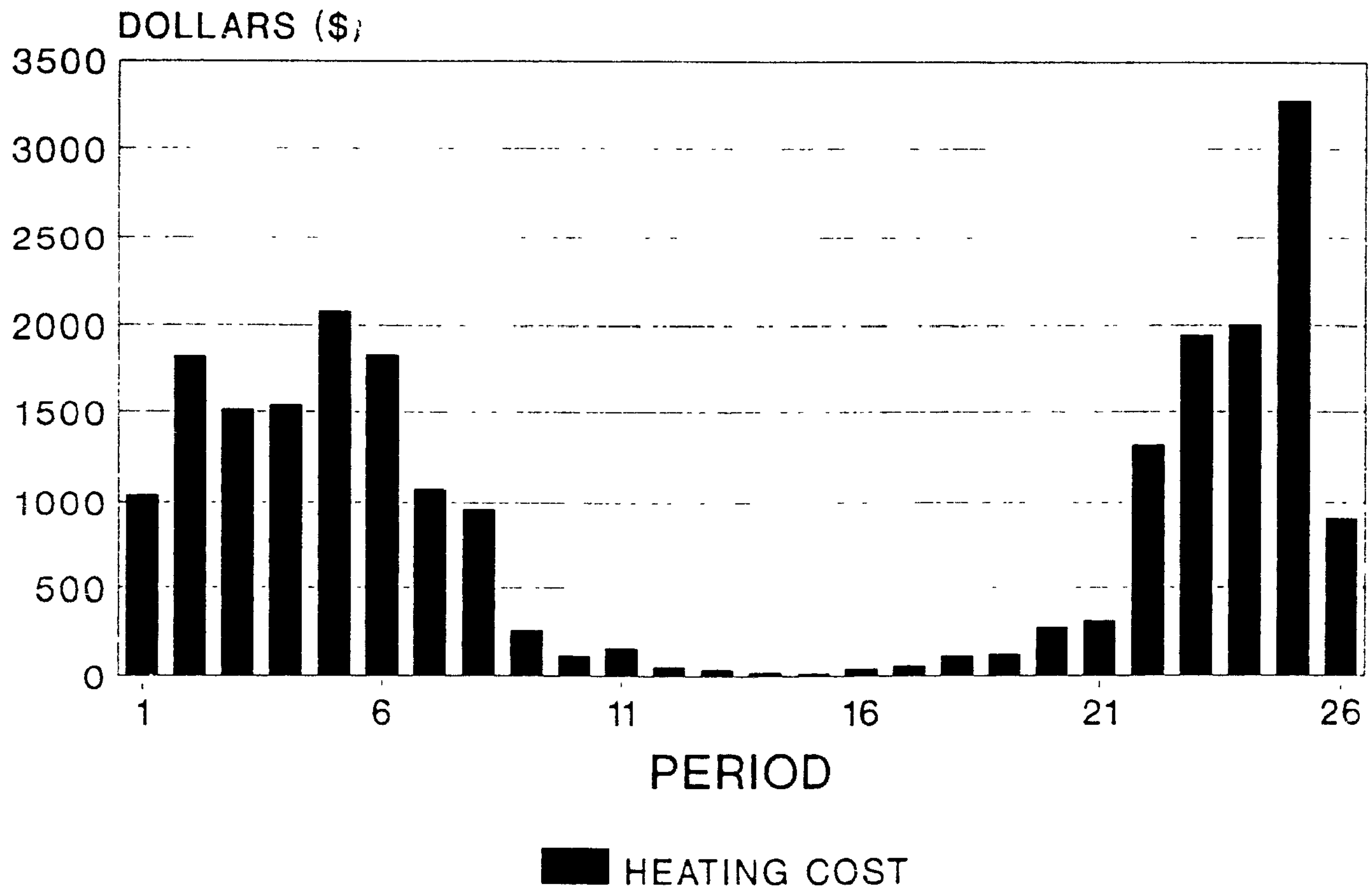


FIGURE 4.3 : LABOR COSTS PER PERIOD IN THE OPTIMAL PLAN

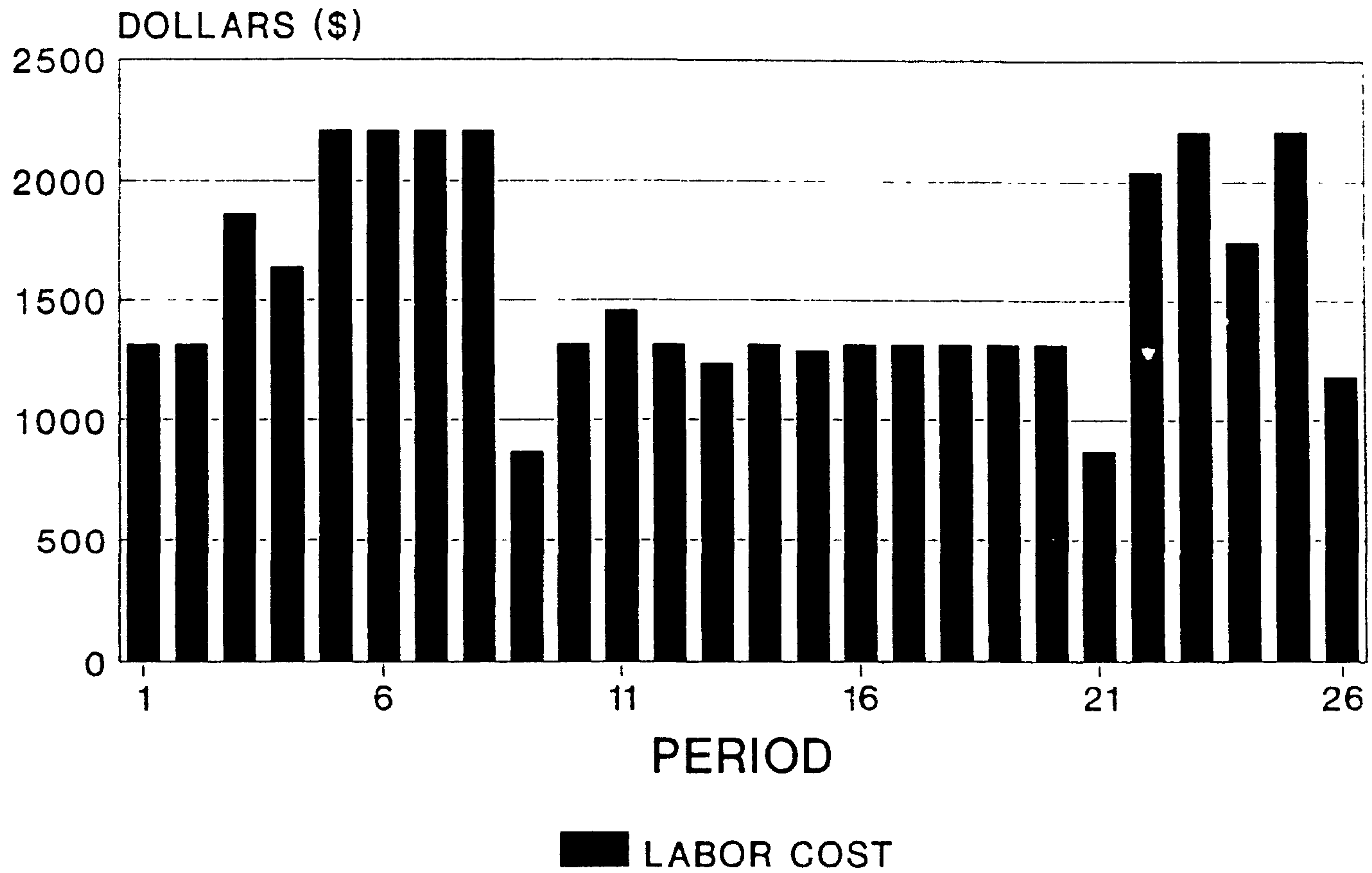


FIGURE 4.4: MATERIAL COSTS PER PERIOD IN THE OPTIMAL PLAN

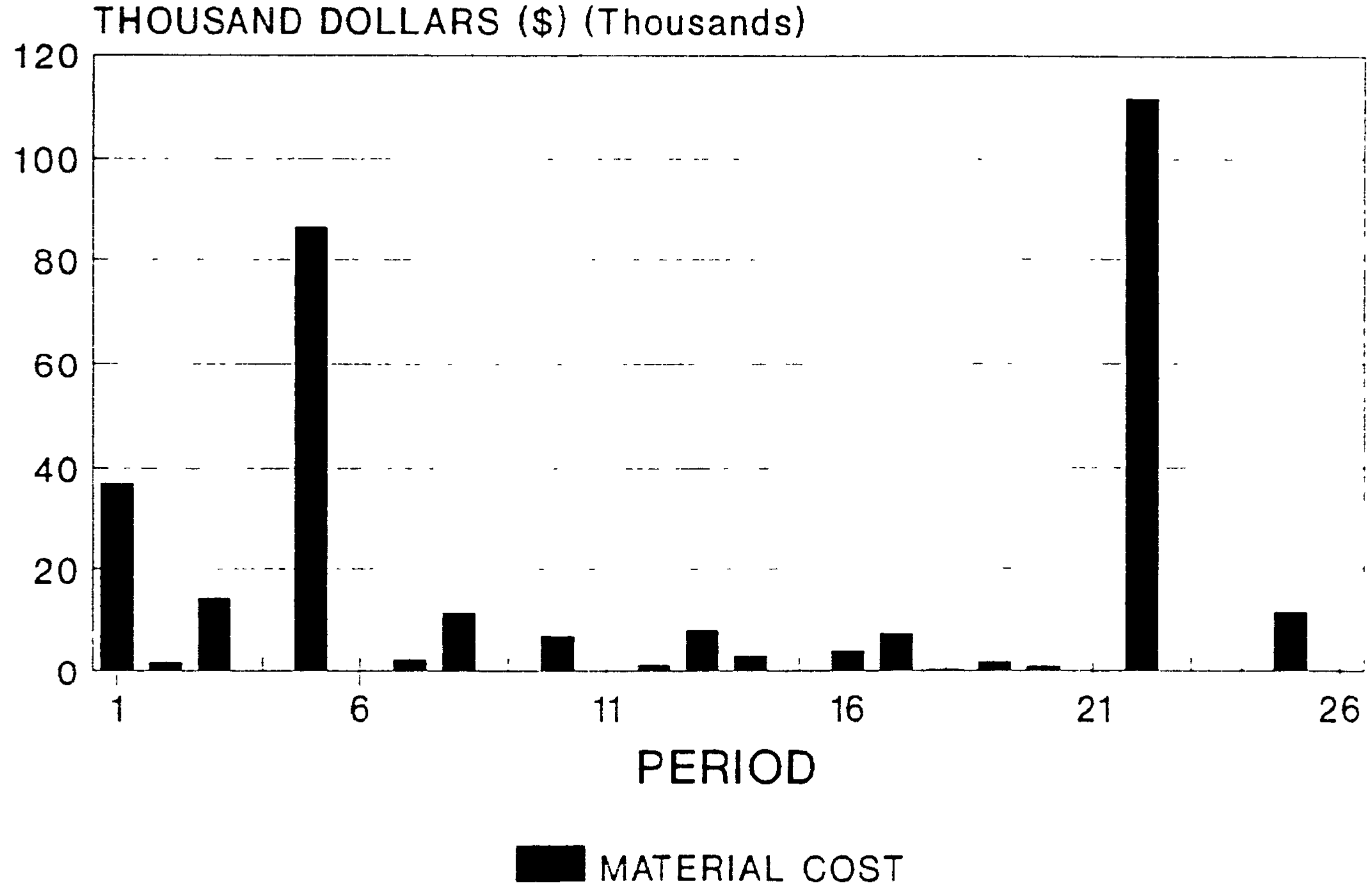


TABLE 4 6 GREENHOUSE AREA USED (Sq Meters) PER PERIOD FOR PLANTS IN THE OPTIMAL PLAN

PERIOD	Mt24	Mt25	Mf15	Mf17	Mf18	Mf19	Mf21	Mf22	Mf23	ZfEE	ZfMD	ZfXX	ZsEE	GfVV	GfEE	Gf8	Gf12	Gf13	TOTAL	% (1)
1													143 15	340 98	97 04				581 17	29 06
2										29 11			501 01	340 98	194 09				1065 20	53 26
3(VV)										29 11			501 01		345 05	118 49			993 66	49 68
4										29 11			501 01		345 05	236 98			1112 16	55 61
5										29 11	703 52		501 01		345 05	421 30			2000 00	100 00
6(EE)											1407 05					421 30			1828 35	91 42
7											1407 05					421 30	38 34		1866 69	93 33
8											1407 05						68 16	190 46	1665 68	83 28
9											1407 05						68 16	338 60	1813 82	90 69
10(MD)			82 38														68 16	338 60	489 14	24 46
11			384 43														68 16	338 60	791 19	39 56
12			384 43	15 07														338 60	738 10	36 90
13			384 43	70 32	95 75														550 49	27 52
14			384 43	70 32	446 83	36 49													938 06	46 90
15				70 32	446 83	170 28													687 43	34 37
16				70 32	446 83	170 28		48 05											735 47	36 77
17					446 83	170 28		224 22	88 27										929 61	46 48
18						170 28		224 22	411 94										808 71	40 44
19	12 27							224 22	411 94										658 99	32 95
20	122 66	5 86						224 22	411 94										775 24	38 76
21	122 66	58 58							411 94										603 74	30 19
22	122 66	58 58										1808 20							2000 00	100 00
23	122 66	58 58										1808 20							1999 44	99 47
24		58 58										1808 20							1866 78	93 34
25												1808 20		191 80					2000 00	100 00
26(XX)														340 98					340 98	17 05

(1) % INDICATES AREA USED FRON TOTAL GREENHOUSE PLANTING AREA

VV VALENTINES EE EASTER MD MOTHERS DAY XX CHRISTMAS

TABLE 4 7 . LABOR USE (Hours) PER PERIOD FOR PLANTS IN THE OPTIMAL PLAN

PERIOD	Mt24	Mt25	Mf15	Mf17	Mf18	Mf19	Mf21	Mf22	Mf23	ZIEE	ZIMD	ZIXX	ZsEE	GIVV	GIEE	GI8	GI12	GI13	TOTAL	%(2)
1												-	23 36	118 40	98 24				240 00	100 00
2										4 13			41 75	98 27	95 85				240 00	100 00
3(VV)										5 48			63 12	14 21	136 58	119 95			339 35	84 84
4										4 85			55 17		113 81	117 03			296 86	74 21
5										4 09	93 88		29 82		99 44	156 77			400 00	100 00
6(EE)										0 54	232 34		6 46		14 38	146 29			400 00	100 00
7											249 71					21 42	28 88		400 00	100 00
8											216 05					7 55	22 96	143 44	400 00	100 00
9											98 80						13 49	47 03	159 32	79 66
10(MD)			56 35								26 06						23 67	34 03	240 71	60 18
11			128 14														13 64	117 57	265 36	66 34
12			129 16	10 42													2 84	97 58	240 00	100 00
13			122 04	23 44	66 20													14 11	225 78	94 08
14			42 21	73 62	146 94	25 23													240 00	100 00
15			6 10	22 32	150 13	56 76													235 31	98 05
16				7 72	141 85	57 21	33 22												240 00	100 00
17				1 12	49 06	54 06	74 74	61 00											240 00	100 00
18					7 09	18 70	75 03	107 01	1 57										240 00	100 00
19	24 ,9					2 10	71 8	109 40	0 52										240 00	100 00
20	59 5	1 55					24 62	100 77	0 55										240 00	100 00
21	74 28	33 20					0 56	45 00	0 05										159 5	66 50
22	70 57	05 47						6 54	[illegible]			256 72							370 75	92 69
23	25 55	00 55							[illegible]			340 40							400 00	100 00
24	0 41	2 20										301 07							316 98	79 24
25		50										253 93		144 44					400 00	100 00
26(XX)												33 49		82 33					215 82	53 95
TOTAL	257 80	127 90	484 60	88 64	563 26	214 66	282 55	519 28	10 02	19 09	922 83	1185 93	219 69	557 55	564 00	669 01	111 48	553 76	7385 85	
PERCENT1	0 60	1 73	6 56	1 20	7 60	2 91	3 83	7 00	0 8	0 26	12 49	16 06	2 97	7 55	7 64	9 03	1 51	7 50	100 00	

(1) PERCENT FROM ALL YEAR TOTAL

(2) % FROM TOTAL AVAILABLE LABOR HOURS PER PERIOD

VV VALENTINES EE EASTER MD MOTHERS DAY XX CHRISTMAS space constraint. In this manner, labor was fully used in 15 of the 26 periods per year as compared to 3 periods for space. This is also shown in Table 4.8 which lists the amount of surplus labor hours and space area in real figures and percentage forms. This indicates that maximum labor and space surpluses were found in period 26. On the other hand, minimum labor and space surpluses, were found in periods 15 and 23 respectively. This is also shown in Figures 4.5 and 4.6 which illustrate respectively the usage level of greenhouse area and labor hours per period in the optimal plan.

4.3.1 Opportunity Costs

The QSB output, present in Appendix E, lists the values of the opportunity costs or dual prices for the maximum available resources or right hand side values. This gives the rate of improvement in the objective function value as the level of available constraint is increased by one unit keeping all other resources fixed. In other words, this price reflects the marginal value product from a unit increase in the resource. The dual prices of the labor constraints, shown in Table 4.8, indicate that a one hour increase in available labor for the second period, would yield the maximum value of 78.76 dollars to increase the objective function. This is much higher than the hourly labor wage (5.5 dollars), and hence additional labor should be hired since marginal revenue (MR) is larger than marginal cost (MC). The same conclusion of hiring additional labor could still be valid for 11 additional periods since MR > MC for these periods. However, changing the level of labor hours would increase the value of the objective function as long as the level of resource change would still fall within the ranges of sensitivity analysis for the optimal plan. These ranges will be discussed in the next section. It should be noted that a zero dual price would reflect a non-binding or surplus constraint.

As for space which was fully used for only three periods,

TABLE 4.8: LABOR AND SPACE SURPLUS WITH DUAL PRICE PER PERIOD

LABOR				SPACE			
Period	Surplus (hours)	% *	Dual Price (dollars)	Period	Surplus (sq m)	% *	Dual Price (dollars)
1	0 00	0 00	1 57	1	1418 83	70 94	0 00
2	0 00	0 00	78 76	2	934 80	46 74	0 00
3(VV)	60 65	15 16	0 00	3(VV)	1006 34	50 32	0 00
4	103.14	25 79	0 00	4	887 84	44 39	0 00
5	0.00	0 00	20 76	5	0 00	0 00	6 21
6(EE)	0.00	0 00	22 79	6(EE)	171 65	8 58	0 00
7	0 00	0 00	26 41	7	133 31	6 67	0 00
8	0.00	0 00	68 63	8	334 32	16 72	0 00
9	40 68	20 34	0 00	9	186 18	9 31	0 00
10(MD)	159.29	39 82	0 00	10(MD)	1510 86	75 54	0 00
11	134 64	33 66	0 00	11	1208 81	60 44	0 00
12	0 00	0 00	22 97	12	1261 90	63 10	0 00
13	14 22	5 92	0 00	13	1449 51	72 48	0 00
14	0.00	0 00	13.28	14	1061 94	53 10	0 00
15	4 69	1 95	0 00	15	1312 57	65 63	0 00
16	0 00	0 00	13 32	16	1264 53	63 23	0 00
17	0.00	0.00	5 68	17	1070 39	53 52	0 00
18	0 00	0 00	9 58	18	1191 29	59 56	0 00
19	0 00	0 00	1 22	19	1341 01	67 05	0 00
20	0 00	0.00	12 32	20	1224 76	61 24	0 00
21	80 39	33.50	0.00	21	1396 26	69 81	0 00
22	29.24	7.31	0 00	22	0 00	0 00	1 69
23	0.00	0 00	10 88	23	10 56	0 53	0 00
24	83 02	20 76	0 00	24	133 22	6 66	0 00
25	0 00	0 00	1 89	25	0 00	0 00	18 04
26(XX)	144.18	40 05	0 00	26(XX)	1659 02	82 95	0 00

* · PERCENTAGE FROM AVAILABLE

VV: VALENTINES EE: EASTER MD MOTHERS DAY XX CHRISTMAS

FIGURE 4.5: USE OF GREENHOUSE PLANTING AREA PER PERIOD

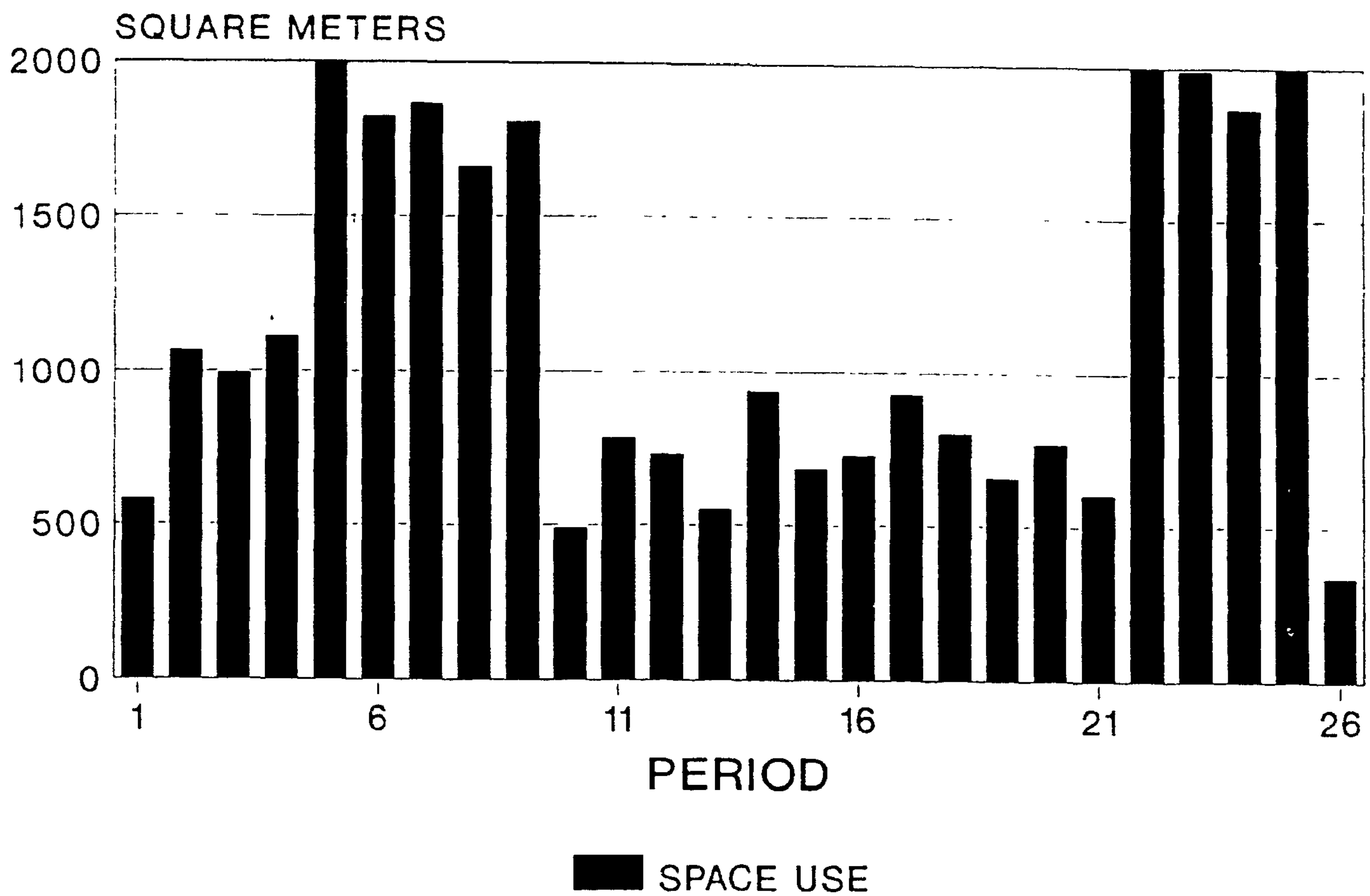
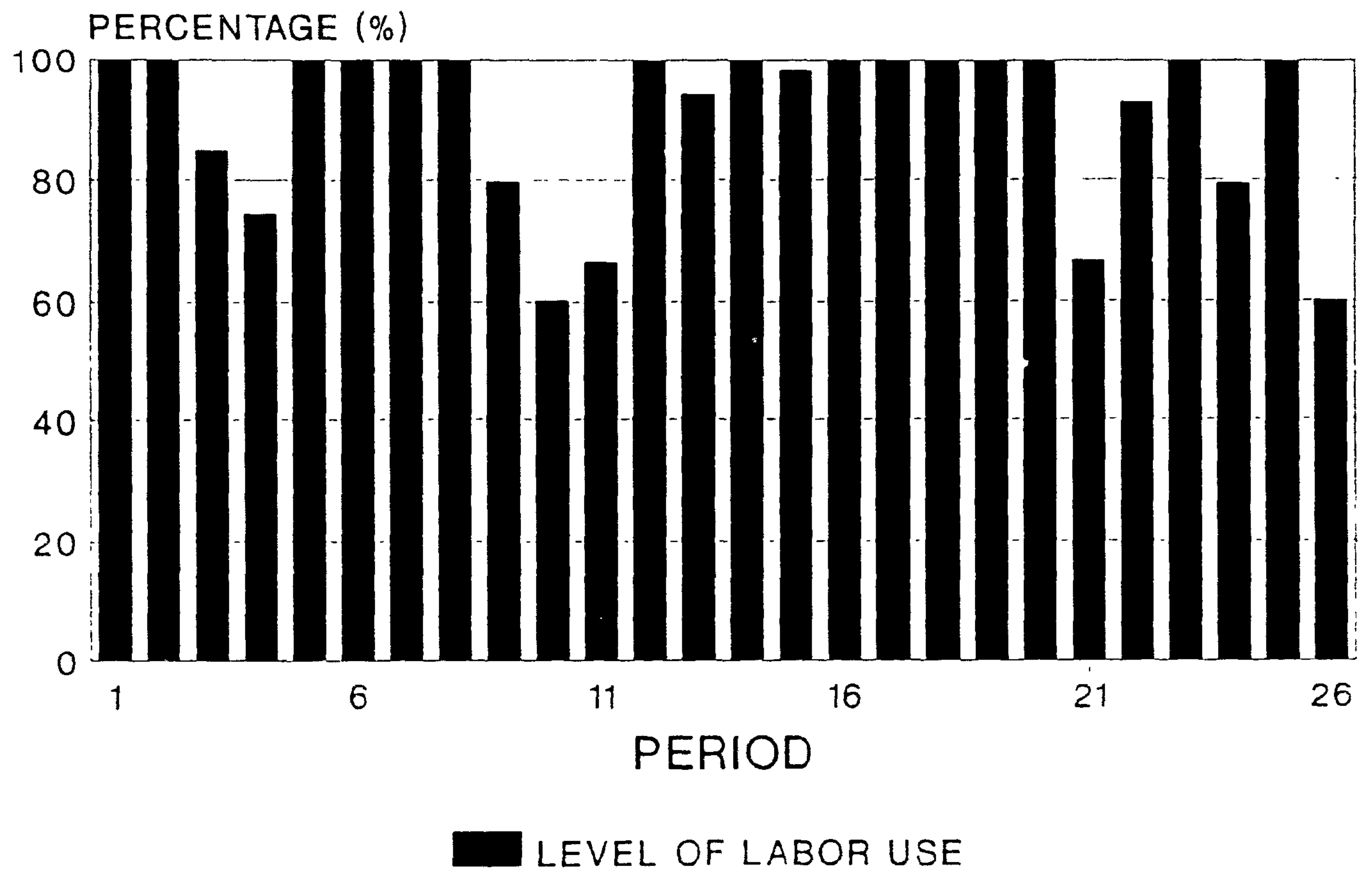


FIGURE 4.6: LEVEL OF LABOR HOURS USED PER PERIOD



it was concluded that the maximum dual prices or returns per additional square meter were found to be 18.04 dollars in the 25th period. Other lower returns were calculated at 6.21 dollars for the fifth period, and 1.69 dollars for the 22nd period. Therefore renting or buying additional space for planting would be a profitable decision, if total returns exceeded the cost. However, in this case, additional factors have to be considered such as land availability, location, and fixed costs.

4.4 Sensitivity Analysis

Sensitivity analysis, or post-optimality analysis, shows the range over which the optimum production plan remains optimal. This analysis helps the management to increase the level of certainty facing any changes in the coefficients of the objective function which represent net revenues, or changes in the right hand side or constraint levels.

In other words, finding the allowable maximum and minimum ranges reflects how sensitive is the optimal solution to data changes. The allowable ranges for available labor are presented in Table 4.9. This indicated that the minimum allowable range for labor varied between -40.05% in the 26th period, as compared to the original available limit, to -0.91% in the 19th period. As for the maximum allowable range, it varied between +1.08% for the 23rd period to +infinity for several periods.

Table 4.10 shows the sensitivity analysis range for available space area. The minimum allowable limit ranged from -0.34% in the 22nd period to -82.95% for the 26th period. However, the maximum limit of space was found to be more flexible, as 24 of the 26 periods were at +infinity. The sensitivity analysis for the objective function values are listed in Tables 4.11 A and 4.11B. These show the allowable change in the net profits for every plant, keeping all other data fixed, to keep the optimal plan valid, or in other

TABLE 4.9: SENSITIVITY ANALYSIS FOR AVAILABLE LABOR HOURS IN RHS *

Period	Minimum Limit	%	Original Limit	Maximum Limit	%
1	157 57	-34 35	240	243 43	1 43
2	237 17	-1 18	240	267 90	11 63
3	339 35	-15 16	400	+ INFINITY	+ INFINITY
4	296 86	-25 79	400	+ INFINITY	+ INFINITY
5	367 49	-8 13	400	420 49	5 12
6	380 35	-4 91	400	419 16	4 79
7	371 12	-7 22	400	465 24	16 31
8	360 16	-9 96	400	418 95	4 74
9	159 32	-20 34	200	+ INFINITY	+ INFINITY
10	240 71	-39 82	400	+ INFINITY	+ INFINITY
11	265 36	-33 66	400	+ INFINITY	+ INFINITY
12	227 11	-5 37	240	261 25	8 85
13	225 78	-5 92	240	+ INFINITY	+ INFINITY
14	229 52	-4 37	240	243 73	1 55
15	235 31	-1 95	240	+ INFINITY	+ INFINITY
16	231 60	-3 50	240	247 40	3 08
17	230 11	-4 12	240	245 64	+ INFINITY
18	237 51	-1 04	240	243 10	1 29
19	237 81	-0 91	240	244 36	1 82
20	161 48	-32 72	240	250 45	4 36
21	159 61	-33 50	240	+ INFINITY	+ INFINITY
22	370 76	-7 31	400	+ INFINITY	+ INFINITY
23	394 18	-1 45	400	404 34	1 08
24	316 98	-20 76	400	+ INFINITY	+ INFINITY
25	394 05	-1 49	400	408 28	2 07
26	215 82	-40 05	360	+ INFINITY	+ INFINITY

* TIME UNITS WERE CHANGED TO HOURS

TABLE 4.10: SENSITIVITY ANALYSIS FOR AVAILABLE GREEN HOUSE AREA IN SQUARE METERS

Period	Minimum Limit	%	Original Limit	Maximum Limit	%
1	581.1732	-70 94	2000	+Infinity	+Infinity
2	1065 196	-46 74	2000	+Infinity	+Infinity
3	993 6641	-50 32	2000	+Infinity	+Infinity
4	1112 155	-44 39	2000	+Infinity	+Infinity
5	1718 987	-14 05	2000	2061 26	3 06
6	1828 351	-8 58	2000	+Infinity	+Infinity
7	1866 694	-6 67	2000	+Infinity	+Infinity
8	1665 678	-16 72	2000	+Infinity	+Infinity
9	1813 816	-9 31	2000	+Infinity	+Infinity
10	489 1446	-75 54	2000	+Infinity	+Infinity
11	791 1940	-60 44	2000	+Infinity	+Infinity
12	738 0972	-63 10	2000	+Infinity	+Infinity
13	550 4908	-72 48	2000	+Infinity	+Infinity
14	938 0598	-53 10	2000	+Infinity	+Infinity
15	687 4267	-65 63	2000	+Infinity	+Infinity
16	735 4747	-63 23	2000	+Infinity	+Infinity
17	929 6082	-53 52	2000	+Infinity	+Infinity
18	808 7068	-59 56	2000	+Infinity	+Infinity
19	658 9926	-67 05	2000	+Infinity	+Infinity
20	775 2425	-61 24	2000	+Infinity	+Infinity
21	603 7406	-69 81	2000	+Infinity	+Infinity
22	1993 218	-0 34	2000	2012 51	+Infinity
23	1989 435	-0 53	2000	+Infinity	+Infinity
24	1866 777	-6 66	2000	+Infinity	+Infinity
25	1984 509	-0 77	2000	2007 83	0 39
26	340 9820	-82 95	2000	+Infinity	+Infinity

TABLE 4 11A SENSITIVITY ANALYSIS FOR OBJECTIVE FUNCTION

(Xi)	Minimum Limit	Original Coefficient	Maximum Limit	(Xi)	Minimum Limit	Original Coefficient	Maximum Limit
Vt 1	-Infinity	-5 97	90 30	Mt 7	-Infinity	43 20	196 08
Vt 2	-Infinity	-9 32	94 76	Mt 8	-Infinity	47 99	196 76
Vt VV	-Infinity	-4 45	158 69	Mt 9	-Infinity	52 18	306 63
Vt 4	-Infinity	-10 61	110 74	Mt MD	-Infinity	67 13	360 70
Vt 5	-Infinity	-9 14	103 37	Mt 11	-Infinity	58 04	335 18
Vt EE	-Infinity	0 41	154 64	Mt 12	-Infinity	61 16	267 78
Vt 7	-Infinity	-3 22	188 66	Mt 13	-Infinity	63 64	188 84
Vt 8	-Infinity	0 76	116 30	Mt 14	-Infinity	65 60	68 21
Vt 9	-Infinity	4 13	184 92	Mt 15	-Infinity	66 70	83 40
Vt MD	-Infinity	12 73	193 71	Mt 16	-Infinity	67 67	105 32
Vt 11	-Infinity	9 09	168 06	Mt 17	-Infinity	67 82	77 54
Vt 12	-Infinity	11 64	142 63	Mt 18	-Infinity	67 88	83 36
Vt 13	-Infinity	13 84	135 39	Mt 19	-Infinity	67 27	79 97
Vt 14	-Infinity	15 42	78 70	Mt 20	-Infinity	66 39	85 59
Vt 15	-Infinity	16 50	42 55	Mt 21	-Infinity	64 84	74 60
Vt 16	-Infinity	17 27	48 45	Mt 22	-Infinity	63 75	72 04
Vt 17	-Infinity	17 49	63 49	Mt 23	-Infinity	59 88	60 18
Vt 18	-Infinity	17 54	41 23	Mt 24	55 59	55 90	58 94
Vt 19	-Infinity	17 08	52 53	Mt 25	46 82	52 30	53 27
Vt 20	-Infinity	16 38	39 45	Mt XX	-Infinity	59 68	133 55
Vt 21	-Infinity	15 12	52 43	Mf 1	-Infinity	37 62	225 52
Vt 22	-Infinity	13 24	37 40	Mf 2	-Infinity	28 87	219 40
Vt 23	-Infinity	11 12	38 72	Mf VV	-Infinity	44 40	290 15
Vt 24	-Infinity	7 96	35 90	Mf 4	-Infinity	26 50	289 80
Vt 25	-Infinity	4 96	37 91	Mf 5	-Infinity	31 63	286 77
Vt XX	-Infinity	6 93	94 48	Mf EE	-Infinity	56 93	370 99
Mt 1	-Infinity	39 05	122 12	Mf 7	-Infinity	45 15	287 56
Mt 2	-Infinity	34 98	108 28	Mf 8	-Infinity	55 53	256 26
Mt VV	-Infinity	47 27	181 27	Mf 9	-Infinity	64 34	385 37
Mt 4	-Infinity	34 23	232 26	Mf MD	-Infinity	88 20	442 27
Mt 5	-Infinity	35 80	245 78	Mf 11	-Infinity	77 18	408 98
Mt EE	-Infinity	50 48	280 52	Mf 12	-Infinity	83 83	329 48

• EXPLANATION OF VARIABLES SYMBOLS

I First letter indicates plant variety		
A African Violet	B Begonia	C Cyclamen
H Hyadrangea	G Geranium	M Chrysanthemum
Z Azalea		
II Second letter indicates pot size		
f Fifteen cm	t Ten cm	s Seventeen & half cm
III Last two letters/digits indicate marketing period		
EE Easter	MD Mother's Day	VV Valentines
XX Christmas		
IV.Other Notations		
ELEE Easter Lily for Easter	PNf · Poinsettia fifteen cm	
PNtw. Poinsettia twenty cm	PNtf Poinsettia twenty five cm	

TABLE 4.11B. SENSITIVITY ANALYSIS FOR OBJECTIVE FUNCTION (Continued)

(Xi)	Minimum Limit	Original Coefficient	Maximum Limit	(Xi)	Minimum Limit	Original Coefficient	Maximum Limit
Mf 13	-Infinity	90 18	220 51	Cf MD	-Infinity	25 79	560 05
Mf 14	-Infinity	93 62	132 18	Cf XX	-Infinity	71 13	395 82
Mf 15	94 32	96 36	103 80	EL EE	-Infinity	32 56	211 32
Mf 16	-Infinity	98 39	126 91	Gt VV	-Infinity	26 69	94 47
Mf 17	95 11	98 90	99 76	Gt EE	-Infinity	29 67	149 23
Mf 18	98 58	99 03	101 65	Gt 7	-Infinity	23 26	69 05
Mf 19	94 93	97 82	98 19	Gt 8	-Infinity	25 22	111 95
Mf 20	-Infinity	95 98	102 05	Gt 9	-Infinity	26 61	175 58
Mf 21	92 23	92 67	97.86	Gt MD	-Infinity	35 00	168 97
Mf 22	83 09	87 75	88 97	Gt 11	-Infinity	28 88	150 22
Mf 23	80 36	82 22	87.52	Gt 12	-Infinity	29 92	120 37
Mf 24	-Infinity	73 93	75 32	Gt 13	-Infinity	30 86	72 07
Mf 25	-Infinity	66 13	73.51	Gf VV	134 08	136 74	225 94
Mf XX	-Infinity	73 56	247 70	Gf EE	139 36	141 85	143 69
Zf VV	-Infinity	174 72	184 26	Gf 7	-Infinity	127 56	174 03
Zf EE	149 84	186 54	188 20	Gf 8	129 17	131 23	138 28
Zf MD	203 75	212 09	214 53	Gf 9	-Infinity	134 17	188 91
Zf XX	178 79	198 37	209 02	Gf MD	-Infinity	152 84	206 31
Zs VV	-Infinity	183 48	268.77	Gf 11	-Infinity	138 61	176 19
Zs EE	197.62	201 23	223 44	Gf 12	123 41	141 04	171 23
Zs MD	-Infinity	244 00	252 49	Gf 13	138 65	142 78	156 93
Zs XX	-Infinity	224 68	296 95	Hf VV	-Infinity	-8 81	443 05
Bt EE	-Infinity	70 57	154.64	Hf EE	-Infinity	5 13	336 65
Bt MD	-Infinity	78 45	185 10	Hf MD	-Infinity	59 74	467 97
Bf EE	-Infinity	163 93	192 80	Hf XX	-Infinity	47 40	412 13
Bf MD	-Infinity	191 24	244 50	Hs VV	-Infinity	105 27	529 84
Ct VV	-Infinity	-53 49	258 52	Hs EE	-Infinity	134 61	406 12
Ct EE	-Infinity	-61 29	278 05	Hs MD	-Infinity	214 22	577 51
Ct MD	-Infinity	-46 07	351.18	Hs XX	-Infinity	201 43	506 72
Ct XX	-Infinity	-29 40	235 95	PNf	-Infinity	93 35	270 04
Cf VV	-Infinity	14 26	401.84	PNtw	-Infinity	55 32	514 75
Cf EE	-Infinity	-4 15	445 05	PNtf	-Infinity	92 57	747 93

* : EXPLANATION OF VARIABLES SYMBOLS

I. First letter indicates plant variety :

A: African Violet	B Begonia	C Cyclamen
H. Hyadrangea	G Geranium	M Chrysanthemum
Z: Azalea		

II Second letter indicates pot size :

f : Fifteen cm	t Ten cm	s: Seventeen & half cm

III. Last two letters/digits indicate marketing period

EE: Easter	MD. Mother's Day	VV: Valentines
XX : Christmas		

IV. Other Notations

ELEE: Easter Lily for Easter	PNf Poinsettia fifteen cm
PNtw: Poinsettia twenty cm	PNtf. Poinsettia twenty five cm

words, so as not to alter either the variables or their values in the optimal mix. The minimum coefficient was -infinity for most variables (110 out of 128), whereas the range for maximum coefficient varied from a low of 0.3 cents for Chrysanthemums 10 cm produced for the 23rd period (Mt23), to a high of 655.36 cents for Poinsettia 25 cm (PNtf).

4.5 Results of Other Models

Other models were formulated, based on the main model, to simulate increasing factor costs and to compare the profitability of various production periods within the year. This comparison would allow part time producers to choose a favourable production season that maximizes their net returns depending on their cost structure. Other models reflect additional marketing constraints. The results of these models, listed in flow chart form in Figures 4.7A and 4.7B, are discussed in the following sections.

4.5.1 Models with Marketing Constraints

Three additional models were built to simulate marketing constraints that include pot size and holiday quotas. The results of these models along with the values of the objective functions are presented in Tables 4.12 and 4.13.

Simulating the constraint of pot size quota, model 12 has shown that the distribution of pot sizes in the optimal plan, satisfied the designed percentages. In this manner, pots of Chrysanthemum 15 cm, restricted at a quota of over 70%, were 91.79% of the total Chrysanthemum pots produced. Geranium 10 and 15 cm were produced at 50% each, and Azalea 15 cm constituted 100% of all Azalea produced. The latter two plants satisfied the pot size quotas of 50% and above 70% respectively.

As for the holiday quota, which divided the number of plants produced for the four major holidays according to designed percentages, model 11 showed that only Azalea 17.5

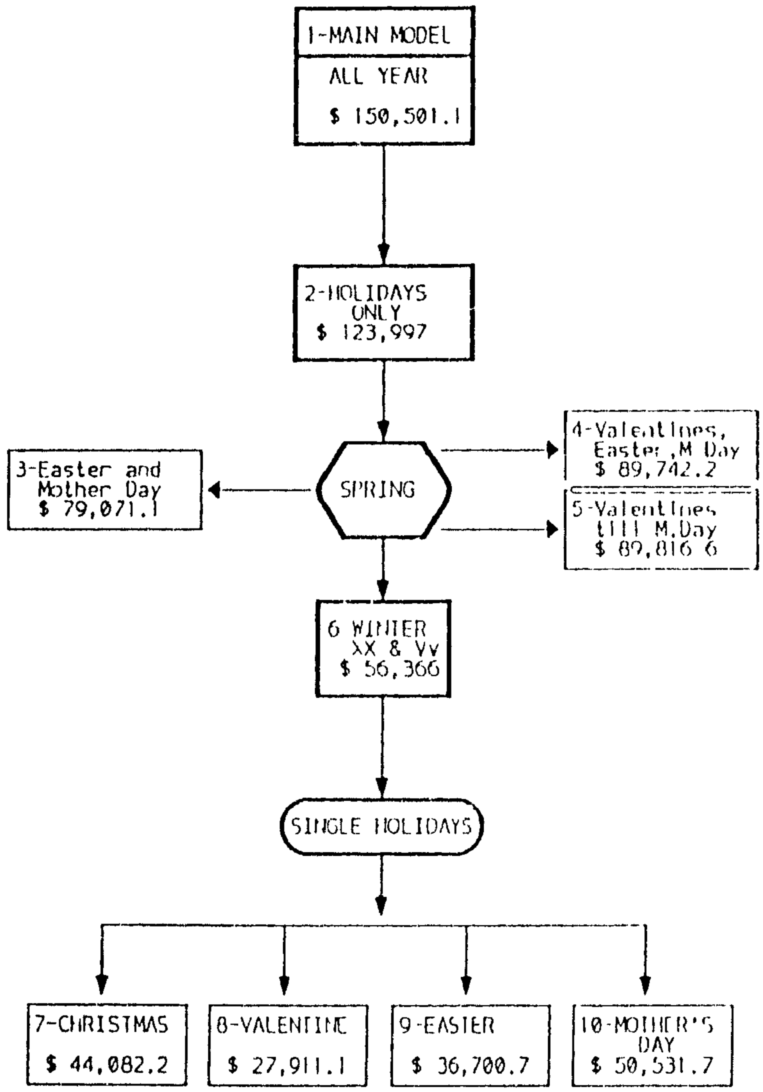


FIGURE 4.7A: VALUES OF THE OBJECTIVE FUNCTIONS FOR THE OTHER MODELS IN A FLOW CHART FORM

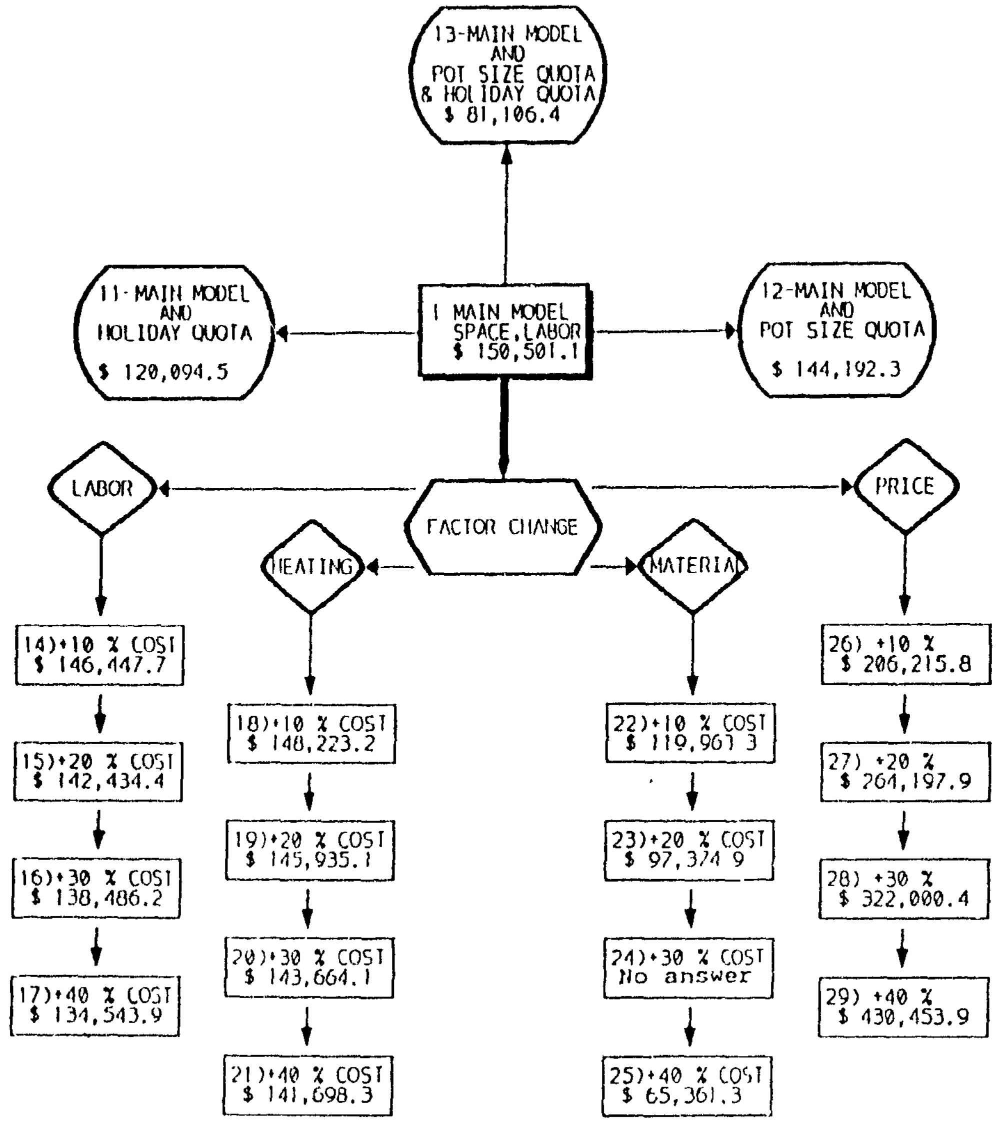


FIGURE 4.7B: VALUES OF THE OBJECTIVE FUNCTIONS FOR THE OTHER MODELS IN A FLOW CHART FORM

TABLE 4.12· OPTIMAL PLANS FOR ADDITIONAL CONSTRAINTS

PLANT VARIETY	PLANT UNITS PER MODEL *		
	11	12	13
VtEE			678 37
Mt1	1487 33		
Mt25		1744 93	
Mf15	1735 06	4606 36	2284 54
Mf17	1941 03	570 1	1550 41
Mf18	3876 51	3725 4	3983 43
Mf19	1018 65	2339 87	1256 73
Mf21	3373 18	1716 59	2893 6
Mf22	932 16	3730 36	797 75
Mf23		1009 119	
Mf24	1707 76	769 02	546 28
Mf25		1037 83	
ZfVV		8509 4	690 0
ZfEE		10365 7	
ZfMD		17815 3	
ZfXX		17967 5	
ZsVV	1380 9		
ZsEE	5523 7		295 7
ZsMD	4142 78		
ZsXX	2761 85		
Gt7		9913 327	18569 54
Gt8			732 47
Gt9			4219 44
Gt13		848 93	7863 34
GfVV	13002 3		13603 3
GfEE			
Gf7	1243 44		
Gf8	18030 93	1058 8	463 29
GfMD			
Gf11	3810 08		3465 16
Gf12	4147 07	5280 59	10781 32
Gf13	12290 8	4422 9	3071 7
HsEe			1785 91
HsMD			2069 99
HsXX			1379 99
Pnf	4511 1		5713 2
O F V. ($)	120094 5	144192 3	81106 4

* MODEL 11 HOLIDAY QUOTA
MODEL 12 POT SIZE QUOTA
MODEL 13 POT SIZE AND HOLIDAY QUOTAS

** EXPLANATION OF VARIABLES SYMBOLS

Gf: Geranium, 15 cm
Mt· Mums, 10 cm
Mf. Mums, 15 cm
Zf Azalea, 15 cm
Zs Azalea, 17.5 cm

TABLE 4 13 SUMMARY OF MARKETING CONSTRAINTS MODELS

CONSTRAINT	MODEL 11 (1) ESTIMATED	MODEL 11 (1) REQUIRED	MODEL 12 (2) ESTIMATED	MODEL 12 (2) REQUIRED	MODEL 13 (3) ESTIMATED	MODEL 13 (3) REQUIRED
I POT SIZE QUOTA						
Chrysanthemum, 10 cm	NOT REQUIRED		8 21%	<= 30%	0%	<= 30%
Chrysanthemum, 15 cm			91 79%	>= 70%	100%	>= 70%
Azalea, 15 cm			100%	>= 70%	70%	>= 70%
Azalea, 17 5 cm			0%	<= 30%	30%	<= 30%
Geranium, 10 cm			50%	= 50%	50%	= 50%
Geranium, 15 cm			50%	= 50%	50%	= 50%
Hydrangea, 15 cm			0%	<= 15%	0%	<= 15%
Hydrangea, 17 5 cm			0%	>= 85%	100%	>= 85%
Poinsettia, 15 cm			0%	>= 75%	100%	>= 75%
Poinsettia, other			0%	<= 25%	0%	<= 25%
II HOLIDAY QUOTA						
Valentine Day	10%	= 10%	NOT REQUIRED		10%	= 10%
Easter	40%	= 40%			40%	= 40%
Mothers day	30%	= 30%			30%	= 30%
Christmas	20%	= 20%			20%	= 20%

(1) MODEL 11 INCLUDES THE HOLIDAY QUOTA
(2) MODEL 12 INCLUDES THE POT SIZE QUOTA
(3) MODEL 13 INCLUDES BOTH QUOTAS

cm, was produced for the four main holidays. Consequently, the number of Azalea units produced for these occasions, indicated that the holiday quota, of 40%, 30%, 20%, and 10% for Easter, Mother's Day, Christmas, and Valentines respectively, was fulfilled.

Model 13 simulated both the pot size and holiday quotas. As a result, Chrysanthemum 15 cm, Hydrangea 17.5 cm, and Poinsettia 15 cm made up 100% of the produced pot sizes of the relevant varieties. Geraniums, on the otherhand, were divided equally for the two pot sizes, whereas Azalea 15 cm constituted 70% of the total Azalea produced. As for the holiday quota, there were four plants produced for the main holidays, African Violets 10 cm, Azalea 15 and 17.5 cm, and Hydrangea 17.5 cm. Again the production of these plants was distributed among the holidays according to the designed quota. Therefore both of the quota marketing constraints were satisfied.

It was noted that the value of the objective function for the holiday quota constraint (120,094.50 $) was lower than that of the pot size constraint (144,192.30 $). This value was lowest when both constraints were considered together (81,106.40 $).

4.5.2 <u>Simulation of Input and Output Price Increase</u>

Sixteen models were built to simulate increases in the selling price and input costs such as heating, labor, and materials. These increases ranged from 10% to 40% of the original values for each of the inputs. This would show the degree of variation and sensitivity of the total net returns of the main model, with respect to changes in input costs. Table 4.14 lists the values of the objective functions for different input costs. In this manner, it was noted that of the input costs, changes in material costs had the largest effect on the value of the total net returns. A 10% increase in material costs decreased the net returns by 20.3% as

TABLE 4 14 VALUES OF OBJECTIVE FUNCTION FOR DIFFERENT INPUT COSTS & % CHANGE

PERCENTAGE CHANGE	INPUT MATERIAL	% *	LABOR	% *	PRICES(1)	% *	HEAT	% *
10 %	119963 3	-20 3	146447 7	-2 7	206215 8	37 0	148223 2	-1 5
20 %	97374 9	-35 3	142434 4	-5 4	264197 9	75 5	145935 1	-3 0
30 %	X	X	138486 2	-8 0	322000 4	114 0	143664 1	-4 5
40 %	65361 3	-56 6	134543 9	-10 6	430453 9	186 0	141698 3	-5 8
ORIGINAL MODEL = $150,501.10								

* · AS PERCENTAGE CHANGE FROM THE VALUE OF ORIGINAL MODEL

(1) · SALE PRICES ARE INCREASED BY RESPECTIVE PERCENTAGE

TABLE 4.15. OPTIMAL PLANS FOR SEASONS AND SINGLE HOLIDAYS

PLANT VARIETY	PLANT UNITS PER MODEL (1) 2	3	4	5	6	7	8	9	10
ZIVV					6327.9		2994 0		
ZIEE			5428 7	5428.7					
ZIMD	19642.1	21776 0	19642 2	19240 6					'9642 1
ZIXX	20964 9				16905 6	22222 2			
ZsVV			9469 1	9469.1			12361 0		
ZsEE	3369.4	1362.1						11591 8	
GIVV	5029 3				8610 7				
GIEE	12844 2	20169.8	8255 2	8255 2				9428 6	
GIMD	5805 2	1004 0	5805 2	4604 8					5805 2
GI8				2103 9					
O F V ($)	123997	79071.1	89742 2	89816 8	56366 0	44082 2	27911.1	36700 7	50531 7

O.F V. . OBJECTIVE FUNCTION VALUE

(1) MODEL DESCRIPTION

MODEL 2 VV,EE,MD & XX

MODEL 3 EE & MD

MODEL 4· VV,EE, & MD

MODEL 5 VV UNTIL MD

MODEL 6 XX & VV

MODEL 7: XX

MODEL 8· VV

MODEL 9 EE

MODEL 10 MD

(2) EXPLANATION OF VARIABLES SYMBOLS

GI Geranium, 15 cm

ZI Azalea, 15 cm

Zs · Azalea, 17 5 cm

compared to 2.7% and 1.5% for labor and heating costs respectively. This table indicates that heating costs were not the most sensitive input in the production costs.

An increase in the selling prices had a large positive effect on the net returns. This ranged from a 37% for a 10% increase in price to a 186% increase for a 40% price increase. This showed that increasing the product price would have a larger effect on the net returns than decreasing any of the input costs. This result reflects the importance of adopting means that can increase prices, such as the addition of value to crops, or other ways that will increase the demand levels.

4.5.3 Models for Other Occasions

Nine models were formulated to maximize net returns for various periods of the year. These periods included seasons such as spring and winter, and the four main holidays. The optimal plan was also obtained for a production year which included only the four main holidays (model 2). The results of these models, were listed in Table 4.15. It was shown that the latter model, with four production periods, had lower net returns (123,997 $) than the original model (150,510.10 $) which included 26 periods. In this manner, the value of the holiday period amounted to about 82.4% of the value of the original model. This can be explained by the fact that the main model included larger choice of decision variables.

In comparing the spring models, it was found that model 5, which included all the spring periods (Valentines till Mother's Day), yielded larger net returns than models 3 and 4, which included parts of the spring. The same reason as the previous case could explain this result.

As for seasons, the spring model (model 4) which optimized production plans for Easter and Mother's Day, resulted in larger net revenues than the winter model (model 6) which involved the Christmas and Valentines holidays. This could be attributed to higher production costs in winter.

In the case of individual holidays, the production plan for Mother's day (10) yielded the highest net returns of 50,531.70 dollars. Production for Christmas (7) ranked second in income with 44,082.20 dollars. It was followed by Easter (9) and Valentines (8) with 36,700.70 and 27,911.10 dollars respectively.

4.6 Summary and Discussion

The main linear programming model to maximize net returns in pot flowers, indicated that Azalea 15 cm, marketed for Christmas, was the plant with the highest level produced for a single period with 20091 units. This figure amounted to 20.61% of the total yearly production. As for variety, Geranium 15 cm, produced for five main periods during the spring, accounted for the largest production during the year (38.83% of total production), while Azalea 17.5 cm, was the variety with the lowest production (3.67% of total production).

It should be noted that a long season of production coupled with high heating costs, have discouraged the complete production process of Azalea in Québec, and resulted in the import of semi-finished plants to be forced locally. Therefore, the model results depend on the presence of low prices of the imported product. In contrast, Geranium, the variety with the highest level of production in the optimal plan, has a relatively shorter season of production (6-8 weeks) with lower production costs. This plant which is produced totally in Québec, has a wide popularity among producers and consumers. In fact, several ornamental counsellors (Senecal, 1989) have indicated that the production of this plant was largest among many ornamental plants in the province. However, it should be noted that this plant has been more widely used for landscaping purposes than as a pot flower.

Geranium used for landscaping is largely sold in trays or 10 cm pots. The optimal plan, which suggested the production of 15 cm Geranium pots, might have indicated the importance of marketing better quality plants, as far as plant and flower size were concerned.

Moreover since Geranium was to be produced for periods eight (16th to 29th of April), twelve and thirteen (June 4th to July 1st), which are not holiday periods, draws the attention to off-season marketing periods. These two factors might constitute reasons for the success of the 15 cm pots of Geranium.

The same result was found for Chrysanthemum, which was to be produced for several non-holiday periods throughout the year. This approach is more common in Europe, where plants are marketed all year round. However, it should be noted that the importance of these marketing periods, as calculated by the optimal plan, reflect the cost and resource distribution as performed by the optimization process, and not the importance of the dates per se.

This indicates that improved and aggressive marketing techniques, such as discount packages and price concessions, might encourage production and increase profits during those periods where production costs and resource allocation are optimum.

Cost accounting performed in this study, which showed the distribution of costs among different inputs, has revealed interesting results. The material costs accounted for major portions of production costs (83.1%), while heating costs accounted for 6.1%. However, this could be attributed to the method used in this study, which calculated heating costs depending on the area used per plants. However, unless the greenhouse could be built in a way to separate or isolate heated compartments every period (2 weeks) based on the used area, the heating costs should be calculated for the whole 2000 square meters. Consequently, the total heating costs were estimated at 37,633.90 dollars per year. This figure was calculated based on the energy requirements listed in Table 3.1. This figure amounts to 9.63% of the total costs but is still below labor costs (10.37%) and material costs (80%).

This method of calculation will reduce the total net returns to 135,714.70 dollars. With total costs in mind, this indicates that the ratio of net benefits to total operating or variable costs is about 34.73%, which reflects a relatively high rate of return. A comprehensive evaluation of profitability, however, has to include portions of the fixed costs.

The optimal plan also reflected the rate of resource use and productivity. In this respect, it was concluded that the greenhouse space area was not fully used in most periods, in contrast to available labor hours, which were fully used in 15 of the 26 periods.

Additional units of labor hours in deficient periods, had high values of marginal productivity. This ranged from 78.76 dollars per hour in period 2 to 1.22 dollars in period 19. The wage rate of 5.50 dollars per hour, was exceeded in 11 of the 15 periods when labor was deficient. This encourages the hiring of additional part time workers to increase net returns. The plan would remain viable as long as available labor hours do not exceed the range set in the sensitivity analysis. The situation was different for space, in which the value of marginal productivity ranged from a maximum of 18.04 dollars to 1.69 dollars in three space deficient periods.

The analysis also included a sensitivity analysis, which indicated the ranges of plant net profits, and variations in constraints levels that would keep the the optimum plan feasible. These were listed in Tables 4.9 to 4.11B.

Marketing constraints, such as pot size and holiday quotas were added to the main model. The values of these constraints were estimated based on interviews with producers and ornamental counsellors. The pot size quota, divided the production of a certain plant variety among different pot sizes, in a designed percentage. The optimal plan, produced Chrysanthemums 15 and 10 cm, into 91.79% and 8.21% portions respectively. Geraniums 15 and 10 cm were divided equally, while Azalea 15 cm made up 100% of the produced Azaleas.

The holiday quota, on the other hand, distributed the production of the plants commonly produced for the four main holidays into a distribution of 40%, 30%, 20%, and 10% for Easter, Mother's Day, Christmas, and Valentines respectively. The optimal plan, which produced one plant variety common for the four holidays, Azalea 17.5 cm, satisfied this requirement.

Net returns for the models with additional marketing constraints were found to be lower than the main model, which only had space and labor constraints. However, the model with the pot size quota yielded higher net returns than the model with the holiday quota.

Other models which maximized net returns for different periods of the year, indicated that the spring model, which included Easter and Mother's Day, had higher net returns than the winter model, which included Christmas and Valentines. This could be attributed to higher production costs during the winter season. As for individual holidays, production for Mother's Day yielded the highest net profits. This was followed by Christmas, Easter, and Valentines.

The value of the objective function was analyzed for varying percentages of input costs and selling prices. It was concluded that variations in material costs had the largest effect. A 10% increase in material costs reduced the net returns by 20.3% compared to 2.7% and 1.5% for labor and heating costs respectively. Increased selling prices, raised substantially the value of net returns. This varied from 37% for a 10% price increase to 186% for a 40% price increase.

This analysis has thus increased available information, and contributes to better decisions being made in the production of greenhouse pot flowers.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and Conclusion

This study simulated the economic conditions and cultural practices followed in the production of major pot flowers in the province of Quebec. This was done to optimize the use of greenhouse space and maximize net returns. A linear programming model was formulated to investigate the optimal crop mix given limitations of labor and space availability, and market restrictions. In this process, variable production costs, which include labor, material, and heating, were estimated from interviews with producers and ornamental counsellors in the area of Montreal, and other governmental publications. It should be noted that the discussed model is a normative one, therefore the results imply optimality for the given set of prices and resources.

Results of the optimal plan showed that Azalea 15 cm, produced for Christmas, had the largest production level for a single period (20.61% of total output), while Geranium 15 cm, was the crop produced with the highest level for the whole year (38.83% of total output). The plan also recommended the production of off-season crops which were produced for periods other than the holiday periods. This included Chrysanthemums 10 and 15 cm, and Geranium 15 cm. Moreover, non-traditional pot sizes, such as Geranium 15 cm, and Chrysanthemums 10 cm were included in the plan. However, it should be noted that the conclusion to include off-season crops and non-traditional pot sizes in the optimal plan, were due to the relative profitability of these plants when marketed for a specific period, and the satisfaction of resource constraints in these periods. Considerable care has to be taken in the formulation process so as to reflect production conditions related to the investigated production firms.

The optimal plan reflects levels of resource use for different seasons and assigned values for resource productivity. This increases the understanding of the related factors affecting profitability, and shows timing of resource use that constrain production efficiency. Successive application of this technique in Quebec can lead to a better allocation of production resources, and improved decisions and practices. These practices include the choice of mother plants, level of mechanization, production techniques, plant spacings, and levels of labor use.

The model's sensitivity analysis, which includes various levels of input and output price changes, indicates the range of values for which the plants' net returns and levels of resource use, could vary to keep the optimal plan valid. This increases the level of certainty and quality of information for management. In other words, it shows the robustness of the optimal production plan in the face of uncertain prices and resource availabilities. This study also provides a general idea concerning the relative profitability of different periods and holidays of the year.

In conclusion, the use of linear programming as an optimizing technique to allocate space use in the pot flower industry, has the potential to be a powerful tool to improve the quality of decision making in the greenhouses of Quebec. Improving the productivity of the greenhouse space due to more efficient use of greenhouse facilities, will reduce production costs, and increase profitability. Moreover, LP as a flexible management tool is very important for the pot flowers which are designed for various holidays of the year. Since some of the holiday dates vary between years, and affect the cost structure of plants, a flexible design tool as LP, was found to be most appropriate.

Moreover, the use of LP, which contributes to improving the producer's managerial abilities, will allow the greenhouse growers, which operate in a rapidly growing and competitive environment, to remain viable, competitive, and successful.

5.2 Implications of Research

The following points, achieved in this study, are considered to be contributions to knowledge:

1-This study represents one of the ways to illustrate the usefulness of the computer as a horticultural production aid. Producers could implement this technique in everyday planning to improve decisions with minimum costs. However a good pre-program to translate operating data into the proper format and a post-program to explain output data are necessary for efficient use of this technique.

2-The application of LP in the pot flower industry, is believed to be the first trial in this field in the province of Quebec. It is hoped that this might open the door for further LP applications and research in ornamental production in this province.

3-The process of model formulation, illustrated in this study, required a sound knowledge in cost accounting. Such knowledge would allow producers to allocate production costs for each plant product; to better evaluate production practices; and to understand resource productivity and associated limitations. Thus gathering this information in the process of model formulation, will act as an information system to direct corrective cost reduction actions (such as methods of production, or plant quantity, or variety).

4-This study showed the usefulness of LP as an improved decision making ability tool to increase the amount of available information for greenhouse managers in the floral industry. This included the optimal product mix, values of resource use and productivity, quantities of input use, estimates of net profits, and sensitivity of results.

5.3 Recommendations for Further Research

Based on the above summary and conclusion, the following recommendations for further research can be made regarding the use of LP in the pot flower industry:

1) To include additional secondary pot flowers such as Asiatic lily, Rose bush, Impatiens, and some bulb plants like Tulips, Iris, and others.
2) To simulate several production layers in the greenhouse. Since many greenhouses use hanging baskets, multiple layer benches, and to use the space under the benches.
3) To include other filling plants with pot flowers such as house plants and bedding plants so as to maximize the use of space in all periods.
4) To formulate a multiple period model which permits an optimization process for two or three year periods.
5) To include other non-traditional pot sizes of plants to the list of production variables.
6) To study the effect of using a larger number of plant spacings during the production cycle. This may show a better use of space but will result in higher labor costs.
7) To compare results of the LP model with other forms of mathematical programming such as integer programming.

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APPENDICES

Appendix A

Listing of the questionnaire distributed to producers

INFORMATION GÉNÉRALE

Nom de la Pépinière ____________________

Endroit : ____________________

Nom du gérant : ____________________

Date : ____________________

No. d'employés : Temps plein : ______* hrs/semaine ________

: Temps partiel: ______* hrs/semaine ________

Surface Totale : ____________________

Surface Plantée: ____________________

Type : ____________________
(Vitre/plastique)
Epaisseur(S/D) : ____________________
(Single/double)
Age Couverture : ____________________

Forme ** : ____________________

Chauffé par : ____________________

Ventilation : ____________________
(Fan/Naturellle)
Autre Remarques: ____________________

: ____________________

---

*- Surface Plantée : Dimension des bancs : Long.= * Larg.=
Passages Long.= * Larg.=

** Forme : Gothique OU semi-circulaire

Liste des Plantes Présentes

Violet Africaine	________	Lil de Pâques	________
Azalées	________	Géraniums	________
Begonias	________	Hydrangée	________
Chrysanthèmes	________	Poinsettia	________
Cyclamen	________		

Item	Nom de la Plante	Nom de la Plante
Varietés plus Importantes		
Specifications *		
Commencé en (bouture,bulbe.)		
Source (Local/Importe..)		
Saison de Croissance		
de/à		
Jours		
Saison de mise en marché		
Nombre de plants par pots		
Grandeur de pot plus import.		
Distance d'espacement		
à--- âge en jours		
à--- âge en jours		
à -- âge en jours		
Grandeur de Production **		
COÛTS DES MATÉRIAUX		
Bouture(Si plus multiplier)		
Terre/pot		
Pot		
Fertilisants/pot		
Pesticides/pot		
Emballage		
Main d'oeuvre/pot		
Chauffage/pot		
Transport/pot		
Entretien/pot		
Electricité/pot		
Usage de CO2/pot		
Coûts fixee/pot		
Autres (Précisez)		
AUTRES INFORMATIONS		
Mélange de Medium Utilisé		
Pourcentages %		
Addition au medium		
Besoin en Main d'oeuvre		
(heures/100 pots/semaine)		
(heures/100 pots/saison)		
Nombres d'heures de gestion		
(/100 pots/semaine)		
(/100 pots/saison)		
Salaire/heure		
Man d'vre exprimnt Salare/hr		
Prix de vente moyen		
% moyen perte dans producton		
Demande		
Temp.moyenne de la serre		

* Specifications : Saison courte,longue,chaude,froide

** Grandeur de Production : Grand (plus de 20,000),Moyen(entre 10-20,000) Petit (moins de 10,000)

Appendix B

Tables of CREAQ : 1) Heating requirements for the region of Montreal

2) Conversion table for different energy sources

TABLE B-1: HEATING REQUIREMENTS FOR A JOINT GREENHOUSE FOR THE MONTREAL REGION

Consommation mensuelle de combustible par unité de surface														
Température intérieure Jour	Nuit	jan	fév	mars	avr	mai	juin	juil	août	sept	oct	nov	déc	total
- °C -		- l/m² -												
26	26	18.3	14.3	11.6	7.3	4.4	2.4	1.7	2.3	4.1	7.6	11.4	17.1	102.5
	24	17.6	13.7	11.0	6.8	4.0	2.0	1.3	1.9	3.6	7.0	10.7	16.4	96.0
	22	16.9	13.1	10.4	6.3	3.6	1.7	1.0	1.4	3.1	6.3	10.0	15.7	89.7
	20	16.2	12.6	9.9	5.9	3.2	1.3	0.7	1.1	2.6	5.7	9.4	15.0	83.5
	18	15.5	12.0	9.3	5.4	2.8	1.0	0.5	0.8	2.1	5.1	8.7	14.3	77.5
	16	14.8	11.4	8.7	4.9	2.4	0.8	0.4	0.6	1.7	4.5	8.0	13.6	72.0
	14	14.1	10.8	8.2	4.5	2.1	0.7	0.3	0.4	1.4	4.0	7.4	12.9	66.7
	12	13.4	10.2	7.6	4.0	1.8	0.6	0.3	0.4	1.1	3.4	6.7	12.2	61.8
	10	12.7	9.7	7.0	3.6	1.6	0.5	0.2	0.3	1.0	3.0	6.1	11.5	57.2
24	24	17.1	13.4	10.7	6.5	3.7	1.9	1.2	1.8	3.4	6.7	10.3	16.0	92.6
	22	16.4	12.8	10.1	6.1	3.3	1.5	0.8	1.3	2.9	6.0	9.7	15.3	86.2
	20	15.7	12.2	9.5	5.6	2.9	1.1	0.6	0.9	2.4	5.4	9.0	14.6	80.0
	18	15.0	11.6	9.0	5.1	2.5	0.9	0.4	0.6	1.9	4.8	8.3	13.9	74.1
	16	14.4	11.0	8.4	[illegible].6	2.2	0.6	0.2	0.4	1.5	4.2	7.7	13.1	68.5
	14	13.7	10.4	7.8	4.2	1.8	0.5	0.2	0.3	1.2	3.7	7.0	12.4	63.2
	12	13.0	9.9	7.3	3.7	1.6	0.4	0.1	0.2	0.9	3.1	6.3	11.7	58.3
	10	12.3	9.3	6.7	3.3	1.4	0.4	0.1	0.2	0.8	2.7	5.7	11.0	53.8
22	22	16.0	12.4	9.7	5.8	3.1	1.4	0.8	1.2	2.7	5.8	9.3	14.8	83.0
	20	15.3	11.8	9.2	5.3	2.7	1.0	0.5	0.9	2.2	5.2	8.6	14.1	76.8
	18	14.6	11.3	8.6	4.8	2.3	0.7	0.3	0.6	1.7	4.5	8.0	13.4	70.9
	16	13.9	10.7	8.0	4.4	1.9	0.5	0.2	0.4	1.3	4.0	7.3	12.7	65.3
	14	13.2	10.1	7.5	3.9	1.6	0.4	0.1	0.2	1.0	3.4	6.6	12.0	60.0
	12	12.5	9.5	6.9	3.5	1.3	0.3	0.1	0.2	0.7	2.8	6.0	11.3	55.1
	10	11.8	8.[illegible]	6.3	3.0	1.1	0.2	0.1	0.1	0.6	2.4	5.3	10.6	50.5
20	20	14.9	11.5	8.8	5.0	2.5	0.9	0.5	0.8	2.1	4.9	8.3	13.7	73.8
	18	14.2	10.9	8.[illegible]	4.6	2.1	0.6	0.3	0.5	1.6	4.3	7.6	13.0	67.9
	16	13.5	10.3	7.7	4.1	1.7	0.4	0.1	0.3	1.2	3.7	7.0	12.3	62.3
	14	12.8	9.7	7.1	3.6	1.4	0.3	0.1	0.2	0.9	3.1	6.3	11.6	57.0
	12	12.1	9.2	6.6	3.2	1.1	0.2	0.0	0.1	0.[illegible]	2.6	5.6	10.9	52.1
	10	11.4	8.6	6.0	2.8	0.9	0.1	0.0	0.1	[illegible]	2.1	5.0	10.1	47.6
18	18	13.8	10.6	8.0	4.3	1.9	0.6	0.2	0.5	1.5	4.1	7.3	12.6	65.2
	16	13.1	10.0	7.4	3.8	1.5	0.3	0.[illegible]	0.3	1.1	3.5	6.6	11.8	59.6
	14	12.4	9.4	6.8	3.4	1.2	0.2	0.0	0.1	0.7	2.9	6.0	11.1	54.3
	12	11.7	8.8	6.3	2.9	0.9	0.1	0.0	0.1	0.5	2.3	5.3	10.4	49.4
	10	11.0	8.3	5.7	2.5	0.7	0.1	0.0	0.0	0.3	1.9	4.7	9.7	44.9
16	16	12.7	9.7	7.1	3.6	1.4	0.3	0.1	0.3	1.0	3.3	6.3	11.4	57.2
	14	12.0	9.1	6.5	3.2	1.1	0.2	0.0	0.1	0.7	2.7	5.7	10.7	51.9
	12	11.3	8.5	6.0	2.7	0.8	0.1	0.0	0.1	0.4	2.1	5.0	10.0	47.0
	10	10.6	7.9	5.4	2.3	0.6	0.0	0.0	0.0	0.3	1.7	4.4	9.3	42.4
14	14	11.6	8.8	6.3	3.0	1.0	0.2	0.0	0.1	0.6	2.5	5.4	10.3	49.7
	12	10.9	8.2	5.7	2.5	0.7	0.1	0.0	0.1	0.4	2.0	4.7	9.6	44.8
	10	10.2	7.6	5.1	2.1	0.5	0.0	0.0	0.0	0.2	1.5	4.1	8.9	40.3
12	12	10.5	7.9	5.[illegible]	2.4	0.6	0.1	0.0	0.1	0.3	1.8	4.5	9.2	42.8
	10	9.8	7.4	4.9	1.9	0.4	0.0	0.0	0.0	0.2	1.4	3.8	8.5	38.3
10	10	9.5	7.1	4.6	1.8	0.3	0.0	0.0	0.0	0.2	1.3	3.6	8.2	36.6

Source: CREAQ, Agdex 717/290, September 1987

TABLE B-2: TABLE OF CONVERSION FOR DIFFERENT ENERGY SOURCES

Source d'énergie	Unité de mesure	Energie brute (Kilojoule)	Efficacité (%)	Energie nette (Kilojoule)	Facteur de conversion à utiliser
Electricité	kWh	3 600	100	3 600	8,0939
Mazout n° 6	litre	42 200	75	31 650	0,9206
Mazout n° 5	litre	41 100	75	30 825	0,9453
Mazout n° 4	litre	40 000	75	30 000	0,9713
Mazout n° 2	litre	38 850	75	29 138	1,0000 réf.
Gaz naturel	mètre cube	37 890	90	34 101	0 8545
Gaz naturel	mètre cube	37 890	65	24 628	1,1831
Gaz propane	litre	25 529	92	23 487	1,2406
Gaz propane	litre	25 529	80	20 423	1,4267
Charbon	kilogramme	30 328	75	22 746	1,2810
Bois mou (1) 20% d'hum. (276 kg/m³)	kilogramme	17 910	60	10 746	2,7115
Bois dur (1) 20% d'hum. (476 kg/m³)	kilogramme	17 '45	65	11 339	2,5697
Résidus de bois 35% d'hum.	kilogramme	13 956	60	8 374	3,4796

Source: CREAQ, Agdex 717/290, September 1987

Appendix C

Costs of production : labor, heating, and materials

TABLE C-1: TOTAL MATERIAL COSTS PER POT IN CENTS

Plant	Pot size	Cutting	Medium	Pot	Fertilizer	Pesticide	Package	Transport	Subtotal
African Violet	10 cm	33	4	8	3	3	15	5	71
Azalea	15 cm	500	0	0	2	6	30	16 5	554 5
Azalea	17 5 cm	625	0	0	3	7	40	22	697
Begonia	10 cm	30	4	8	3	3	15	5	68
Begonia	15 cm	30	14	17	10 5	10 5	30	11.25	123 25
Chrysanthemum	10 cm	20*2	4	8	2	4 5	15	5	78 5
Chrysanthemum	15 cm	20*5	14	17	7	16	30	11 25	195.25
Cyclamen	10 cm	60	4	8	2	4.5	15	5	98 5
Cyclamen	15 cm	60	14	17	7	16	30	11 25	155 25
Easter Lily	15 cm	100	14	17	6	13	30	11 25	191 25
Geranium	10 cm	43	5.8	8 5	3	5	15	5	85 3
Geranium	15 cm	43	14	17	7.25	17 5	30	11 25	140
Hydrangea	15 cm	300	0	0	4	6	30	16 5	356 5
Hydrangea	17 5 cm	300	0	0	6	7	40	22	375
Poinssettia	15 cm	55	14	17	8	16	30	11 25	151 25
Poinssettia	20 cm	55*2	21	61	11 5	23	56	22 5	305
Poinssettia	25 cm	55*3	28	88	15	30	75 3	30	431 3

TABLE C-2: TOTAL COSTS AND NET RETURNS OF PLANTS PRODUCED FOR CHRISTMAS

Plant	Pot size	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
African Violet	10 cm	35 130	17 940	71 000	124 070	131 000	6 930
Azalea	15 cm	32 460	39.170	554 500	626 130	824 500	198 370
Azalea	17 5 cm	33 760	63 060	697 000	793 820	1018 500	224 680
Chrysanthemums	10 cm	60 040	20 030	78 500	158 570	218 250	59 680
Chrysanthemums	15 cm	72 290	46 900	195 250	314 440	388 000	73 560
Cyclamen	10 cm	127 400	21.750	98 500	247 650	218 250	-29 400
Cyclamen	15 cm	160 300	49.820	155 250	365 370	436 500	71 130
Hydrangea	15 cm	80 130	88 970	356 500	525 600	582.000	56 400
Hydrangea	17.5 cm	87.920	111.650	375.000	574.570	776.000	201 430
Poinssettia	15 cm	87 460	55.940	151 250	294 650	388.000	93 350
Poinssettia	20 cm	100.100	121.580	305 000	526 680	582 000	55 320
Poinssettia	25 cm	119.300	181.330	431.300	731.930	824 500	92 570

TABLE C-3: TOTAL COSTS AND NET RETURNS OF PLANTS PRODUCED FOR VALENTINES

Plant	Pot size	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
African Violet	10 cm	35.130	29.320	71.000	135 450	131.000	-4 450
Azalea	15 cm	32.460	62.820	554.500	649 780	824.500	174.720
Azalea	17.5 cm	33 760	104 260	697.000	835 020	1018 500	183 480
Chrysanthemums	10 cm	60.040	32 440	78 500	170.980	218 250	47 270
Chrysanthemums	15 cm	72 290	76.060	195 250	343 600	388 000	44 400
Cyclamen	10 cm	127.400	45 840	98.500	271.740	218 250	-53 490
Cyclamen	15 cm	160 300	106 690	155.250	422 240	436 500	14 260
Geranium	10 cm	29 630	13 580	85 300	128 510	155 200	26 690
Geranium	15 cm	35 970	26.790	140.000	202 760	339.500	136 740
Hydrangea	15 cm	80 130	154.180	356 500	590.810	582.000	-8 810
Hydrangea	17.5 cm	87.920	207.810	375 000	670.730	776 000	105 270

TABLE C-4. TOTAL COSTS AND NET RETURNS OF PLANTS PRODUCED FOR EASTER

Plant	Pot size	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
African Violet	10 cm	35 130	24 460	71 000	130 590	131 000	0 410
Azalea	15 cm	32 460	51 000	554 500	637 960	824 500	186 540
Azalea	17 5 cm	33 760	86 510	697 000	817 270	1018 500	201 230
Begonia	10 cm	36 660	18 770	68 000	123 430	194 000	70 570
Begonia	15 cm	43 770	57 050	123 250	224 070	388 000	163 930
Chrysanthemums	10 cm	60 040	29 230	78 500	167 770	218 250	50 480
Chrysanthemums	15 cm	72 290	63 530	195 250	331 070	388 000	56 930
Cyclamen	10 cm	127 400	53 640	98 500	279 540	218 250	61 290
Cyclamen	15 cm	160 300	125 100	155 250	440 650	436 500	4 150
Easter Lily	15 cm	59 960	55 730	191 250	306 910	339 500	32 560
Geranium	10 cm	29 630	10 600	85 300	125 530	155 200	29 670
Geranium	15 cm	35 970	21 680	140 000	197 650	339 500	141 850
Hydrangea	15 cm	80 130	140 240	356 500	576 870	582 000	5 130
Hydrangea	17 5 cm	87 920	178 470	375 000	641 390	776 000	134 610

TABLE C-5 TOTAL COSTS AND NET RETURNS OF PLANTS PRODUCED FOR MOTHER'S DAY

Plant	Pot size	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
African Violet	10 cm	35 130	12 140	71 000	118 270	131 000	12 730
Azalea	15 cm	32 460	25 450	554 500	612 410	824 500	212 090
Azalea	17 5 cm	33 760	43 740	697 000	774 500	1018 500	244 000
Begonia	10 cm	36 660	10 890	68 000	115 550	194 000	78 450
Begonia	15 cm	43 770	29 740	123 250	196 760	388 000	191 240
Chrysanthemums	10 cm	60 040	12 580	78 500	151 120	218 250	67 130
Chrysanthemums	15 cm	72 290	32 260	195 250	299 800	388 000	88 200
Cyclamen	10 cm	127 400	38 420	98 500	264 320	218 250	-46 070
Cyclamen	15 cm	160 300	95 160	155 250	410 710	436 500	25 790
Geranium	10 cm	29 630	5 270	85 300	120 200	155 200	35 000
Geranium	15 cm	35 970	10 690	140 000	186 660	339 500	152 840
Hydrangea	15 cm	80 130	76 630	356 500	513 260	582 000	68 740
Hydrangea	17 5 cm	87 920	98 860	375 000	561 780	776 000	214 220

TABLE C 6 TOTAL COSTS & NET RETURNS OF AFRICAN VIOLET 10 CM, FOR NON-HOLIDAY PERIODS

Period	Date	Costs (cents/pot)				Selling Price	Net Returns
		Labor	Heating	Material	Subtotal		
1	Jan 8	35 130	24 290	71 00	130 420	124 450	-5 970
2	Jan 22	35 130	27 640	71 00	133 770	124 450	-9 320
4	Feb 19	35 130	28 930	71 00	135 060	124 450	-10 610
5	March 5	35 130	27 460	71 00	133 590	124 450	-9 140
7	April 2	35 130	21 540	71 00	127 670	124 450	-3 220
8	April 16	35 130	17 560	71 00	123 690	124 450	0 760
9	April 30	35 130	14 190	71 00	120 320	124 450	4 130
11	May 21	35 130	9 230	71 00	115 360	124 450	9 090
12	June 4	35 130	6 680	71 00	112 810	124 450	11 640
13	June 18	35 130	4 480	71 00	110 610	124 450	13 840
14	July 2	35 130	2 900	71 00	109 030	124 450	15 420
15	July 16	35 130	1 820	71 00	107 950	124 450	16 500
16	July 30	35 130	1 050	71 00	107 180	124 450	17 270
17	Aug 13	35 130	0 830	71 00	106 960	124 450	17 490
18	Aug 27	35 130	0 780	71 00	106 910	124 450	17 540
19	Sept 10	35 130	1 240	71 00	107 370	124 450	17 080
20	Sept 24	35 130	1 940	71 00	108 070	124 450	16 380
21	Oct 8	35 130	3 200	71 00	109 330	124 450	15 120
22	Oct 22	35 130	5 080	71 00	111 210	124 450	13 240
23	Nov 5	35 130	7 200	71 00	113 330	124 450	11 120
24	Nov 19	35 130	10 360	71 00	116 490	124 450	7 960
25	Dec 3	35 130	13 360	71 00	119 490	124 450	4 960

TABLE C-7 TOTAL COSTS AND NET RETURNS OF CHRYSANTHEMUMS 10 CM, FOR NON-HOLIDAY PERIODS

Period	Date	Costs (cents/pot) Labor	Heating	Material	Subtotal	Selling Price	Net Returns
1	Jan 8	60 040	29 750	78 500	168 290	207 340	39 050
2	Jan 22	60 040	33 820	78 500	172 360	207 340	34 980
4	Feb 19	60 040	34 570	78 500	173 110	207 340	34 230
5	March 5	60 040	33 000	78 500	171 540	207 340	35 800
7	April 2	60 040	25 600	78 500	164 140	207 340	43 200
8	April 16	60 040	20 810	78 500	159 350	207 340	47 990
9	April 30	60 040	16 620	78 500	155 160	207 340	52 180
11	May 21	60 040	10 760	78 500	149 300	207 340	58 040
12	June 4	60 040	7 640	78 500	146 180	207 340	61 160
13	June 18	60 040	5 160	78 500	143 700	207 340	63 640
14	July 2	60 040	3 200	78 500	141 740	207 340	65 600
15	July 16	60 040	2 100	78 500	140 640	207 340	66 700
16	July 30	60 040	1 130	78 500	139 670	207 340	67 670
17	Aug 13	60 040	0 980	78 500	139 520	207 340	67 820
18	Aug 27	60 040	0 920	78 500	139 460	207 340	67 880
19	Sept 10	60 040	1 530	78 500	140 070	207 340	67 270
20	Sept 24	60 040	2 410	78 500	140 950	207 340	66 390
21	Oct 8	60 040	3 960	78 500	142 500	207 340	64 840
22	Oct 22	60 040	5 050	78 500	143 590	207 340	63 750
23	Nov 5	60 040	8 920	78 500	147 460	207 340	59 880
24	Nov 19	60 040	12 900	78 500	151 440	207 340	55 900
25	Dec 3	60 040	16 500	78 500	155 040	207 340	52 300

TABLE C-8 TOTAL COSTS AND NET RETURNS OF CHRYSANTHEMUMS 15 CM FOR NON HOLIDAY PERIODS

Period	Date	Costs (cents/pot)				Selling	Net
		Labor	Heating	Material	Subtotal	Price	Returns
1	Jan 8	72 290	63 440	195 250	330 980	368 600	37 620
2	Jan 22	72 290	72 190	195 250	339 730	368 600	28 870
4	Feb 19	72 290	74 560	195 250	342 100	368 600	26 500
5	March 5	72 290	69 430	195 250	336 970	368 600	31 630
7	April 2	72 290	55 910	195 250	323 450	368 600	45 150
8	April 16	72 290	45 530	195 250	313 070	368 600	55 530
9	April 30	72 290	36 720	195 250	304.260	368 600	64 340
11	May 21	72 290	23 880	195 250	291 420	368 600	77 180
12	June 4	72 290	17 230	195 250	284 770	368 600	83 830
13	June 18	72 290	10 880	195 250	278 420	368 600	90 180
14	July 2	72 290	7 440	195 250	274 980	368 600	93 620
15	July 16	72 290	4 700	195 250	272 240	368 600	96 360
16	July 30	72 290	2 670	195 250	270 210	368 600	98 390
17	Aug 13	72 290	2 160	195 250	269 700	368 600	98 900
18	Aug 27	72 290	2 030	195 250	269 570	368 600	99 030
19	Sept 10	72 290	3 240	195 250	270 780	368 600	97 820
20	Sept 24	72 290	5 080	195 250	272 620	368 600	95 980
21	Oct 8	72 290	8 390	195 250	275 930	368 600	92 670
22	Oct 22	72 290	13 310	195 250	280 850	368 600	87 750
23	Nov 5	72 290	18 840	195 250	286 380	368 600	82 220
24	Nov 19	72 290	27 130	195 250	294 670	368 600	73 930
25	Dec 3	72 290	34 930	195 250	302 470	368 600	66 130

TABLE C-9: TOTAL COSTS AND NET RETURNS OF GERANIUM 10 CM, FOR NON-HOLIDAY PERIODS

Period	Date	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
5	March 5	29 630	12 200	85 300	127 130	147 440	20 310
7	April 2	29 630	9 250	85 300	124 180	147 440	23 260
8	April 16	29 630	7 290	85 300	122 220	147 440	25 220
9	April 30	29 630	5 900	85 300	120 830	147 440	26 610
11	May 21	29 630	3 630	85 300	118 560	147 440	28 880
12	June 4	29 630	2 590	85 300	117 520	147 440	29 920
13	June 18	29 630	1 650	85 300	116 580	147 440	30 860

TABLE C-10: TOTAL COSTS AND NET RETURNS OF GERANIUM 15 CM, FOR NON-HOLIDAY PERIODS

Period	Date	Costs (cents/pot)			Subtotal	Selling Price	Net Returns
		Labor	Heating	Material			
5	March 5	35 970	24 680	140 000	200 650	322 530	121 880
7	April 2	35 970	19 000	140 000	194 970	322 530	127 560
8	April 16	35 970	15 330	140 000	191 300	322 530	131 230
9	April 30	35 970	12 390	140 000	188 360	322 530	134 170
11	May 21	35 970	7 950	140 000	183 920	322 530	138 610
12	June 4	35 970	5 520	140 000	181 490	322 530	141 040
13	June 18	35 970	3 780	140 000	179 750	322 530	142 780

Appendix D

Schedules of cultural practices for the produced plants

TABLE D-1: SCHEDULE OF CULTURAL PRACTICES FOR AFRICAN VIOLET

PLANT African Violet,10 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	5	1						
FW Fertigate & Irrigate	3	10	14	14	14	7		
GR. Spray growth regulator	3							
IR Irrigate	1.5					3		
PA Pesticide Application	3	1	1	1	1	1		
PKG:Package plant	9					1		
PG: Place in greenhouse	5	1						
PMD:Prepare media & fill pot	3	1						
PP: Plant cutting (rooted)	4.5	1						
PI Pinch or prune	5							
RS: Respace plants	2		1					
SA: Soak bulb in acaricide	6							
S&H:Shipping & handling	5						1	
SH. Shade plants	1.5							
US: Unshade plants	2.5							
Total Labor (seconds/pot/period)		50.5	47.0	45.0	45.0	37 5	5.0	230.0

TABLE D-2: SCHEDULE OF CULTURAL PRACTICES FOR AZALEA

PLANT Azalea,15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	6						
FW. Fertigate & Irrigate	3	10	14	14	7		
GR: Spray growth regulator	4		2	2	1		
IR Irrigate	1.5				3		
PA Pesticide Application	4	1	1	1	1		
PKG:Package plant	12				1		
PG: Place in greenhouse	6	1					
PMD:Prepare media & fill pot	4						
PP. Plant cutting (rooted)	6						
PI Pinch or prune	7		1				
RS: Respace plants	3						
SA: Soak bulb in acaricide	6						
S&H:Shipping & handling	6	1				1	
SH: Shade plants	2						
US: Unshade plants	3						
Total Labor (seconds/pot/period)		46.0	61.0	54.0	45.5	6 0	212.5

TABLE D-3: SCHEDULE OF CULTURAL PRACTICES FOR AZALEA

PLANT Azalea,17.5 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	6 5							
FW Fertigate & Irrigate	3	2	14	14	14	7		
GR. Spray growth regulator	4.5			2	2	1		
IR: Irrigate	1.5							
PA Pesticide Application	4.5	1		1	1	1		
PKG:Package plant	13.5							
PG: Place in greenhouse	6.5	1						
PMD·Prepare media & fill pot	4.5							
PP: Plant cutting (rooted)	7							
PI. Pinch or prune	8			1				
RS: Respace plants	3.5							
SA· Soak bulb in acaricide	6							
S&H:Shipping & handling	6.5	1					1	
SH: Shade plants	2.25							
US Unshade plants	3.25							
Total Labor (seconds/pot/period)		23.5	42 0	63.5	55.5	30.0	6.5	221.0

TABLE D-4: SCHEDULE OF CULTURAL PRACTICES FOR BEGONIA

PLANT Begonia, 10 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	5	1						
FW: Fertigate & Irrigate	3	10	14	14	14	7		
GR. Spray growth regulator	3							
IR: Irrigate	1.5					3		
PA· Pesticide Application	3	1	1	1	1	1		
PKG:Package plant	9					1		
PG. Place in greenhouse	5	1						
PMD.Prepare media & fill pot	3	1						
PP: Plant cutting (rooted)	4.5	1						
PI: Pinch or prune	5			1	1			
RS: Respace plants	2		1					
SA: Soak bulb in acaricide	6							
S&H:Shipping & handling	5						1	
SH: Shade plants	1.5							
US: Unshade plants	2.5							
Total Labor (seconds/pot/period)		50.5	47.0	50.0	50.0	37.5	5.0	240.0

TABLE D-5· SCHEDULE OF CULTURAL PRACTICES FOR BEGONIA

PLANT Begonia, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	10 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	6	1							
FW: Fertigate & Irrigate	3	4	14	14	14	14	7		
GR: Spray growth regulator	4								
IR· Irrigate	1 5						3		
PA: Pesticide Application	4	1	1	1	1	1	1		
PKG Package plant	12						1		
PG· Place in greenhouse	6	1							
PMD Prepare media & fill pot	4	1							
PP. Plant cutting (rooted)	6	1							
PI· Pinch or prune	7				1	1			
RS: Respace plants	3			1					
SA· Soak bulb in acaricide	6								
S&H·Shipping & handling	6							1	
SH. Shade plants	2								
US· Unshade plants	3								
Total Labor (seconds/pot/period)		38 0	46 0	49 0	53 0	53 0	41.5	6 0	286.5

TABLE D-6 SCHEDULES OF CULTURAL PRACTICES FOR CHRYSANTHEMUMS

PLANT Chrysanthemums, 10 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	5	1						
FW· Fertigate & Irrigate	3	5	12	14	14	7		
GR Spray growth regulator	3			1	1			
IR. Irrigate	1.5					3		
PA Pesticide Application	3	1	1	1	1	1		
PKG Package plant	9					1		
PG Place in greenhouse	5	1						
PMD Prepare media & fill pot	3	1						
PP Plant cutting (rooted)	4 5	1						
PI Pinch or prune	5		1	1				
RS Respace plants	2		1					
SA· Soak bulb in acaricide	6							
S&H Shipping & handling	5						1	
SH· Shade plants	1 5		14	14	14			
US· Unshade plants	2 5		14	14	14			
Total Labor (seconds/pot/period)		35 5	102.0	109 0	104 0	37.5	5 0	393 0

TABLE D-7: SCHEDULES OF CULTURAL PRACTICES FOR CHRYSANTHEMUMS

PLANT Chrysanthemums, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6	1						
FW Fertigate & Irrigate	3	10	14	14	14	7		
GR Spray growth regulator	4			1	1			
IR Irrigate	1.5					3		
PA Pesticide Application	4	1	1	1	1	1		
PKG Package plant	12					1		
PG Place in greenhouse	6	1						
PMD Prepare media & fill pot	4	1						
PP Plant cutting (rooted)	6	1						
PI Pinch or prune	7		1	1				
RS Respace plants	3		1					
SA Soak bulb in acaricide	6							
S&H Shipping & handling	6						1	
SH Shade plants	2		14	14	14			
US Unshade plants	3		14	14	14			
Total Labor (seconds/pot/period)		56.0	126.0	127.0	120.0	41.5	6.0	473.5

TABLE D-8: SCHEDULE OF CULTURAL PRACTICES FOR CYCLAMEN

PLANT Cyclamen, 10 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks
DF: Drench Fungicide	5	1							
FW Fertigate & Irrigate	3	3	7	7	7	7	7	7	7
GR· Spray growth regulator	3								
IR· Irrigate	1 5	7	7	7	7	7	7	7	7
PA Pesticide Application	3	1	1	1	1	1	1	1	1
PKG:Package plant	9								
PG· Place in greenhouse	5	1							
PMD Prepare media & fill pot	3	1							
PP: Plant cutting (rooted)	4 5	1							
PI· Pinch or prune	5								
RS· Respace plants	2			0	0	0	1		
SA· Soak bulb in acaricide	6								
S&H:Shipping & handling	5								
SH: Shade plants	1 5	0	14	14	14	14	14	14	0
US Unshade plants	2 5	0	14	14	14	14	14	14	0
Total Labor (seconds/pot/period)		40.0	90 5	90 5	90 5	90 5	92 5	90 5	34 5

PLANT Cyclamen, 10 cm	secs	9 th 2 wks	10 th 2 wks	11 th 2 wks	12 th 2 wks	13 th 2 wks	14 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	5								
FW. Fertigate & Irrigate	3	7	7	7	7	7	3		
GR: Spray growth regulator	3			1	1				
IR: Irrigate	1 5	7	7	7	7	7	7		
PA: Pesticide Application	3	1	1	1	1	1	1		
PKG·Package plant	9						1		
PG. Place in greenhouse	5								
PMD.Prepare media & fill pot	3								
PP: Plant cutting (rooted)	4 5								
PI: Pinch or prune	5								
RS: Respace plants	2								
SA: Soak bulb in acaricide	6								
S&H:Shipping & handling	5							1	
SH: Shade plants	1.5								
US· Unshade plants	2 5								
Total Labor (seconds/pot/period)		34 5	34 5	37.5	37.5	34 5	31 5	5 0	834 5

TABLE D-9: SCHEDULE OF CULTURAL PRACTICES FOR CYCLAMEN

PLANT Cyclamen, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	9 th 2 wks
DF Drench Fungicide	6	1								
FW Fertigate & Irrigate	3	3	7	7	7	7	7	7	7	7
GR Spray growth regulator	4									
IR Irrigate	1 5	7	7	7	7	7	7	7	7	7
PA Pesticide Application	4	1	1	1	1	1	1	1	1	1
PKG Package plant	12									
PG Place in greenhouse	6	1								
PMD Prepare media & fill pot	4	1								
PP Plant cutting (rooted)	6	1								
PI Pinch or prune	7									
RS Respace plants	3				0	0	1			
SA Soak bulb in acaricide	6									
S&H Shipping & handling	6		0							
SH Shade plants	2	0	14	14	14	14	14	14	14	
US Unshade plants	3	0	14	14	14	14	14	14	14	
Total Labor (seconds/pot/period)		45.5	****	****	****	105.5	108.5	105.5	105.5	35.5

PLANT Cyclamen, 15 cm	secs	10 th 2 wks	11 th 2 wks	12 th 2 wks	13 th 2 wks	14 th 2 wks	15 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6								
FW Fertigate & Irrigate	3	7	7	7	7	7	3		
GR Spray growth regulator	4			1	1				
IR Irrigate	1.5	7	7	7	7	7	7		
PA Pesticide Application	4	1	1	1	1	1	1		
PKG.Package plant	12						1		
PG Place in greenhouse	6								
PMD.Prepare media & fill pot	4								
PP Plant cutting (rooted)	6								
PI Pinch or prune	7								
RS Respace plants	3								
SA. Soak bulb in acaricide	6								
S&H Shipping & handling	6							1	
SH Shade plants	2								
US Unshade plants	3								
Total Labor (seconds/pot/period)		35.5	35.5	39.5	39.5	35.5	35.5	6.0	1050

TABLE D-10: SCHEDULE OF CULTURAL PRACTICES FOR EASTER LILY

PLANT Easter Lily,15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6	1									
FW Fertigate & Irrigate	3	10	14	14	14	14	14	14	7		
GR Spray growth regulator	4				1						
IR Irrigate	1 5								3		
PA Pesticide Application	4	1	1	1	1	1	1	1	1		
PKG Package plant	12								1		
PG Place in greenhouse	6	1									
PMD Prepare media & fill pot	4	1									
PP Plant cutting (rooted)	6	1									
PI Pinch or prune	7										
RS Respace plants	3				1						
SA Soak bulb in acaricide	6	1									
S&H Shipping & handling	6									1	
SH Shade plants	2										
US Unshade plants	3										
Total Labor (seconds/pot/period)		62 0	46 0	46 0	53.0	46 0	46 0	46.0	41.5	6 0	392.5

TABLE D-11: SCHEDULE OF CULTURAL PRACTICES FOR GERANIUM

PLANT Geranium, 10 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	Mkting Date	Total secs
DF: Drench Fungicide	5	1					
FW: Fertigate & Irrigate	3	10	14	14	7		
GR. Spray growth regulator	3		2	1			
IR: Irrigate	1.5				3		
PA: Pesticide Application	3	1	1	1	1		
PKG:Package plant	9				1		
PG: Place in greenhouse	5	1					
PMD.Prepare media & fill pot	3	1					
PP: Plant cutting (rooted)	4.5	1					
PI: Pinch or prune	5						
RS: Respace plants	2		1				
SA: Soak bulb in acaricide	6						
S&H.Shipping & handling	5					1	
SH: Shade plants	1.5						
US. Unshade plants	2.5						
Total Labor (seconds/pot/period)		50.5	53.0	48.0	37.5	5.0	194.0

TABLE D-12: SCHEDULE OF CULTURAL PRACTICES FOR GERANIUM

PLANT Geranium, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	Mkting Date	Total secs
DF. Drench Fungicide	6	1						
FW. Fertigate & Irrigate	3	5	12	14	14	7		
GR: Spray growth regulator	4			2	1			
IR: Irrigate	1.5					3		
PA: Pesticide Application	4	1	1	1	1	1		
PKG:Package plant	12					1		
PG: Place in greenhouse	6	1						
PMD:Prepare media & fill pot	4	1						
PP: Plant cutting (rooted)	6	1						
PI: Pinch or prune	7							
RS: Respace plants	3			1				
SA: Soak bulb in acaricide	6							
S&H:Shipping & handling	6						1	
SH: Shade plants	2							
US: Unshade plants	3							
Total Labor (seconds/pot/period)		41.0	40.0	57.0	50.0	41.5	6.0	235.5

TABLE D-13 SCHEDULE OF CULTURAL PRACTICES FOR HYDRANGEA

PLANT Hydrangea, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6	1								
FW Fertigate & Irrigate	3	5	12	14	14	14	14	7		
GR Spray growth regulator	4		2	2	2					
IR Irrigate	1 5							3		
PA Pesticide Application	4	1	1	1	1	1	1	1		
PKG Package plant	12							1		
PG Place in greenhouse	6	1								
PMD Prepare media & fill pot	4									
PP Plant cutting (rooted)	6									
PI Pinch or prune	7					1	1			
RS Respace plants	3			1						
SA Soak bulb in acaricide	6									
S&H Shipping & handling	6	1							1	
SH Shade plants	2				7	14	14			
US Unshade plants	3				7	14	14			
Total Labor (seconds/pot/period)		37 0	48 0	57.0	89 0	123 0	123 0	41 5	6 0	524 5

TABLE D-14 SCHEDULE OF CULTURAL PRACTICES FOR HYDRANGEA

PLANT Hydrangea, 17.5 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6 5	1								
FW Fertigate & Irrigate	3	10	14	14	14	14	14	7		
GR Spray growth regulator	4 5		2	2	2					
IR Irrigate	1 5							3		
PA Pesticide Application	4 5	1	1	1	1	1	1	1	0	
PKG Package plant	13 5							1		
PG Place in greenhouse	6 5	1								
PMD Prepare media & fill pot	4 5									
PP Plant cutting (rooted)	7									
PI Pinch or prune	8					1	1			
RS Respace plants	3.5			1						
SA Soak bulb in acaricide	6									
S&H Shipping & handling	6.5	1							1	
SH Shade plants	2.25				7	14	14			
US Unshade plants	3 25				7	14	14			
Total Labor (seconds/pot/period)		54 0	55 5	59 0	94.0	131.5	131.5	43 5	6 5	575 5

TABLE D-15: SCHEDULE OF CULTURAL PRACTICES FOR POINSETTIA

PLANT Poinsettia, 15 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	6	1									
FW Fertigate & Irrigate	3	10	14	14	14	14	14	14	7		
GR Spray growth regulator	4			1		1					
IR Irrigate	1.5								3		
PA Pesticide Application	4	1	1	1	1	1	1	1	1		
PKG Package plant	12								1		
PG Place in greenhouse	6	1									
PMD Prepare media & fill pot	4	1									
PP Plant cutting (rooted)	6	1									
PI Pinch or prune	7		1								
RS Respace plants	3		0	1							
SA Soak bulb in acaricide	6										
S&H Shipping & handling	6									1	
SH Shade plants	2			7	14	14					
US Unshade plants	3			7	14	14					
Total Labor (seconds/pot/period)		56.0	53.0	88.0	116.0	120.0	46.0	46.0	41.5	6.0	572.5

TABLE D-16: SCHEDULE OF CULTURAL PRACTICES FOR POINSETTIA

PLANT Poinsettia,20 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	9 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	7	1										
FW Fertigate & Irrigate	3	5	12	14	14	14	14	14	14	7		
GR Spray growth regulator	5				1		1					
IR Irrigate	1 5									3		
PA Pesticide Application	5	1	1	1	1	1	1	1	1	1		
PKG Package plant	15									1		
PG Place in greenhouse	7	1										
PMD Prepare media & fill pot	5	1										
PP Plant cutting (rooted)	8	1										
PI Pinch or prune	9			1								
RS Respace plants	4				1							
SA Soak bulb in acaricide	6											
S&H Shipping & handling	7										1	
SH Shade plants	2 5				7	14	14					
US Unshade plants	3 5				7	14	14					
Total Labor (seconds/pot/period)		47.0	41.0	56 0	98 0	131.0	136 0	47 0	47.0	45.5	7 0	655 5

TABLE D-17: SCHEDULE OF CULTURAL PRACTICES FOR POINSETTIA

PLANT Poinsettia,25 cm	secs	1 st 2 wks	2 nd 2 wks	3 rd 2 wks	4 th 2 wks	5 th 2 wks	6 th 2 wks	7 th 2 wks	8 th 2 wks	9 th 2 wks	Mkting Date	Total secs
DF Drench Fungicide	8	1										
FW Fertigate & Irrigate	3	10	14	14	14	14	14	14	14	7		
GR Spray growth regulator	6				1	0	1					
IR Irrigate	1 5									3		
PA Pesticide Application	6	1	1	1	1	1	1	1	1	1		
PKG Package plant	18									1		
PG Place in greenhouse	8	1										
PMD Prepare media & fill pot	5	1										
PP Plant cutting (rooted)	10	1										
PI Pinch or prune	10		1									
RS Respace plants	5			1								
SA Soak bulb in acaricide	6											
S&H Shipping & handling	8										1	
SH Shade plants	3				14	14	14					
US Unshade plants	4				14	14	14					
Total Labor (seconds/pot/period)		67.0	58.0	53.0	152.0	146.0	152.0	48 0	48.0	49 5	8.0	781.5

Appendix E

1) List of abbreviations for decision variables

2) Mathematical formulation of model componenets

3) Listing of model results (QSB format)

TABLE E-1: LIST OF ABBREVIATIONS OF DECISION VARIABLES

I.DECISION VARIABLES			
Symbol	Plant	Pot Size	Period
Vti	African Violet	10 cm	i=1 to 26
VtXX	African Violet	10 cm	Christmas
VtVV	African Violet	10 cm	Valentine
VtEE	African Violet	10 cm	Easter
VtMD	African Violet	10 cm	Mother Day
Mti	Chrysanthemums	10 cm	i=1 to 26
MtXX	Chrysanthemums	10 cm	Christmas
MtVV	Chrysanthemums	10 cm	Valentine
MtEE	Chrysanthemums	10 cm	Easter
MtMD	Chrysanthemums	10 cm	Mother Day
Mfi	Chrysanthemums	15 cm	i=1 to 26
MfXX	Chrysanthemums	15 cm	Christmas
MfVV	Chrysanthemums	15 cm	Valentine
MfEE	Chrysanthemums	15 cm	Easter
MfMD	Chrysanthemums	15 cm	Mother Day
ZfXX	Azalea	15 cm	Christmas
ZfVV	Azalea	15 cm	Valentine
ZfEE	Azalea	15 cm	Easter
ZfMD	Azalea	15 cm	Mother Day
ZsXX	Azalea	17.5 cm	Christmas
ZsVV	Azalea	17.5 cm	Valentine
ZsEE	Azalea	17.5 cm	Easter
ZsMD	Azalea	17.5 cm	Mother Day
BtEE	Begonia	10 cm	Easter
BtMD	Begonia	10 cm	Mother Day
BfEE	Begonia	15 cm	Easter
BfMD	Begonia	15 cm	Mother Day
CtXX	Cyclamen	10 cm	Christmas
CtVV	Cyclamen	10 cm	Valentine
CtEE	Cyclamen	10 cm	Easter
CtMD	Cyclamen	10 cm	Mother Day
CfXX	Cyclamen	15 cm	Christmas
CfVV	Cyclamen	15 cm	Valentine
CfEE	Cyclamen	15 cm	Easter
CfMD	Cyclamen	15 cm	Mother Day
EIEE	Easter Lily	15 cm	Easter

TABLE E-1: LIST OF ABBREVIATIONS OF DECISION VARIABLES

I.DECISION VARIABLES-Continued			
Symbol	Plant	Pot Size	Period
Gti	Geranium	10 cm	i= 7-13
GtVV	Geranium	10 cm	Valentine
GtEE	Geranium	10 cm	Easter
GtMD	Geranium	10 cm	Mother Day
Gfi	Geranium	15 cm	i= 7-13
GfVV	Geranium	15 cm	Valentine
GfEE	Geranium	15 cm	Easter
GfMD	Geranium	15 cm	Mother Day
HfXX	Hydrangea	15 cm	Christmas
HfVV	Hydrangea	15 cm	Valentine
HfEE	Hydrangea	15 cm	Easter
HfMD	Hydrangea	15 cm	Mother Day
HsVV	Hydrangea	17.5 cm	Valentine
HsEE	Hydrangea	17 5 cm	Easter
HsMD	Hydrangea	17.5 cm	Mother Day
HsXX	Hydrangea	17 5 cm	Christmas
Pnf	Poinssettia	15 cm	Christmas
Pntw	Poinssettia	20 cm	Christmas
Pntf	Poinssettia	25 cm	Christmas

2) MATHEMATICAL FORMULATION OF MODEL COMPONENTS

I.Decision Variables

In mathematical formulation, this is illustrated as follows:

Xn_{ik} = Where X is the number of plant units of variety n with pot size i that is to be marketed at period k.

Using the plants abbreviations :

$(Xav)_{ik}$ = units of african violet of pot size i produced for market in period k. (i = t (ten cm), k = 26 periods including holidays)

$(Xaz)_{ik}$ = units of azalea of pot size i produced for market in period k. (i = f,s (fifteen cm, seventeen & a half cm), k = VV, EE, MD, XX)

$(Xbg)_{ik}$ = units of begonia of pot size i produced for market in period k. (i = t,f (ten cm, fifteen cm), k = EE, MD)

$(Xmm)_{ik}$ = units of chrysanthemums of pot size i produced for market in period k. (i = t,f (ten cm, fifteen cm), k = 26 periods including holidays).

$(Xcm)_{ik}$ = units of cyclamen of pot size i produced for market in period k. (i = t,f (ten cm, fifteen cm), k = VV, EE, MD, XX)

$(Xll)_{ik}$ = units of easter lily of pot size i produced for market in period k. (i = f (fifteen cm), k = EE)

$(Xgm)_{ik}$ = units of geranium of pot size i produced for market in period k. (i = t,f (ten cm, fifteen cm), k = Spring including VV, EE, MD ; k= 8 periods.)

$(Xhn)_{ik}$ = units of hydrangea of pot size i produced for market in period k. (i = f,s (fifteen cm, seventeen & a half cm), k = VV, EE, MD, XX)

$(Xpn)_{ik}$ = units of poinsettia of pot size i produced for marketing in period k. (i = f,s,tf (fifteen cm, seventeen & a half, twenty five cm), k = XX)

II. Objective Function

In mathematical formulation, this is illustrated as follows:

$$MAX\sum (Xav_{ik}*Pav_{ik}+Xaz_{ik}*Paz_{ik}+Xbg_{ik}*Pbg_{ik}+Xmm_{ik}*Pmm_{ik}$$

$$+Xcm_{ik}*Pcm_{ik}+X\ll_{ik}*P\ll_{ik}+Xgm_{ik}*Pgm_{ik}+Xhn_{ik}*Phn_{ik}$$

$$+Xpn_{ik}*Ppn_{ik})$$

for all i= 1 to m
all j=1 to 26

where

Pav_{ik} = the net profits from one unit of african violet of pot size i produced for market in period k

Paz_{ik} = the net profits from one unit of azalea of pot size i produced for market in period k

Pbg_{ik} = the net profits from one unit of begonia of pot size i produced for market in period k

Pmm_{ik} = the netprofits from one unit of chrysanthemum of pot size i produced for market in period k

Pcm_{ik} = the net profits from one unit of cyclamen of pot size i produced for market in period k

Pll_{ik} = the net profits from one unit of easter lily of pot size i produced for market in period k

Pgm_{ik} = the net profits from one unit of geranium of pot size i produced for market in period k

Phn_{ik} = the netprofits from one unit of hydrangea of pot size i produced for market in period k

Ppn_{ik} = the netprofits from one unit of poinsettia of pot size i produced for market in period k

III. Constraints

1-Available labor hours per period

In mathematical formulation, this is illustrated as follows:

$$MAX\sum(Xav_{ik}*Lav_{jik}+Xaz_{ik}*Laz_{jik}+Xbg_{ik}*Lbg_{jik}+Xmm_{ik}*Lmm_{jik}$$

$$+Xcm_{ik}*Lcm_{jik}+X{<}_{ik}*L{<}_{jik}+Xgm_{ik}*Lgm_{jik}+Xhn_{ik}*Lhn_{jik}$$

$$+Xpn_{ik}*Lpn_{jik})\leq TTL_{j}$$

for all i= 1 to m
all j=1 to 26
k=1 to 26

where

$(Lav)_{ijk}$ = hours of labor required during period j for production of one unit of african violet of pot size i for market in period k.

$(Laz)_{ijk}$ = hours of labor required during period j for production of one unit of azalea of pot size i for market in period k.

$(Lbg)_{ijk}$ = hours of labor required during period j for production of one unit of begonia of pot size i for market in period k.

$(Lmm)_{ijk}$ = hours of labor required during period j for production of one unit of chrysanthemum of pot size i for market in period k.

$(Lcm)_{ijk}$ = hours of labor required during period j for production of one unit of cyclamen of pot size i for market in period k.

$(Lll)_{ijk}$ = hours of labor required during period j for production of one unit of easter lily of pot size i for market in period k.

$(Lgm)_{ijk}$ = hours of labor required during period j for production of one unit of geranium of pot size i for market in period k.

$(Lhn)_{ijk}$ = hours of labor required during period j for production of one unit of hydrangea of pot size i for market in period k.

$(Lpn)_{ijk}$ = hours of labor required during period j for production of one unit of poinsettia of pot size i for market in period k.

TTL_j = total hours of labor available for period j, j = 1 to 26

<u>2-Available space area per period</u>

In mathematical formulation, this is illustrated as follows:

$$MAX\sum (Xav_{ik}*Sav_{jik}+Xaz_{ik}*Saz_{jik}+Xbg_{ik}*Sbg_{jik}+Xmm_{ik}*Smm_{jik}$$

$$+Xcm_{ik}*Scm_{jik}+X\text{«}_{ik}*S\text{«}_{jik}+Xgm_{ik}*Sgm_{jik}+Xhn_{ik}*Shn_{jik}$$

$$+Xpn_{ik}*Spn_{jik}) \leq TTS_j$$

for all i= 1 to m
all j=1 to 26
k=1 to 26

where

$(Sav)_{ijk}$ = Space area in square meters required during period j for production of one unit of african violet of pot size i for market in period k.

$(Saz)_{ijk}$ = Space area in square meters required during period j for production of one unit of azalea of pot size i for market in period k.

$(Sbg)_{ijk}$ = Space area in square meters required during period j for production of one unit of begonia of pot size i for market in period k.

$(Smm)_{ijk}$ = Space area in square meters requiredduring period j for production of one unit of chrysanthemum of pot size i for market in period k.

$(Scm)_{ijk}$ = Space area in square meters requiredduring period j for production of one unit of cyclamen of pot size i for market in period k.

$(Sll)_{ijk}$ = Space area in square meters requiredduring period j for productionof one unit of easter lily of pot size i for market in period k.

$(Sgm)_{ijk}$ = Space area in square meters requiredduringperiod j for production of one unit of geranium of pot size i for market in period k.

$(Shn)_{ijk}$ = Space area in square meters requiredduringperiod j for production of one unit of hydrangea of pot size i for market in period k.

$(Spn)_{ijk}$ = Space area in square meters required during period j for production of one unit of poinsettia of pot size i for market in period k.

TTS_j = Total available greenhouse space area for period j, j=1 to 26

Listing of the results for the Pot Flower LP Model in QSB format

Summarized Results for THESIS Page : 1

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
1	vt1	0	+96.269882	16	vt16	0	+31.178577
2	vt2	0	+104.07543	17	vt17	0	+46.004128
3	vtvv	0	+163.14359	18	vt18	0	+23.694553
4	vt4	0	+121.35314	19	vt19	0	+35.451130
5	vt5	0	+112.51233	20	vt20	0	+23.067625
6	vtee	0	+154.22734	21	vt21	0	+37.313553
7	vt7	0	+191.88277	22	vt22	0	+24.161144
8	vt8	0	+115.54488	23	vt23	0	+27.596832
9	vt9	0	+180.79086	24	vt24	0	+27.937582
10	vtmd	0	+180.98232	25	vt25	0	+32.949135
11	vt11	0	+158.96704	26	vtxx	0	+87.546333
12	vt12	0	+130.99257	27	mt1	0	+83.071854
13	vt13	0	+121.55462	28	mt2	0	+73.297203
14	vt14	0	+63.281277	29	mtvv	0	+134.00293
15	vt15	0	+26.054903	30	mt4	0	+198.02809

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

Summarized Results for THESIS Page : 2

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
31	mt5	0	+209.97527	46	mt20	0	+19.203310
32	mtee	0	+230.03546	47	mt21	0	+9.7578030
33	mt7	0	+152.87671	48	mt22	0	+8.2921572
34	mt8	0	+148.77318	49	mt23	0	+.30230340
35	mt9	0	+254.45323	50	mt24	+2453.1528	0
36	mtmd	0	+293.57495	51	mt25	+1171.6061	0
37	mt11	0	+277.14349	52	mtxx	0	+73.867477
38	mt12	0	+206.61746	53	mf1	0	+187.89838
39	mt13	0	+125.20306	54	mf2	0	+190.53113
40	mt14	0	+2.6136103	55	mfvv	0	+245.75453
41	mt15	0	+16.697113	56	mf4	0	+263.30127
42	mt16	0	+37.648708	57	mf5	0	+255.14366
43	mt17	0	+9.7181301	58	mfee	0	+314.06479
44	mt18	0	+15.477635	59	mf7	0	+242.40982
45	mt19	0	+12.704782	60	mf8	0	+200.72505

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

Summarized Results for THESIS Page : 3

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
61	mf9	0	+321.03281	76	mf24	0	+1.3907028
62	mfmd	0	+354.07175	77	mf25	0	+7.3761978
63	mf11	0	+331.79636	78	mfxx	0	+174.13992
64	mf12	0	+245.64656	79	zfvv	0	+9.5355024
65	mf13	0	+130.33403	80	zfee	+323.47046	0
66	mf14	0	+38.555103	81	zfmd	+15633.881	0
67	mf15	+3661.2058	0	82	zfxx	+20091.084	0
68	mf16	0	+28.518593	83	zsvv	0	+85.293762
69	mf17	+669.66827	0	84	zsee	+3578.6636	0
70	mf18	+4255.5132	0	85	zsmd	0	+8.4865541
71	mf19	+1621.7399	0	86	zsxx	0	+72.272285
72	mf20	0	+6.0679502	87	btee	0	+84.067337
73	mf21	+2135.4690	0	88	btmd	0	+106.65463
74	mf22	+3923.2205	0	89	bfee	0	+28.866682
75	mf23	+100.61419	0	90	bfmd	0	+53.263897

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

Summarized Results for THESIS Page : 4

Variables No.	Names	Solution	Opportunity Cost	Variables No.	Names	Solution	Opportunity Cost
91	ctvv	0	+312.01163	106	gt11	0	+121.34163
92	ctee	0	+339.33768	107	gt12	0	+90.453934
93	ctmd	0	+397.24960	108	gt13	0	+41.210052
94	ctxx	0	+265.35257	109	gfvv	+8524.5527	0
95	cfvv	0	+387.58377	110	gfee	+8626.1895	0
96	cfee	0	+449.20129	111	gf7	0	+46.468433
97	cfmd	0	+534.26129	112	gf8	+10532.563	0
98	cfxx	0	+324.68835	113	gf9	0	+54.739906
99	elee	0	+178.76445	114	gfmd	0	+53.468758
100	gtvv	0	+67.776001	115	gf11	0	+37.576294
101	gtee	0	+119.56433	116	gf12	+1704.1075	0
102	gt7	0	+45.790825	117	gf13	+8465.0791	0
103	gt8	0	+86.732811	118	hfvv	0	+451.86069
104	gt9	0	+148.96947	119	hfee	0	+331.52438
105	gtmd	0	+133.96730	120	hfmd	0	+408.22946

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

3

Summarized Results for THESIS Page : 5

Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
121 hfxx	0	+364.73044	136 S8	0	+1.9064981
122 hsvv	0	+424.57330	137 S9	+146460.58	0
123 hsee	0	+271.50903	138 S10	+573454.31	0
124 hsmd	0	+363.28796	139 S11	+484713.72	0
125 hsxx	0	+305.29276	140 S12	0	+.63815939
126 pnf	0	+176.69029	141 S13	+51177.902	0
127 pntw	0	+459.42834	142 S14	0	+.36900613
128 pntf	0	+655.36292	143 S15	+16883.191	0
129 S1	0	+.04348177	144 S16	0	+.36996174
130 S2	0	+2.1876786	145 S17	0	+.15764722
131 S3	+218348.02	0	146 S18	0	+.26624355
132 S4	+371304.81	0	147 S19	0	+.03395739
133 S5	0	+.57662874	148 S20	0	+.34218735
134 S6	0	+.63298362	149 S21	+289402.34	0
135 S7	0	+.73353904	150 S22	+105262.42	0

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

Summarized Results for THESIS Page : 6

Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
151 S23	0	+.30224070	166 S38	+1261.9027	0
152 S24	+298880.59	0	167 S39	+1449.5092	0
153 S25	0	+.05238785	168 S40	+1061.9402	0
154 S26	+519062.97	0	169 S41	+1312.5732	0
155 S27	+1418.8268	0	170 S42	+1264.5253	0
156 S28	+934.80341	0	171 S43	+1070.3917	0
157 S29	+1006.3358	0	172 S44	+1191.2911	0
158 S30	+887.84448	0	173 S45	+1341.0073	0
159 S31	0	+620.80298	174 S46	+1224.7575	0
160 S32	+171.64815	0	175 S47	+1396.2594	0
161 S33	+133.30573	0	176 S48	0	+169.14755
162 S34	+334.32205	0	177 S49	+10.564489	0
163 S35	+186.18318	0	178 S50	+133.22214	0
164 S36	+1510.8554	0	179 S51	0	+1803.6265
165 S37	+1208.8059	0	180 S52	+1659.0179	0

Maximum value of the OBJ = 1.505011E+07 Iters. = 57

Sensitivity Analysis for RHS Page : 1

B(i)	Min. B(i)	Original	Max. B(i)	B(i)	Min. B(i)	Original	Max.B(i)
B-1	+567254.94	+864000.0	+876341.8	B-19	+856121.62	+864000.0	+879703.8
B-2	+853820.25	+864000.0	+964453.1	B-20	+581329.00	+864000.0	+901637.3
B-3	+1221652.0	+1440000.	+Infinity	B-21	+574597.62	+864000.0	+Infinity
B-4	+1068695.3	+1440000.	+Infinity	B-22	+1334737.6	+1440000.	+Infinity
B-5	+1322948.5	+1440000.	+1513755.	B-23	+1419054.8	+1440000.	+1455607.
B-6	+1369261.1	+1440000.	+1508988.	B-24	+1141119.4	+1440000.	+Infinity
B-7	+1336045.1	+1440000.	+1674869.	B-25	+1418572.5	+1440000.	+1469792.
B-8	+1296576.6	+1440000.	+1508234.	B-26	+776937.00	+1296000.	+Infinity
B-9	+573539.44	+720000.0	+Infinity	B-27	+581.17322	+2000.000	+Infinity
B-10	+866545.69	+1440000.	+Infinity	B-28	+1065.1965	+2000.000	+Infinity
B-11	+955286.25	+1440000.	+Infinity	B-29	+993.66418	+2000.000	+Infinity
B-12	+817578.12	+864000.0	+940490.3	B-30	+1112.1555	+2000.000	+Infinity
B-13	+812822.12	+864000.0	+Infinity	B-31	+1718.9874	+2000.000	+2061.261
B-14	+826283.00	+864000.0	+877425.3	B-32	+1828.3518	+2000.000	+Infinity
B-15	+847116.81	+864000.0	+Infinity	B-33	+1866.6943	+2000.000	+Infinity
B-16	+833757.56	+864000.0	+890650.5	B-34	+1665.6780	+2000.000	+Infinity
B-17	+828383.06	+864000.0	+884304.5	B-35	+1813.8168	+2000.000	+Infinity
B-18	+855021.50	+864000.0	+875149.4	B-36	+489.14465	+2000.000	+Infinity

Sensitivity Analysis for RHS Page : 2

B(i)	Min. B(i)	Original	Max. B(i)	B(i)	Min. B(i)	Original	Max. B(i)
B-37	+791.19409	+2000.00	+Infinity	B-45	+658.9926	+2000.0000	+Infinity
B-38	+738.09729	+2000.00	+Infinity	B-46	+775.2425	+2000.0000	+Infinity
B-39	+550.49084	+2000.00	+Infinity	B-47	+603.7406	+2000.0000	+Infinity
B-40	+938.05981	+2000.00	+Infinity	B-48	+1993.218	+2000.0000	+2012.508
B-41	+687.42676	+2000.00	+Infinity	B-49	+1989.435	+2000.0000	+Infinity
B-42	+735.47473	+2000.00	+Infinity	B-50	+1866.777	+2000.0000	+Infinity
B-43	+929.60828	+2000.00	+Infinity	B-51	+1984.509	+2000.0000	+2007.834
B-44	+808.70886	+2000.00	+Infinity	B-52	+340.9820	+2000.0000	+Infinity

Sensitivity Analysis for OBJ Coefficients   Page :

C(j)	Min. C(j)	Original	Max. C(j)	C(j)	Min. C(j)	Original	Max. C(j)
C(1)	- Infinity	-5.96999	+90.299889	C(19)	- Infinity	+17.0800	+52.5311
C(2)	- Infinity	-9.31999	+94.755432	C(20)	- Infinity	+16.3799	+39.4476
C(3)	- Infinity	-4.44999	+158.69359	C(21)	- Infinity	+15.1200	+52.433[illegible]
C(4)	- Infinity	-10.6100	+110.74314	C(22)	- Infinity	+13.2100	+37.4011
C(5)	- Infinity	-9.14000	+103.37232	C(23)	- Infinity	+11.1200	+38.7168
C(6)	- Infinity	+.410000	+154.63734	C(24)	- Infinity	+7.96000	+35.897[illegible]
C(7)	- Infinity	-3.22000	+188.66277	C(25)	- Infinity	+4.96000	+37.9091
C(8)	- Infinity	+.759999	+116.30488	C(26)	- Infinity	+6.92999	+94.176[illegible]
C(9)	- Infinity	+4.13000	+184.92087	C(27)	- Infinity	+39.0499	+122.121
C(10)	- Infinity	+12.7300	+193.71231	C(28)	- Infinity	+34.9800	+108.27[illegible]
C(11)	- Infinity	+9.09000	+168.05705	C(29)	- Infinity	+47.2700	+181.27[illegible]
C(12)	- Infinity	+11.6400	+142.63257	C(30)	- Infinity	+34.2300	+232.258
C(13)	- Infinity	+13.8399	+135.39462	C(31)	- Infinity	+35.7999	+245.77[illegible]
C(14)	- Infinity	+15.4200	+78.701279	C(32)	- Infinity	+50.4800	+280.51[illegible]
C(15)	- Infinity	+16.5000	+42.554905	C(33)	- Infinity	+43.2000	+196.07[illegible]
C(16)	- Infinity	+17.2700	+48.448578	C(34)	- Infinity	+47.9900	+196.76[illegible]
C(17)	- Infinity	+17.4900	+63.494129	C(35)	- Infinity	+52.1800	+306.63[illegible]
C(18)	- Infinity	+17.5400	+41.234554	C(36)	- Infinity	+67.1299	+360.704

Sensitivity Analysis for OBJ Coefficients   Page :

C(j)	Min. C(j)	Original	Max. C(j)	C(j)	Min. C(j)	Original	Max. C(j)
C(37)	- Infinity	+58.0400	+335.18350	C(55)	- Infinity	+44.4000	+290.154
C(38)	- Infinity	+61.1600	+267.77747	C(56)	- Infinity	+26.5000	+289.801
C(39)	- Infinity	+63.6399	+188.84306	C(57)	- Infinity	+31.6299	+286.77[illegible]
C(40)	- Infinity	+65.5999	+68.213608	C(58)	- Infinity	+56.9300	+370.994
C(41)	- Infinity	+66.6999	+83.397110	C(59)	- Infinity	+45.1500	+287.559
C(42)	- Infinity	+67.6699	+105.31870	C(60)	- Infinity	+55.5299	+256.25[illegible]
C(43)	- Infinity	+67.8200	+77.538132	C(61)	- Infinity	+64.3399	+385.37[illegible]
C(44)	- Infinity	+67.8799	+83.357635	C(62)	- Infinity	+88.1999	+442.271
C(45)	- Infinity	+67.2699	+79.974777	C(63)	- Infinity	+77.1800	+408.976
C(46)	- Infinity	+66.3899	+85.593307	C(64)	- Infinity	+83.8300	+329.476
C(47)	- Infinity	+64.8399	+74.597801	C(65)	- Infinity	+90.1800	+220.514
C(48)	- Infinity	+63.7500	+72.042160	C(66)	- Infinity	+93.6200	+132.179
C(49)	- Infinity	+59.8800	+60.182304	C(67)	+94.321503	+96.3600	+103.801
C(50)	+55.592915	+55.9000	+58.936005	C(68)	- Infinity	+98.3899	+126.908
C(51)	+46.818916	+52.2999	+53.269985	C(69)	+95.113106	+98.9000	+99.7592
C(52)	- Infinity	+59.6800	+133.54749	C(70)	+98.580475	+99.0299	+101.648
C(53)	- Infinity	+37.6199	+225.51837	C(71)	+94.925964	+97.8200	+98.1863
C(54)	- Infinity	+28.8700	+219.40114	C(72)	- Infinity	+95.9800	+102.044

Sensitivity Analysis for OBJ Coefficients Page :

C(j)	Min. C(j)	Original	Max. C(j)	C(j)	Min. C(j)	Original	Max. C(j
C(73)	+92.232521	+92.6699	+97.855118	C(91)	- Infinity	-53.4900	+258.521
C(74)	+83.090492	+87.7500	+88.972702	C(92)	- Infinity	-61.2900	+278.047
C(75)	+80.360283	+82.2200	+87.520050	C(93)	- Infinity	-46.0700	+351.179
C(76)	- Infinity	+73.9300	+75.320702	C(94)	- Infinity	-29.4000	+235.952
C(77)	- Infinity	+66.1299	+73.506195	C(95)	- Infinity	+14.2600	+401.843
C(78)	- Infinity	+73.5599	+247.69992	C(96)	- Infinity	-4.15000	+445.051
C(79)	- Infinity	+174.720	+184.25551	C(97)	- Infinity	+25.7900	+560.051
C(80)	+149.83752	+186.539	+188.19902	C(98)	- Infinity	+71.1299	+395.818
C(81)	+203.75400	+212.090	+214.52699	C(99)	- Infinity	+32.5600	+211.324
C(82)	+178.79262	+198.370	+209.01683	C(100)	- Infinity	+26.6899	+94.4659
C(83)	- Infinity	+183.480	+268.77377	C(101)	- Infinity	+29.6700	+149.234
C(84)	+197.62447	+201.230	+223.43649	C(102)	- Infinity	+23.2600	+69.0508
C(85)	- Infinity	+244.000	+252.48656	C(103)	- Infinity	+25.2199	+111.952
C(86)	- Infinity	+224.679	+296.95227	C(104)	- Infinity	+26.6100	+175.579
C(87)	- Infinity	+70.5700	+154.63734	C(105)	- Infinity	+35.0000	+168.967
C(88)	- Infinity	+78.4499	+185.10463	C(106)	- Infinity	+28.8799	+150.221
C(89)	- Infinity	+163.929	+192.79668	C(107)	- Infinity	+29.9200	+120.373
C(90)	- Infinity	+191.240	+244.50391	C(108)	- Infinity	+30.8600	+72.0700

Sensitivity Analysis for OBJ Coefficients Page :

C(j)	Min. C(j)	Original	Max. C(j)	C(j)	Min. C(j)	Original	Max. C(j
C(109)	+134.07829	+136.740	+225.93774	C(119)	- Infinity	+5.13000	+336.654
C(110)	+139.36206	+141.850	+143.68607	C(120)	- Infinity	+59.7400	+467.969
C(111)	- Infinity	+127.560	+174.02843	C(121)	- Infinity	+47.4000	+412.130
C(112)	+129.16890	+131.230	+138.28410	C(122)	- Infinity	+105.270	+529.843
C(113)	- Infinity	+134.170	+188.90991	C(123)	- Infinity	+134.610	+406.119
C(114)	- Infinity	+152.840	+206.30876	C(124)	- Infinity	+214.220	+577.507
C(115)	- Infinity	+138.610	+176.18630	C(125)	- Infinity	+201.429	+506.722
C(116)	+123.40804	+141.039	+171.23326	C(126)	- Infinity	+93.3499	+270.040
C(117)	+138.64516	+142.780	+156.93065	C(127)	- Infinity	+55.3200	+514.748
C(118)	- Infinity	-8.81000	+443.05069	C(128)	- Infinity	+92.5700	+747.932