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PROJECT LEADER:	Dr Hazel MacTavish
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PROJECT CONSULTANT:	Mr Alan Cox (Technical editor)
KEY WORKERS:	Mr Harry Kitchener Mr Dan Drakes Dr Kim Green Ms Jude Bennison Mr Gerrit Heij Mr Albert Kreiss Mr Bob Goemans Dr Bill Parker Mr Tim Briercliffe
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Horticultural Development Council.

Authentication

I declare that this work was done under my supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Dr Hazel MacTavish
Senior Research Consultant
ADAS Arthur Rickwood

Signature………………………….. Date…………………………

Report authorised by:

Dr Bill Parker
Research Manager – Crop Protection & Horticulture
ADAS Wolverhampton

Signature………………………….. Date…………………………

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OBJECTIVES

The UK alstroemeria crop is currently valued at approximately £7.5 million, broadly equivalent to the value of the UK poinsettia and pot chrysanthemum crops (BHS, 1998). Alstroemerias are also produced elsewhere in the World; the success of Dutch alstroemeria producers in particular is based on extensive breeding and research programmes, resulting in increased yields and higher quality crops. In order that UK growers can benefit from this research, it is important to draw together the information available and assess the production practices used in Holland and elsewhere. A comprehensive review will enable UK growers to implement beneficial and cost effective production practices.

The commercial objectives of this review were:

- To draw together, evaluate and present relevant research work on alstroemeria production in the Netherlands, Canada, Japan and elsewhere.

- To investigate and report on advances currently being made by leading alstroemeria growers in the Netherlands and in Canada and elsewhere, and to evaluate their production practices in terms of their relevance to UK alstroemeria production. The practical implementation and assessment of cost/benefits of new technologies and practices needed to be thoroughly evaluated for UK growers.

Particular attention was paid to technologies and practices that could reduce the costs of production, increase quality and provide growers with the knowledge and technology to deal with impending environmental and legislative pressures.

SOURCES OF INFORMATION

The information contained in this report was assembled following:

- A worldwide literature review (over 150 references sourced and reviewed).
- Internet searches (in Dutch and English).
- Obtaining information from the UK Flowers and Plants Association.
- Discussions with over 20 UK growers.
- Visits to five UK growers.
- Visits to six growers and two plant breeders in the Netherlands in June 2002.
- A review of Dutch technical literature (undertaken by Dr Gerrit Heij and Mr Albert Kreiss).
- Consultation with specialist consultants in pests, diseases and soil sterilisation.
- Consultations with UK Plant Clinic diagnosticians for pest and diseases recorded on alstroemeria in the UK.
- Feedback from project co-ordinators.

GLOSSARY OF TERMS

AYR	= All year round
BHS	= Basic Horticultural Statistics for the UK
CCL	= Climate Change Levy
CHP	= Combined Heat and Power
CO_2	= carbon dioxide
EC	= Electrical Conductivity
IPM	= Integrated Pest Management
LD	= long day flowering response
MITC	= Methyl iso-thio cyanate
NCER	= Net Carbon Exchange Rate
NFT	= Nutrient Film Technique
PAR	= Photosynthetically Active Radiation
Pn	= leaf net photosynthesis
PSD	= Pesticide Safety Directorate
RH	= Relative Hunidity
SD	= short day
SOLA	= Specific Off Label Approval
PPM	= Parts per million

EXECUTIVE SUMMARY

Background

- Although alstroemeria have been cultivated for some 180 years, breeding has only been undertaken since the 1940s.
- Some 7-12 species have been instrumental in the development of modern hybrids.
- Many of the hybrid varieties are sterile; new varieties have been produced by irradiation mutations and more recently by *in vitro* embryo rescue.
- The genetic background is complex and varieties can no longer be grouped into specific 'types' with ease.
- Three main breeders produce new varieties. Breeders select primarily for colour, form, productivity, seasonal production , and disease resistance.
- Flower initiation and development is the result of complex interactions between temperature (perceived by the rhizome) and photoperiod (long days and low soil temperatures promote flowering). Varieties respond individually to environmental conditions, especially soil temperature.

Soil preparation and planting

- Clay and sandy-clay soils are best suited to alstroemeria production, which requires good drainage, an organic matter content of at least 20% and a pH of 6.5.
- Weed control is important and may be achieved through chemical or (preferably) physical control in addition to steam sterilisation.
- Rotavating in the old crop and steam sterilisation are recommended before planting a new crop.
- Soil sterilisation is highly desirable between production cycles, for weed, fungal and nematode control. Different methods have been reviewed.
- Sources of recent UK research and contacts for soil sterilisation are presented.
- Hydroponic production of alstroemeria is possible but few producers use this now.
- Plant densities of 3-3.8 plants/gross m² are generally recommended in the UK.

Crop management

- Seasonal production of alstroemeria stems is affected by variety, soil temperature, photoperiod, planting date and other environmental conditions.
- The above factors also influence variation in stem quality and the amount of thinning required.
- It is important to obtain plant material of suitable quality at appropriate times in order to achieve control over timing, production levels and quality of flowers.
- There is a great challenge for UK producers to supply a steady stream of flowers of specific colours AYR, and the importance of UK-specific variety trials and knowledge of the influence of environmental factors on crop production seasonality is crucial.

Temperature requirements

<u>*Air temperature*</u>

- Alstroemeria perform best at an air temperature of less than 15°C. Above this temperature, carbon loss through respiration exceeds carbon gain through photosynthesis.
- Dutch recommendations are for 13°C night and 14-16°C day temperature after planting; followed by 17-20°C (day) maximum during production. Maintenance of RH at 80% is recommended.
- UK producers heat to achieve a 9°C night and a 12°C day in winter, and strive to keep the temperature down to less than 20°C in the summer by venting etc.
- Although alstroemeria production is influenced more by soil than air temperature, flowering is encouraged when air temperatures are 10°C plus in a 12-14h day.
- The energy demand for the crop is in the region of 1.5 million KWh/ha/annum.
- The energy saving potential of temperature integration needs to be evaluated for Alstroemeria.
- Ventilation, roof sprinklers and misting can be used to maintain air temperatures at suitable levels.
- Although smaller micro-turbine types of combined heat and power (CHP) units may have benefits, including reducing energy costs, the current energy supply and price situation make the investment look unattractive.

Soil Temperature

- A constant soil temperature of 14-16°C is generally recommended for alstroemeria, to maximise production and minimise thinning and other management costs.
- Correct soil temperature control increases flower yield/m², decreases the number of vegetative shoots, reduces crop height and spreads the flowering window more evenly AYR. More class I stems *may* be produced.
- Cultivars respond individually to soil cooling, and some respond negatively.
- Supplementary lighting and soil cooling together spread the flowering window wider and increase production at otherwise low times of the year.
- Low temperature treatment of rhizomes and subsequent high intensity lighting increased the spread of flower development, although the practicalities of using this may be slim.
- Soil temperatures in the UK may be **cooler** than desirable for much of the year thus, rather than soil 'cooling', the term 'constant soil temperature control' may be more descriptive of this key objective.
- Any economic advantage from soil temperature control needs to take into consideration the varieties being grown, market demands and the environmental factors controlled, such as supplementary light.
- Photoperiod and soil temperature control also act in a combined way to increase productivity; however, most of the benefit is due to soil temperature control.
- Pumping cool borehole or chilled water through pipes to cool soil is used in Holland.
- As the canopy grows, reflectance from the crop or mulches reduce radiative heat absorbed by the soil. In addition, fogging and ventilation to reduce air temperature reduces soil heating.
- Improved monitoring of UK glasshouse soil temperatures throughout the year will be required to assess the need for improved soil temperature control, potentially via heating. The costs and benefits of this will need to be assessed.
- There is a lack of knowledge on soil temperature fluctuations under relevant UK conditions. There is a recommendation to monitor the soil temperature to assess the costs and benefits, and the effects on varieties.

Irrigation techniques

- Irrigation is one of the key factors regulating growth and ultimately productivity in alstroemeria. Yield increases of 12-15 % have been observed in the UK by improving irrigation systems.
- Monitoring of soil moisture (e.g. using tensiometers) is necessary to prevent overwatering and also to ensure uniform water distribution throughout the cropped area.
- Productivity and quality of alstroemeria can be improved with more attention to management of soil water content and with the use of low level irrigation systems such as drippers.
- Control over irrigation in the early months sets the pattern of growth in the early years. Appropriate irrigation can lead to yield increases of up to 20% in the first year, together with improved stem quality.
- More UK relevant information is required for irrigation of alstroemeria in order to improve uniformity, productivity and quality.

Crop nutrition

- Since alstroemeria is a long-term crop, regular addition of fertilisers over a long growing period is required. Fertilisers are applied with irrigation water (fertigation), usually in a two stock-tank system similar to hydroponic production systems.
- Regular soil nutrient analysis is advised for optimal production, since the nutritional requirements of alstroemeria change as the crop develops. It is important to ensure that soil samples representative of the cropping area are used for analysis. Leaf tissue analysis can provide extra back-up for diagnosis of problems.
- Optimal N:K ratios of 1:1 – 1:1.4 significantly increase the number of flower stems/plant, stem length, fresh stem weight and number of flowers/stem.
- Soil pH should be in the range 5.5 – 6.5. Higher pH values can lead to iron or manganese deficiency.
- Alstroemeria is a salt-sensitive crop. General recommendations are that electrical conductivity should be maintained below 1.5 mS/cm at 25^{o}C, with a maximum of

4.5 mmol/l each of sodium and chloride. Negative effects on yield can occur above these levels.

- Leaf tissue analysis is useful for diagnosing symptoms of toxicity or deficiency, which can otherwise be difficult to distinguish from physiological or virus symptoms.

Supplementary lighting

- The level of incident photosynthetically active radiation (PAR) on alstroemeria crops under glass may be significantly less than the crop requires for optimum production, especially in winter.
- Alstroemeria in very sensitive to irradiation - both to photoperiod and intensity.
- Alstroemeria is a long day (LD) plant and a daylength of ≥ 13h is required to promote flowering. There are varieties that will yield well under relatively sub-optimal lighting conditions.
- Additional assimilation lighting may increase productivity, depending on the variety. Breeders recommend trials be undertaken by producers before regimens are consolidated in to general practice.
- Further productivity benefits are obtained through assimilation lighting + soil cooling and assimilation lighting + CO_2.
- Productivity improvements include an increase in the number of flowering shoots, an increase in the % of flowering shoots and an increase in the number of cymes per inflorescence.
- Dutch producers routinely use 4,000 lux for 13-14 h, with 500 ppm CO_2. There may be benefits for increased light levels beyond this, but no cost:benefit analysis has been done.
- Additional benefits of HID lighting (assimilation lighting) are reduced heating costs (gain of 1°C/2.4 W/m²).
- Substantial UK research has investigated the economics of supplementary lighting; 600W lamps are preferred over 400W lamps.
- For a given lighting regime, UK running costs are approximately twice that for a similar situation in Holland although in reality common sense practice and the better light levels in Southern England would reduce the costs.

- There is a need to assess the incident PAR levels throughout the year under glass and to assess the cost:benefit of supplementary lighting in various situations in the absence of CO_2 and soil cooling .

Carbon dioxide enrichment

- With enhanced control over environmental conditions in the form of soil and air temperature, supplementary lighting and optimum fertigation, CO_2 would be limiting for alstroemeria production in the UK.
- Almost all Dutch producers use supplementary CO_2 to 500 ppm, combined with supplementary lighting, benefiting from a 10-15% productivity increase across all varieties.
- It is suggested that research be undertaken to assess the efficiency of photosynthesis *in situ* on various sites in the UK, which have better light than Holland, to assess the need for supplementary CO_2. For those producers who have supplementary lighting, the need will similarly need to be assessed.

Pests and diseases

Fungal pathogens, viruses and pests affecting alstroemeria are reviewed with regard to:

- symptoms;
- cultural control;
- biological control ;
- chemical control;

The most common diseases found in UK crops are *Pythium, Phytophthora* and *Rhizoctonia* root trots, *Botrytis,* and, more especially, virus problems. The aphid transmitted alstroemeria mosiac virus was found to be widespread in a survey of crops in 2000.

The major pests infesting alstroemeria in the UK are whitefly, aphids, thrips, spider mites, caterpillars, leafhoppers, slugs and snails and nematodes. Several of these are important as virus vectors as well as being pests in their own right.

- Biological control methods, within IPM strategies, are available for most pest problems and are the preferred option.
- With the loss of pesticides and increasing use of IPM, controlling leafhoppers and caterpillars remains a challenge for effective IPM control.
- The damage caused by alstroemeria mosaic virus varies with variety and crop production, and in some cases, appears to cause little damage.

Harvesting and post-harvest handling

- Harvesting and packing alstroemeria is very labour intensive. Various novel systems for transporting cut flowers from the glasshouse to packhouse have been developed and are widely used in Holland.
- Machines to grade, bunch and pack are currently being developed and offer promise of further labour saving, especially for large scale nurseries, though there may be some spin-off benefits for smaller nurseries.
- Leaf yellowing is the major factor affecting vase life, rather than flower senescence. Gibberellins may be used in vase solutions to reduce leaf yellowing and prolong vase life.

Environmental legislation

- The legislation affecting various aspects of Alstroemeria production is reviewed.

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- Tim Petit, HRI Wellesbourne.

In addition to the personal communications specified in the text of section 9, the following Entomologists provided information towards this section on pests of alstroemeria; Neil Helyer and Alan Horgan, Fargro Ltd. ; Scott Meadows, States of Jersey Department of Agriculture and Fisheries; Clare Sampson, BCP Ltd, and Graeme Murphy, Ontario Ministry of Agriculture, Food and Rural Affairs.

1. INTRODUCTION

Alstroemeria species, along with their improved cultivars and hybrids, have become important cut flowers in recent years. Over 60 species have been described, and some have been in cultivation for over 180 years. The genus is native to South America, and most species may be found in Chile. The flower is also known as the Peruvian lily, the Princess lily, the Inca lily, lily of the Incas, the Brazilian Parrot lily, the Chilean lily and the lily of Peru.

Within the last 20 years, alstroemeria has established itself as one of the top 10 cut flowers sold in Europe. It is an important greenhouse flower crop because of consumer interest, excellent vase life, high wholesale value, high productivity in greenhouses and low energy requirements for production during winter. Well suited to production in a temperate climate, some varieties flower all-year-round (AYR). However, when the soil temperature is greater than 20°C or less than 8°C alstroemeria stops flowering; the optimum soil temperature for production is 14-16°C.

The aims of recent research and development on alstroemeria production have been: higher yields/m^2, improved quality, a healthy root system and more efficient use of fertiliser and water. Research has also focussed on promoting earlier winter and spring flowering, and extending the harvest during warm growing conditions, such as in summer.

1.1. Genetic make-up and plant breeding

Yields of alstroemeria flowers can vary from 150 to 500 stems/m^2, depending on variety and planting schedule. The correct choice of varieties is essential for success in large-scale production, aiming for an even spread of production all-year-round.

Alstroemeria are currently bred by a number of Dutch, UK and American companies, plus several private breeders. Primary objectives for the breeders are vigorous growth forms, continuous year-round flowers, fragrance, compact growth habit, and new flower colours. In addition, male sterile lines that could be used to produce uniform F_1 hybrids are a new, desirable breeding objective. Alstroemeria grown from seed is not uniform and seed is only used for breeding purposes. Unfortunately, alstroemeria contains a virus that is seed-transmitted (cucumber mosaic virus), so virus-free mother plants are needed to prevent the transmission of this virus.

The chromosomes of alstroemeria are very ‘large’, typical of the Amaryllidaceae and Liliaceae. With a basic number of n = 8, breeders and geneticists have been excited by both the large chromosome size and the small chromosome number. This genus still has tremendous opportunities for improvements through breeding and genetics due to the short period in which it has been studied.

Most commercial plants are hybrid cultivars selected for colour, flower form, length of cropping season and resistance to heat, transport damage and disease. Not all cultivars are patented. Plants of the named glasshouse varieties are only available through a few breeder/propagators and they control the supply by selling plants under contract. Usually no propagation is permitted and the grower buys a ‘licence to grow’ and pays an initial royalty. On re-planting the same variety, only payment for the plants is made. The main UK suppliers are Könst, Royal Van Zanten, and Parigo. Growers perceive the cost of the royalty, although large, to be worth it due to the benefits of the improved varieties. The aim of the royalty system was to control areas of alstroemeria grown, and to this end it has been successful.

Alstroemeria is a rhizomatous monocot belonging to the family Amaryllidaceae (formerly Alstroemeriaceae). Alstroemeria has a wide botanical background; the original species are very different from current varieties and have extraordinary appearance and characteristics. Seven species (*Alstroemeria aurantiaca* D. Don es Sweet, *A. haemantha* Ruitz Pav., *A. ligtu* L., *A. pelegrina* L., *A. violocea* Phil., *A. pulchra* Sims and *A. psittacina*) have been the primary contributors to the interspecific hybrids available commercially along with mutations of these hybrids.

1.2. Types of alstroemeria

John Goemans, a specialist plant breeder and founder of Parigo Horticultural Co. Ltd, was the first to recognise the potential of alstroemeria as a glasshouse cut flower crop, based on an observation of a chance seedling growing in a garden in the south of England, and called ‘Walter Fleming’. The genetic origin of this variety remains unknown. John Goemans obtained plants of this hybrid and successfully grew it under glass in the 1950s, rechristening it ‘Orchid’. This variety was sterile. Subsequently, Könst found a tetraploid mutation of this variety, which then became a parent of several varieties known as ‘Orchid’ types. Many of the early varieties produced by van Staaveren were irradiation-induced mutations of ‘Orchid’.

The orchid-type has three to five months of major flower production in the spring, a reduced crop in autumn and relatively low production for the remainder of the year. The second burst of production does not occur in warmer climates. Generally, these cultivars are characterized by tall growing habits (2.5-3.0 m), a large number of flowers produced in a short period, a thermoperiodic cycle for flower initiation, triploid chromosome numbers, and little or no photoperiodic responsiveness. Flowering will most often occur in the spring after the plants have received a cool (10-15^{o}C) winter temperature following the period of non-flowering in the summer. These plants will be divided in the summer months after flower production has ceased; they will remain vegetative until spring.

John Goemans used many species in his breeding programme, which commenced in the 1940s. Those that produced early results were *A. aurea, A. psittacina, A. violacaea* and *A. pellegrina*. His first hybrid, ‘Ballerina’, was produced in 1959 and received an RHS award of merit in 1961. This was closely followed by the hybrids ‘Charm’ and ‘Pride’ and then several other varieties. The Dutch breeders subsequently undertook their own breeding programmes; the first Dutch hybrids arrived in the UK in 1974.

‘Carmen’ was John Goemans’ most successful early (sterile) variety, being the first AYR flowering variety. Several mutations of ‘Carmen’, both natural sports and produced by irradiation, also became commercial varieties (‘Carmen’ types).

John Goemans had produced the first strain of ‘Butterfly’ hybrid seed during the early 1960s. It was eventually widely used as breeding material and several named ‘Butterfly’ hybrids were introduced as varieties. The ‘Butterfly’ varieties have different cultural requirements to the other alstroemeria types and do not lend themselves to growing in a mixed variety glasshouse. Hence, not many are grown in the UK. The butterfly varieties flower for nine to 12 months each year, depending upon cultivar and environmental conditions. Generally, these cultivars are characterized by shorter growing habits, larger and more open flowers, diploid and tetraploid chromosome numbers, and a distinct foliage arrangement. Butterfly varieties are used for potted plant production as well as for cut flowers. Cool temperatures (13-16^{o}C) and long photoperiods will induce and maintain flowering in these varieties. The thermophase is required for flowering, and the photophase only hastens flowering. Propagules of butterfly types are often planted during the summer months, but can be planted at any time of the year. If the plants are given long photoperiods, high light intensities and cool temperatures, they will flower within three to four months.

A further type of alstroemeria was obtained by rigorous selection from *A. aurea*, which is now known as *A. aurantiaca,* to produce varieties such as 'Yellow King'. As a result of the early breeding successes and the need for further improvements, a whole collection of different species was obtained by the European breeders from South America and several new species were introduced into the breeding programmes (although some may have been the same species under a different name). With the advent of embryo rescue techniques, it became possible to achieve crosses in alstroemeria breeding which in the past would not have been possible (Bridgen *et al.*, 1990). Most of the modern varieties are therefore not easily categorised into a type.

Some of the species used in the development of modern varieties are illustrated and described below (information and images taken from www.alstroemeria.com).

Alstroemeria indora (Plate 1.1)

This variety priginates from Brasil, near San Paulo. Grows in shady areas, the plant is activated in the rainy season on riverbanks, in marshy areas or in ditches. It will generate flowers in January.

Plate 1.1. A . indora

Alstroemeria magnifica maxima (Plate 1.2).

This variety originates in Chile, north of Santiago. Grows in desert-like mountainous areas, after it has rained. The plant then produces flowers in the month of November.

Plate 1.2. A. magnifica maxima

Alstroemeria aurautiaca (Plate 1.3)

A. aurea occurs in the open spaces of the woods in Chile, in Region X (Puerto Montt). It flowers in January, which is the summer in Chile. Before World War II, selections were grown in England and in the Netherlands for cut flower production. It has been used in breeding for more than a century.

Plate 1.3. A .aurautiaca

Alstroemeria pulchra (Plate 1.4)

This alstroemeria grows in the hills of Region IV close to the ocean, north of Valparaiso. It starts growing after it has rained (or it starts growing after the rain season has finished) and flowers then in spring (which is in October). This variety is quite often used for breeding.

Plate 1.4. A. pulchra

Alstroemeria spatulatha (Plate 1.5)

Origin: North of Santiago in the V region.

Grows in the mountains at an altitude of 2500-3000 m. This variety will start to grow after it has rained and will flower in January.

Plate 1.5. A. spatulatha

Alstroemeria pelegrina (Plate 1.6)

Origin: region IV in Chile, north of Valparaiso.

Grows on the shoreline of the Pacific Ocean and flowers in November.

Plate 1.6. A. pelegrina

Alstroemeria ligtu (Plate 1.7)

This alstroemeria grows on the plains of region no. VIII in Chile. It flowers in the spring (November). *Alstroemeria ligtu* was one of the first to be brought to Europe and it is still grown as a cut flower in Japan. The flowering season is very short (May-June), but it has a bright colour spectrum ranging from white to pink. Since its leaves are weak, it is no longer used as a parent in today's breeding programmes.

Plate 1.7. A. ligtu

Alstroemeria brasiliensis (Plate 1.8)

A.brasiliensis grows in the province of Sao Paulo, Brazil. The natural habitat of this alstroemeria is a bit swamp-like; the areas are little lakes that dry up after the rain season. This Brasilian alstroemeria was widely used to make ‘Butterfly-types’.

Plate 1.8. A. brasiliensis

Alstroemeria sierra (Plate 1.9)

This alstroemeria with large, dark purple flowers grows on the coastal plains of region IV, south of La Serena. It has strong stems, which can grow anywhere from 40 to 80 cm long and flowers in the spring but mostly in October.

Plate 1.9. A. sierra

Alstroemeria diluta (Plate 1.10)

A. diluta occurs in dry and sandy soil on the plains of Region VII, close to Linares. It will grow 10 to 15 cm tall after it has rained and flowers in the month of November.

Plate 1.10. A. diluta

Alstroemeria pelegrina alba (Plate 1.11)

The origin of this species is not completely clear. It is believed that it is probably a mutation of the pink Pelegrina, which grows on the shoreline of the Pacific Ocean. It flowers in November and has not been found in the wild.

Plate 1.11. A. pelegrina alba

Alstroemeria psittacina (Plate 1.12)

This is a Brasilian alstroemeria that grows close to Sao Paulo on the mountain and hill tops. Flowering time is January. The early Butterfly hybrids originated from this species.

Plate 1.12. A. psittacina

It is possible to observe these alstroemerias species in real life. The Botanical Garden of Utrecht has several varieties planted and they should be flowering in June. *Address:* Museum: Botanische Tuinen Fort Hoofddijk; Street: Budaplein 17; Postal Code: 3584CD; Tel: +31 (0)30 2535455; City: Utrecht, The Netherlands.

1.3. Novel varieties

A few novel varieties have recently been released by breeders, including:

- *Alstresias* – these have a very long vase life, and have 3-4 flowers open at the same time before the first opened flower wilts. Several colours have been released by Könst.
- *Pot or patio alstroemerias* – sold as 'Princess Lilies' by Royal Van Zanten and concurrently being developed by other breeders.
- *Fragrant varieties* – with a fragrance reminiscent of certain varieties of lily.
- *Stripeless varieties* – developed by Royal Van Zanten.

1.4. Colour

Alstroemerias are available in many colours including pink, purple, orange, yellow, red, white and green. Orange is traditionally only popular in the Netherlands (The National colour), whilst in the UK, pale pink and lilac are currently the most popular colours, followed by white (Flowers and Plant Association, 2002).

1.5. Morphology

Alstroemeria has an underground rhizome that develops vertical shoots and new lateral rhizomes that also produce flowering shoots. The shoots can be either reproductive or vegetative depending on the environmental conditions. Since the major part of the plant's development occurs underground, the temperature of the soil plays an important role in this development. After a period of high soil temperatures, the plant produces many shoots (and new rhizomes) but depending on the variety, many of these shoots remain blind (i.e. do not produce flowers). Above the soil, the stems do not generate any lateral stems or roots.

The rhizome is the organ from which aerial shoots and fibrous roots arise. Rhizomes are white fleshy, multi-stemmed, very brittle, and densely covered with down-like hairs. Fibrous roots later thicken into storage roots, called "*Radices medullosae*" (Plate 1.13a, b & c). Plants are propagated by division of the rhizome with attached roots and shoots, or by tissue culture. Starch, in quantities similar to the potato tuber, has been isolated and characterised from the fleshy roots.

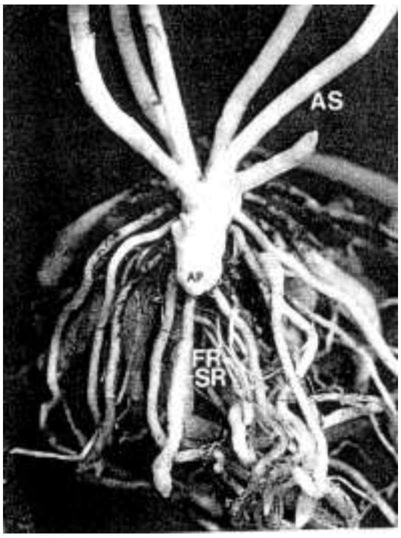


Plate 1.13a. The aerial shoots (AS) arising from the apical region (AP) of the rhizome are initiated alternately. A fibrous root system (FR) is associated with the storage root (SR). From the CRC Handbook of Flowering, Vol. 1.

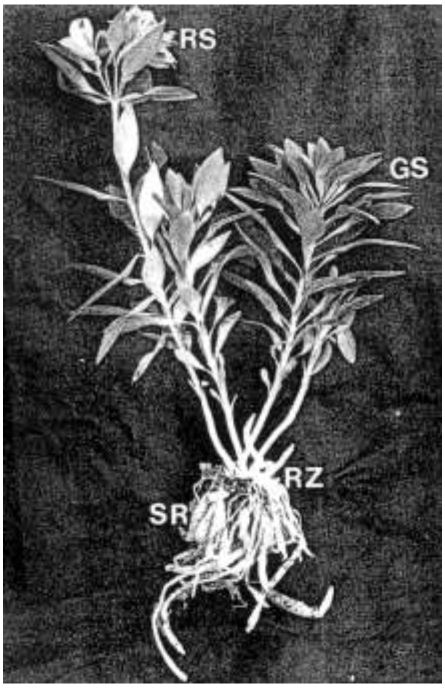


Plate 1.13b. Alstroemeria reproductive (RS) and vegetative shoots (GS) attached to a subterranean rhizome from which develops storage roots (SR). From the CRC Handbook of Flowering, Vol. 1.

Plate 1.13c. Fibrous roots with thickened storage roots (*Radices medullosae)* evident.

In alstroemeria, the leaf petioles twist 180^{o} on the stems so that the original underside becomes the topside. The leaves are entire, grey-green to dark green, almost always thickish, matt to shiny, and mostly hairless on both sides.

The inflorescence is a whorl of simple or compound cymes, which form a terminal branched cluster of flowers (Plate 1.14). Each cyme can consist of several flowers arising sympodially. The perianth segments are separated. They are sometimes nearly equal and sometimes markedly unequal. There are six stamens that are delineate. The inferior ovary is 3-celled and develops into a capsule. One alstroemeria stem can produce one to twelve flowers, each on a lateral pedicel near the tip of the stem.

Plate 1.14. The inflorescence of an alstroemeria

1.6. Dormancy and rhizome storage

Tubers (swollen roots) are storage organs formed during and just after flowering by the same environmental conditions which promote flowering, i.e. long days and low temperatures. These same conditions of long days and low temperatures (9-13^{o}C) also induce dormancy. By maintaining high temperatures in short days, shoot growth continues without dormancy but flower initiation is inhibited. Dormant plants can be prompted into growth by giving a long period of high temperature. Leaving old stems on plants during the rest stage prolongs dormancy, whilst removing shoots and flowers shortens the resting period.

Alstroemeria rhizomes can be stored for several months if they are kept cool (1-3 °C) and moist. Root rots occur if rhizomes are too wet. Bare root storage is not recommended. Potted alstroemeria plants can be stored in pots as long as freezing does not occur.

1.7. Flowering

Flowering in alstroemeria requires both a thermophase (cold treatment), which is perceived by the rhizome and a photophase (a specific photoperiod). The thermophase requirement must be fulfilled prior to the photophase. Each cultivar has a unique thermophase from 10 to 16°C, both in absolute temperature and duration, with genotype determining the temperature range and the duration at that temperature before rhizome meristems are induced. A cold phase to induce flowering (for example 5^{o}C for 6 weeks compared to a continuous 13^{o}C) may be used on *planted* rhizomes. However, not all varieties will respond to this treatment.

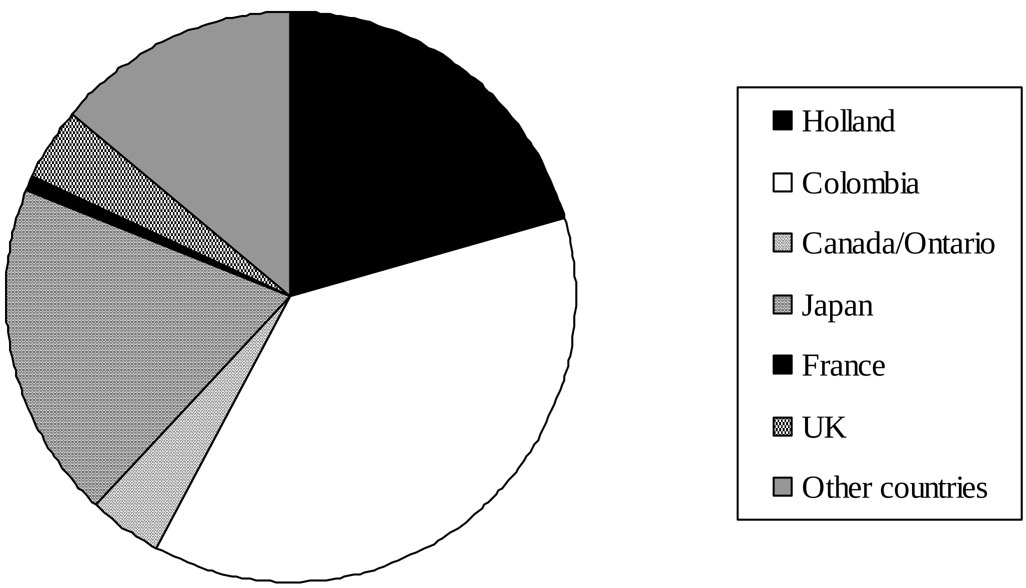
The different genetic make-up of varieties of alstroemeria increases the confusion regarding the flowering mechanism, which is complex. When soil temperature and photoperiod conditions are conducive for flowering, the majority of shoots will initiate flowers. When conditions are marginal, only some shoots will initiate flowers and others will remain vegetative (so-called ‘blind’ shoots). Some varieties can throw up 50-70% blind shoots, which are usually removed by pulling to stimulate more flowering shoots. During non-inducive high soil temperatures, plants will remain vegetative regardless of the photoperiod. After alstroemeria has initiated floral buds, high temperatures will hasten the flowering process. As temperatures increase above

20-25 °C, however, flowers may have weaker stems, bud abortion may occur, and if infected with virus, symptoms may be exhibited and flowering may cease earlier.

1.8. Production statistics

Recent years have seen a reduction in the area of alstroemeria production worldwide from 600 to just over 500 ha. The area grown by the predominant alstroemeria-producing countries are shown in Fig. 1.1.

Figure 1.1. World production of alstroemeria as a proportion of total (500 ha).



In Europe, alstroemeria is grown predominantly in greenhouses, using heating and lights to achieve good winter production, sometimes with cold water pipes in the ground to extend summer production.

In Holland, 60-65% of the 50-55 alstroemeria producers use soil cooling and supplementary assimilation lighting. All supplement with CO_2 and steam sterilise the soil between plantings. Forty percent use integrated pest management (IPM). Dutch producers generally grow between one and three varieties; the average farm size is 1-2 ha. Current Dutch production can be 400 stems/m^2 seasonally; however, there is a move toward production of 250 stems/m^2 AYR, of better quality material. The Dutch cut their flowers at a significantly less mature stage than the UK producers, to reduce transportation damage through the Dutch Auctions. In the last five years, production in Holland has increased, but only relatively modest increases in turnover. The area grown has remained relatively constant, however (Fig. 1.2).

In the tropics, alstroemeria is grown under shade (30-40%) or plastic, and does best at altitudes above 2,400 m. In these conditions, it flowers all-year-round without any climatic modifications. In Colombia, which is the largest world producer of alstroemeria, the steady photoperiod is 12 with high light intensity and temperature of 18-30^{o}C during the day and 8-12^{o}C at night. In Colombia, each producer grows upwards of 20 ha under plastic, with no soil cooling. The flowers (with thicker stems, more flowers/stems and a more intense colour compared with other growing areas) are traded through Miami for the American market.

In Japan, producers each grow around 3000 m^2 of 25-30 varieties. Soil cooling is used by some producers; however, lights are not as yet used. The focus is on flower quality.

In Canada/Ontario, production units are larger in area than in Japan, and alstroemeria is commonly produced alongside snapdragons, for example. Both soil cooling and lighting are used, but not supplementary CO_2. Producers in all countries are advised by Dutch breeders (who supply plant material and agronomic advice) to use drip irrigation systems.

In the UK, there are around 20 specialist alstroemeria producers of various sizes making a total of 25 ha in 2001 (Table 1.1). There has been a small amount of variation, but production has been reasonably steady over the last six years. Each producer grows between seven and 25 varieties, to obtain a mixture of colours, AYR. A selection of UK producers was contacted and asked to supply information on various points related to alstroemeria production (Fig. 1.3a-3f). These producers represent 10 ha, or 40% of total UK production.

Figure 1.2. Trends in Dutch alstroemeria production (million bunches), turnover (billion Euro) and area grown in the period 1997-2001.

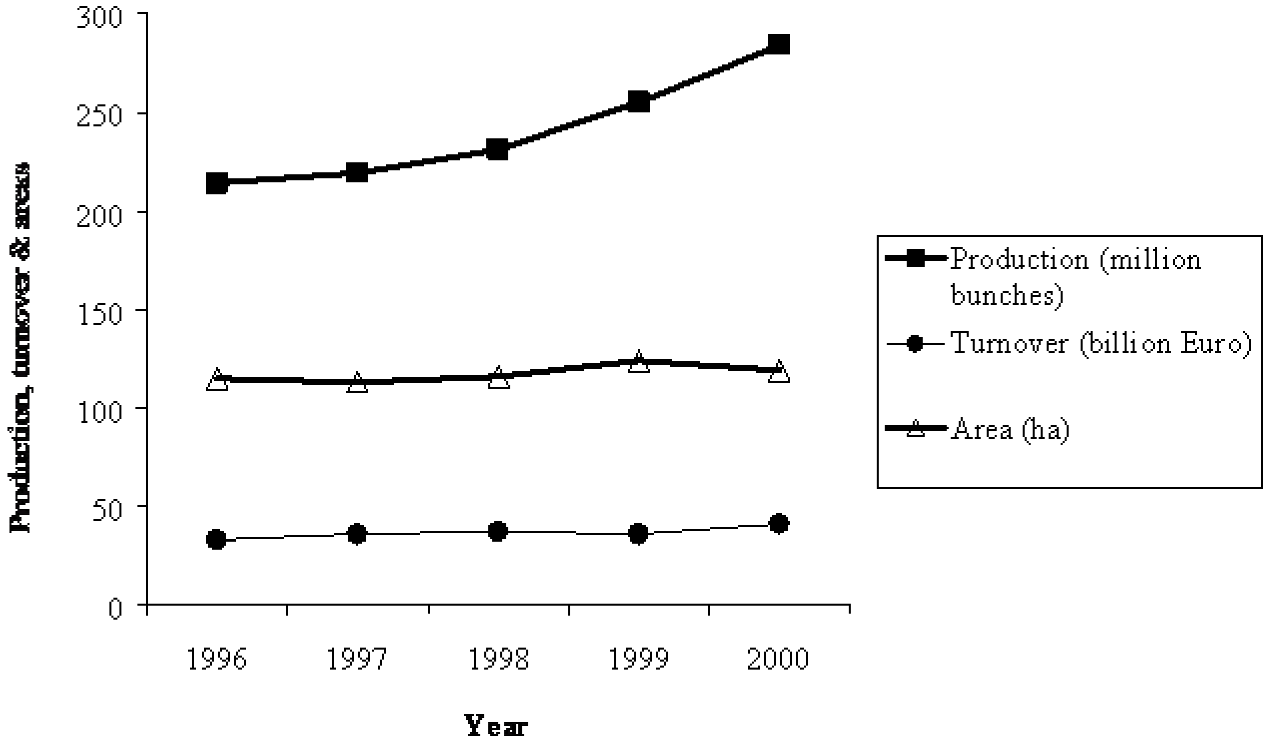


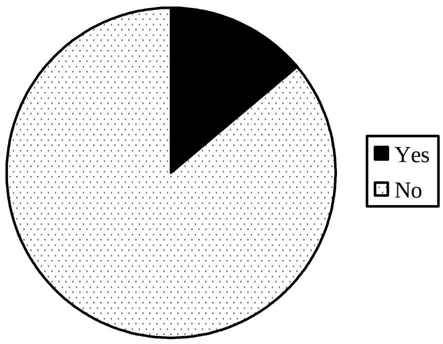
Table 1.1. Area of alstroemeria production in the UK 1996-2001.

Year	Area (ha)
1996	26.0
1997	25.4
1998	24.8
1999	24.9
2000	26.4
2001	25.4

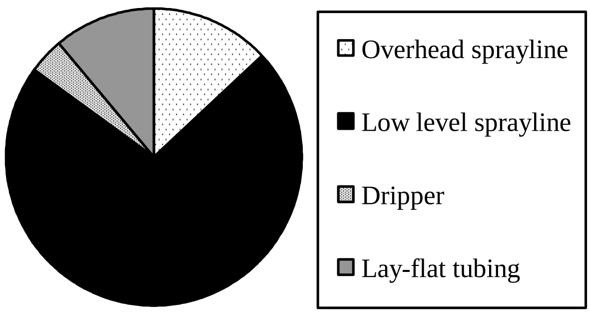
Source: DEFRA (formally MAFF)

Figure 1.3. Results of a survey of production practices by UK alstroemeria growers. The survey covered 10ha or 40% of the total UK production.

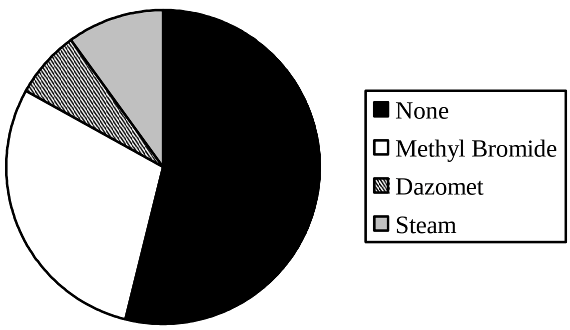
a) Use of thermal shades and screens



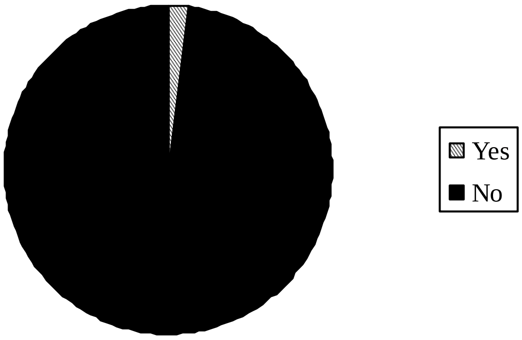
b) Type of irrigation equipment used



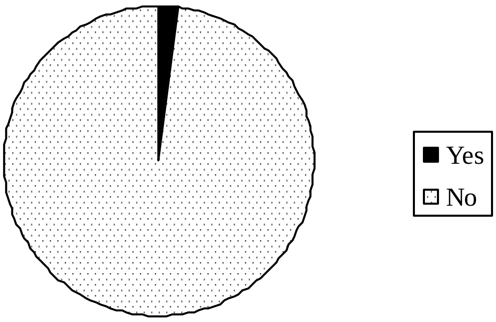
c) Soil sterilization method



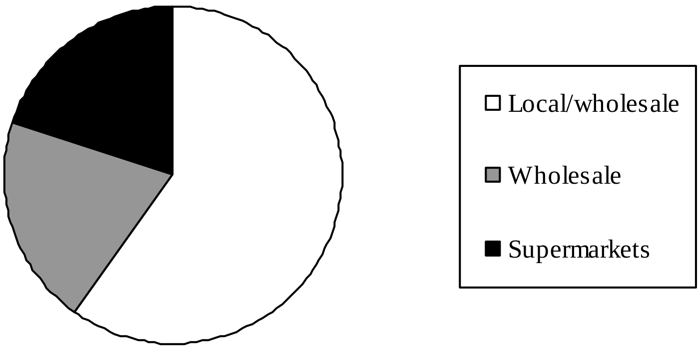
d) $C0_2$ supplementation used



e) Use of supplementary assimilation lighting



f) Type of market supplied

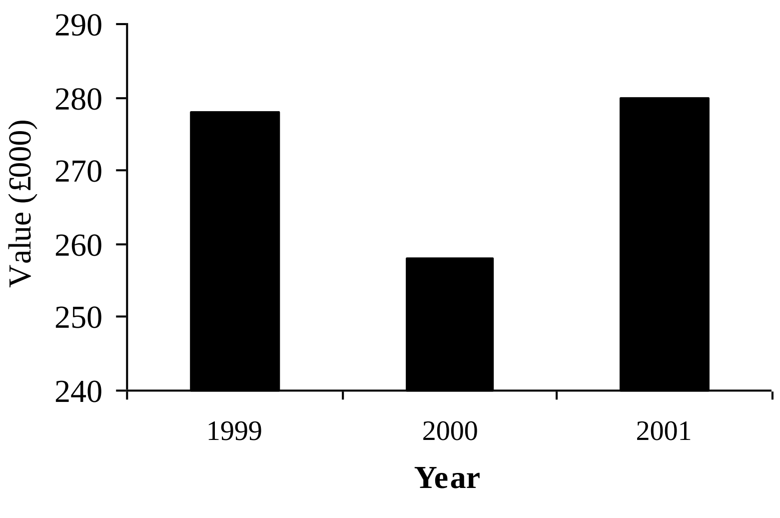


Thus, 40% of producers in the UK predominantly use no screens, low level spraylines, and a range of soil sterilisation options (including none); only a few use supplementary CO_2 and assimilation lighting, and these are predominantly the larger growers. A mixture of markets is supplied, predominantly local markets, florists and wholesalers. It is fair to say that it is the larger producers only that use CO_2 and assimilation lighting. In general, larger producers use the recommended dripper and low level irrigation also.

UK production may be between 150 and 500 stems/m^2. Stem quality is generally considered by both Dutch and UK breeders/producers to be significantly better than Dutch produce. Generally, UK producers replant 25% of the nursery each year, with a four-year crop rotation cycle.

The value of UK alstroemeria production at the farm gate in recent years has been variable (Fig. 1.4). The total UK fresh cut flower and indoor plant market is worth over £1.45 billion at retail level, with a 3:1 ratio between cut flowers and indoor plants. Alstroemeria represents a small but reasonably steady proportion of total flower sales.

Figure 1.4. Annual output of UK alstroemeria production (£K) in the period 1999-2001.



A survey of the top 10 varieties sold to UK producers in 2001 by three of the main breeders indicates the most up to date information on varieties under production in the UK (Table 1.2).

Table 1.2. Current top 10 varieties sold to UK producers by two breeders in 2001.

Rank order	Parigo Horticultural Co. Ltd. (UK)	Royal Van Zanten (Holland)
1	Nina	Rebecca
2	Ventura	Victoria
3	Charmaine	Sunny Rebecca
4	Europa	Belinda
5	Candy	Xandra
6	Laguna	Virginia
7	Bonanza	Irena
8	Bellini	Olga
9	Avanti	Amarella
10	Dana	Diverse

1.9. Trade statistics

The top 10 of the 130 varieties traded through the Dutch auction in 2001 are shown in Table 1.3.

Table 1.3. The top 10 alstroemeria varieties traded through the Dutch auctions in 2001 (RVZ = Royal Van Zanten; K = Könst).

Variety	Colour	Breeder/Supplier	Number of bunches ('000)	Price/bunch (€)
Virginia	White	RVZ	12,717	0.17
Granada	Pink	RVZ	9,554	0.19
Jamaica	Yellow	K	8,181	0.14
Yellow King	Yellow	RVZ	7,657	0.10
Diamond	White	RVZ	7,081	0.14
Pink Diamond	Pink	RVZ	4,384	0.12
Fantasy	Red	K	4,259	0.12
Rebecca	Pink	RVZ	4,240	0.13

Source: Dutch auction figures, 2002.

The differences between Tables 1.2 and 1.3 reflect the popularity of varieties Dutch producers grow compared with those favoured by UK producers. Newly purchased varieties are probably still increasing in market share and are thus not captured in the top 10 traded varieties.

The price and supply of alstroemerias varies throughout the year. Supply generally increases during the warmer months (Fig. 1.5), at which time prices also tend to be lower (Fig. 1.6).

Figure 1.5. Alstroemeria sales as a percentage of total flower sales in Dutch auctions in 2001.

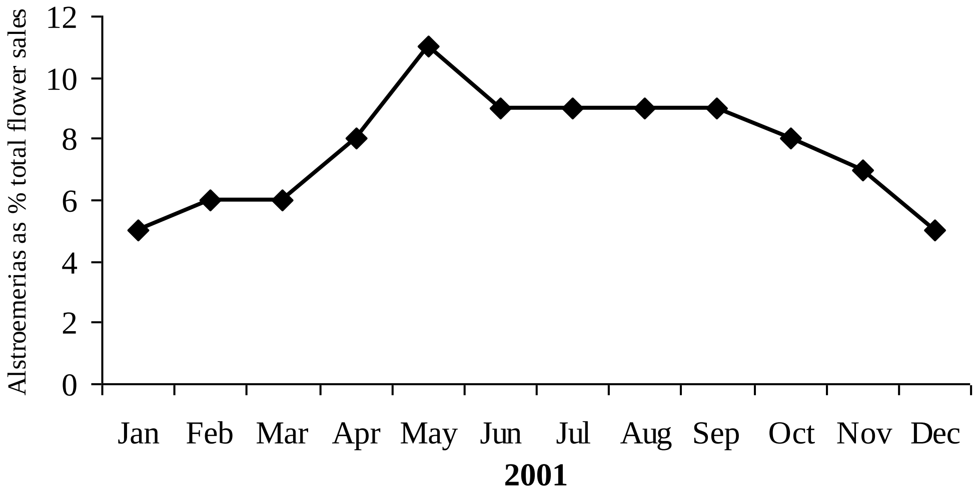
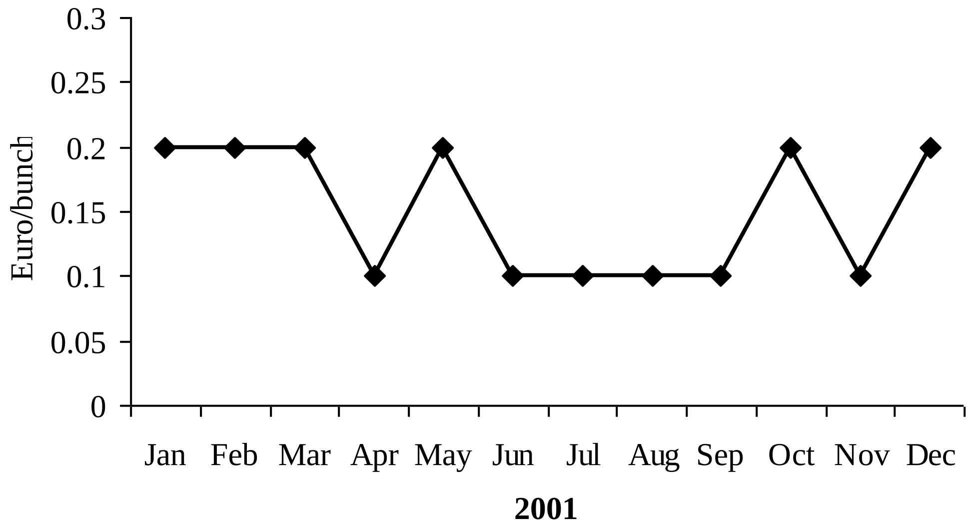


Figure 1.6. Price per bunch (Euros) of alstroemerias sold through Dutch auctions in 2001.



In 2001, alstroemeria passing through the Dutch auctions had a total sales value of €42 million and a total sales volume of 277 million bunches. This represents a 0.6% drop in volume and a 3.8% increase in value compared with previous years, illustrating a positive price trend attributed to a lower supply of better quality material. Better lighting and growing conditions, as well as a more up to date assortment, played integral roles in the price increase (Flora Culture International, Sep 02).

1.10. Summary

- Although alstroemeria has been cultivated for some 180 years, breeding has only been undertaken since the 1940s. There is still considerable scope for variety improvement.
- Some 7-12 species have been instrumental in the development of modern hybrids.
- Many of the hybrid varieties are sterile; some new varieties are produced by irradiation mutations and more recently by *in vitro* embryo rescue techniques.
- The genetic background is complex and varieties can no longer be grouped into specific 'types' with ease.
- New varieties are produced by three main breeders who primarily select for colour, form, productivity, seasonal production variability, and disease resistance.
- Flower initiation and development is the result of complex interactions between temperature, perceived by the rhizome, and photoperiod; long days and low soil temperatures promote flowering. Varieties respond individually to soil environmental conditions.
- After flowering, rhizomes enter a dormant phase.
- Of the total world production of 500 ha, Holland produces 24% and the UK 5%. The major world producer is Columbia at around 190 ha.
- There are marked differences in production methods used in Holland and the UK, notably relating to number of varieties grown, use of supplementary light, CO_2, and the marketing strategy.

2. SOIL PREPARATION AND PLANTING

2.1 Soil type

Alstroemeria can be grown on sandy, sandy clay, light clay and peat soils. The soil must meet the following requirements:

1. Good rooting possible (undisturbed profile).
2. Good structure.
3. Good drainage; a constant moisture content during the entire year.
4. Sufficient nutrients in the right proportion.
5. Low salt concentration.
6. Free from pathogens and parasites.

2.1.1 Sandy soils

The capacity of sandy soils for containing moisture is low. Introduction of organic material to the topsoil improves sandy soils. Manure and other organic materials are recommended for these soils. Fertilisers in sandy soils are quickly eluted by excess water, reducing their availability to plant roots. Therefore, consideration should be given to more frequent and regular watering and fertilisation of these soils.

2.1.2 Clay and sandy-clay soils

Clay and sandy-clay soils with a so-called tapering profile are the most suited to alstroemeria production. A tapering profile means that the soil becomes less heavy from top to bottom. Soils with another profile can provide equally good results provided that the structure of the sub-soil is good.

Clay and sandy-clay soils hold water. Soil that is too wet can increase the risk of root rots. High soil moisture can be avoided by ensuring the topsoil contains sufficient organic material. The organic level can be increased by incorporating 2 to 5 m^3 of organic material per 100 m^2. ‘Fresh’ organic material such as manure, leaf mould, and bark should not be mixed any deeper than 40 cm in the soil. Large amounts of manure in dense soil are not advisable, because the soil becomes too sticky and wet. The ground water level should be generally maintained at 0.9 to 1.1 m.

2.1.3 Peat soils

Alstroemeria grown on peat soils, which are usually moist, provide fewer problems than the production of other plants due to the superficial growth of the rhizomes. On peat soil, the plants display a speedy and lush growth in comparison with those on clay soils.

2.2 Drainage

Deep and undisturbed root growth is desirable. This is determined by the structure of the soil and the soil water level. When the roots are under water, they die off after a short period of time. A low water level encourages the plant to develop deeper roots, but these roots will be killed if the water level increases, even temporarily. For example, roots formed in the summer may die off in autumn. Thus, maintenance of constant moisture content is recommended. Drainage also helps reduce the level of accumulated salts in the soil.

2.3 Soil pH

The pH should be around 6.5. At higher pH (above pH 7.5), nutritional problems such as magnesium and iron deficiency may occur. At very low pHs, the acidity may impede the uptake of trace elements or calcium within the plant.

2.4 Organic material

Organic matter is incorporated into soil to maintain good soil structure. As a result of each year of cultivation, 3-4% of the organic matter in the soil is lost. Organic matter in the soil should therefore be boosted before planting a four-year alstroemeria crop. In general 2-3 m^3 per 100 m^2 of one of the following materials is used:

- manure
- peat moss
- coconut fibre
- other organic materials

Use of dry chicken manure and similar products can lead to excessive release of ammonia. This can lead to tip burn if ventilation is poor, or if plants are regularly wetted via condensation,. Similarly, the roots of young plants may be burned by direct contact with this type of organic material.

2.5 Fertilisers

2.5.1 Base fertiliser

Sampling the soil before planting is essential to optimise nutrients and pH levels from the beginning of the crop. Poorly fertilized crops will grow more slowly. Soil sampling techniques are described in Appendix 1. It is important at this stage to discuss with the laboratory carrying out the tests how the results will be reported back. British laboratories report soil analysis in mg/litre of nutrients, often referring to levels as an index (the ADAS Index classification is given at Appendix 1). Dutch laboratories report in mg/litre or in millimol/litre (mmol/l) for major nutrients or micromol/litre (μmol/l) for minor nutrients. A conversion between mg/l and mmol/l and μmol/l is given in Appendix 2.

Base fertilisers such as ammonium nitrate, triple superphosphate, sulphate of potash and kieserite are normally used, although compound fertilisers with a suitable balance of N, P and K, and sometimes Mg can be used instead. Recommended fertiliser application rates are given in Table 2.1. Soil pH should also be corrected by ground limestone application pre-planting.

Table 2.1. Base fertiliser recommendations based on soil analysis

	Nitrate, P, K or Mg Index (g/m²)						
	0	**1**	**2**	**3**	**4**	**5**	**Over 5**
Ammonium nitrate	30	15	Nil	Nil	Nil	Nil	Nil
Triple superphosphate	150	140	130	110	80	45	Nil
Sulphate of potash	350	300	240	130	Nil	Nil	Nil
Kieserite	240	210	160	80	Nil	Nil	Nil

Once the crop has been planted, fertilisers are usually applied as liquid feeds (see Section 6 – Crop Nutrition).

2.5.2 Compound or mixed fertilisers (most soluble)

These contain at least three elements (N, P and K). The content of each element is expressed as percentages of N, P_2O_5 and K_2O. Some fertilisers also contain Mg and Ca, also expressed as a percentage of MgO and/or CaO. Most compound fertilisers are soluble, and this is recommended for alstroemeria. A suitable standard compound or mixed fertilizer is 11-0-17-4-10, i.e. 11% N, 0% P_2O_5, 17% K_2O, 4% MgO and 10% CaO. If there is enough calcium in the soil the compound may then be: 11-0-19-4-0. With no phosphorus at all, a P-fertiliser should be dug in before planting.

Soil pH has a large influence on the availability and ease of uptake of micronutrients. In general, micronutrients are less well taken up as the pH increases. Peat soils (pH 5-6) almost never suffer this problem. On calcium enriched sandy clay and clay soil, a higher pH can lead to a lack of iron and magnesium in the spring.

2.6 Weed control

Weeds can be a particular problem where beds remain in production for several years, particularly when only part of a house is sterilised at any one time. It is essential to keep the house as clean as possible at all times. Once weeds begin to seed in the house, they will spread rapidly both to pathways and amongst the crop. Chickweed (*Stellaria media*) is the most common problem but groundsel (*Senecio vulgaris*) and sow thistle (*Sonchus* spp.) can also be problematic. Weed control by means other than hand-weeding is extremely restricted.

2.6.1 Herbicide options

There are NO herbicides with label approval for use on protected flower crops. However paraquat (Gramoxone 100) has Specific Off-Label Approval (SOLA) for use on protected ornamentals (SOLAs 1640/01 and 0225/02) for post cultivation as an inter-row directed treatment. Note that SOLAs now have an expiry date of 31 December 2008, and not ‘Unstipulated’ or ‘Unlimited’ as stated on the SOLA documents. Note that SOLA use is at the grower’s risk and that the appropriate approval documents must be obtained before use. SOLA documents can be obtained from the Pesticides Safety Directorate of DEFRA, the NFU, the HDC or ADAS.

2.6.2 Non-chemical options

The best method of weed control is through regular hoeing or cultivating, and this also prevents the weeds from seeding. When the plants are fully grown, there are almost no problems with weeds. Weeds that grow in the paths can be controlled by hoeing.

Many UK producers use wood shavings as a mulch within beds to control weeds and maintain moisture. A layer of 2-3 cm is usual. Note that some hardwood products may be toxic to plant growth. In addition, dust may be a hazard during application, so a risk assessment should be carried out when using wood products. In addition, covering pathways with a strong light-proof material such as Mypex will smother weed growth (Plate 2.1).

There may be some benefit in incorporating wood shavings after cropping, to improve soil texture, but nitrogen may be used up in the breakdown process.

Plate 2.1. Sawdust mulches and Mypex on pathways in the UK.

An alternative method of weed control is flame weeding, which is also an approved organic production treatment. Not only is it chemical-free, it is often cheaper than using chemicals. Flame cultivation machines are widely used in the USA.

The Micro Dragon developed by the Green Dragon comes with options including a heat shroud to concentrate the heat source for use in glasshouses and tunnels. The main components are a 120 litre propane tank linked to a set of burners which are lit using an integral hand lance equipped with its own spark lighter. In practice the lance has evolved an additional role for spot weeding. The price of the Micro Dragon varies according to specification, but starts at around £4,500. Working at around 5km/hr, the running costs are about £14/ha for weed control.

The company usually recommends the installation of a 2,000 litre fuel tank on farms and an arrangement with a company like BP to replenish the LPG fuel. Bulk propane works out about half the price of bottled supplies. Flame weeding is not an incineration process. Operating at between 800 and 1000^{o}C, the heat effectively 'boils' fluids inside the foliage and the cells burst. Flame weeding is non-selective, so if any crop plants are touched they too will be killed.

2.7 Soil sterilisation

Sterilisation of the soil is important to control weed growth, pests (especially nematodes) and soil-borne diseases. For alstroemeria, the major soil-borne problems are weeds, the fungi *Pythium*, *Phytophthora* and *Rhizoctonia*, and nematodes. Some control of weeds and certain diseases may be controlled by 'physical' methods, such as mulches of wood shavings within planting beds or Mypex on pathways (see above).

2.7.1 Chemical soil sterilisation

Chemical soil sterilisation materials include methyl bromide, dazomet and metam-sodium. Use of chloropicrin is not permitted under glass or other protected structures.

2.7.1.1 Methyl bromide

Widely used in glasshouse horticulture until recently, methyl bromide is one of the materials believed to contribute to depletion of the ozone layer. The UK is a signatory to the Montreal Protocol, which made agreements to cut production and use of methyl bromide in developed countries. Under EC regulation 2037/2000, supply and use of methyl bromide will be phased out by 1 January 2005. There are, however, some exceptions for emergency use against outbreaks of particular pests or diseases, and exemptions for critical use are still being evaluated by the Parties to the Montreal Protocol.

There is no single replacement chemical that has the same range of useful attributes for soil sterilisation as methyl bromide (broad-spectrum activity; fumigant effect; heavier than air; short turn-around time). In the future, a range of different treatments, chemical and non-chemical, are likely to be used. A number of UK alstroemeria producers use methyl bromide for soil sterilisation. In Holland, where use of methyl bromide was prohibited in 2000, steam is now used routinely.

2.7.1.2 Dazomet (Basamid)

Dazomet is a prill formulation that is applied to the soil surface (usually by machine) and then incorporated to the required depth. Thorough mixing is essential. On contact with soil moisture, dazomet breaks down to release methyl iso-thiocyanate (MITC) as the main sterilant gas. The surface needs to be sealed during treatment, preferably by polythene sheeting, to retain the gas.

Good soil conditions (temperature, moisture and tilth) are critical for good effect. The soil temperature must be at least 7°C at 15 cm depth, and the soil moisture at least at 50% of moisture holding capacity (preferably 60-70%). The soil temperature should not be too high such that a significant proportion of the gas escapes before the surface can be sealed. Treatment is most effective on soils with less than 5% organic matter content. On organic, marshy and clay soils, MITC binds to the soil, especially at low temperatures, reducing the amount available for sterilisation. A longer aeration time is needed on organic soils.

Before re-planting, a cress seed germination test needs to be done to demonstrate that the soil is free of residual fumes. Product literature indicates that the shortest turn-around time is around nine days at a soil temperature of 20°C, and 22 days at 10°C. Contractor application services for dazomet are increasingly available.

2.7.1.3 Metam-sodium (Discovery 510, Metham Sodium 400)

Metam-sodium decomposes when diluted and on contact with soil to release MITC as the main sterilant gas. Both metam-sodium and MITC are phytotoxic. Metham sodium 400 (40% metam-sodium) has recently been replaced by Discovery 510 (51% metam-sodium). Discovery does not have a statutory interval before replanting can take place, allowing more flexibility in its use; a cress seed germination test *must* be performed and replanting can take place only when this shows there are no residual phytotoxic fumes.

Application is by watering on, watering and rotavation, or injection and rotavation. The surface needs to be sealed, preferably by polythene sheeting, to retain the active gas. As with all chemical sterilants, good soil conditions are critical for good effect. The soil temperature must be at least 10°C at 15 cm depth, the texture suitable for use as a seed-bed to the depth of treatment, and the moisture at around 50% moisture holding capacity.

Metam-sodium has poor fumigant activity compared with methyl bromide. As with dazomet, contractor application services are available.

2.7.1.4 Formalin

Formalin, a 38% solution of formaldehyde in water, is approved by the Pesticides Safety Directorate (PSD) for use as a Commodity Substance. The maximum dose as a soil sterilant is 0.5 litre formalin/m^2, diluted 1 to 4 parts water. It has been used as a disinfectant and soil sterilant for over 100 years, but it is not commonly used now, mainly because it is unpleasant to use and is a potential carcinogen. It must be applied to moist soil, and requires a large water volume. Allow 3-6 weeks for dispersal of fumes from the soil. Formalin is broken down in soil to carbon dioxide and water. It must not be used on dry soil or a phytotoxic polymer can result.

2.7.2 Steam sterilisation

Steam sterilisation is the oldest method of effective control of pests, diseases and weeds, matching methyl bromide in efficacy. It has proven broad-spectrum activity, with no residues, resulting in little delay before re-planting can take place.

Soil is usually heated to 60-80°C for 30 minutes (Dutch alstroemeria producers recommend one hour at 70^{o}C using steam under pressure, or eight hours at 100^{o}C to a depth of 50 cm if not). Some disease suppressive bacteria are maintained. Various methods are used, though sheet steaming is the most common method of use in the UK. A steam boiler is required, but few growers now have steam producing boilers on site for heating or for soil sterilisation of other crops, such as chrysanthemums.

Steaming is relatively slow to do, demanding and expensive in labour. It can be dangerous and is therefore subject to HSE controls. It does, however, have the great advantage over chemical methods in that it is safe to treat part of a house in which there is an adjacent growing crop.

As well as mobile steam boilers being available for purchase or hire, some new methods of soil steaming/soil heating are being developed (e.g. Regero plate steam; UK Sterilizers, who remove, treat and replace the soil).

Steam sterilisation can cause problems in organic soils by releasing high levels of nitrogen or manganese, immediately after sterilisation, to the detriment of the crop. In mineral soils this does not normally happen. Application of an organic fertiliser before steaming, rather than after, is advised.

2.7.3 Economics of sterilisation alternatives

The relative costs of different approaches to soil sterilisation are given in Table 2.2.

Table 2.2. Cost (£/ha) of different methods of soil sterilisation.

Method	Cost £/ha
Methyl bromide	6,000*
Metam-sodium	4,000
Dazomet	4,500
Formaldehyde	2,500
Steam	7,000-15,000#

* Unlikely to be available after 1 January 2005.
# Costs vary widely depending on whether boiler/equipment is hired or owned.

2.7.4 Alternative cultural techniques

Alternative cultural techniques include the use of hydroponics, mulches, debris burners, resistant cultivars, and other pesticides/IPM programmes. However, none of these offer the same broad spectrum of pest, disease and weed control as methyl bromide or steam, and some involve high capital costs.

Hydroponics, whether Nutrient Film Technique (NFT) of rockwool (substrate) culture, requires considerable capital expenditure and a high level of management expertise. The technique does not eliminate the disease risk.

Alternative substrates such as peat raise concerns about depleting valuable wetland wildlife sites by extracting peat. Peat-free alternatives are becoming more widely available, but disease risk is not fully eliminated, and the technique is less suited to flower crops.

Using mulches can suppress weed growth. Black plastic will give best weed suppression, but white is preferred for light reflection.

Some progress has been made by lettuce and celery producers in using propane-fired burners behind a tractor for surface sterilisation of the soil. This method is only effective in the top 1-2 cm, and relies on minimal soil disturbance before the next crop. It is mainly used against *Sclerotinia*, in the sclerotial stage, after harvest. Weed seeds near the soil surface are destroyed. There is some control of pupating insect pests such as leaf miners. Small tractor-mounted units suitable for glasshouse use cost around £7,000. Pedestrian-operated wheeled burners are considerably cheaper.

The number of fungicides and herbicides for use on protected crops is declining, and many rely on Specific Off-Label Approval (SOLA). The problem increases where minor crops are concerned and availability is reduced even further. Resistance to existing products is also becoming more widespread. While integrated pest management (IPM) of aerial pests is widely practiced, the use of similar approaches for managing soil-borne diseases is not a practical proposition at present.

Some progress is being made on investigating the use of certain green crop residues for partial soil sterilisation. Antagonistic organisms in the residues may reduce the harmful effect of plant pathogens.

2.7.5 Best options

Table 2.3 summarises the best current options for alstroemeria producers in terms of soil pest, disease and weed control, taking efficacy, practicality and cost into consideration.

Table 2.3. Likely best options for pre-planting control of soil-borne pest and diseases, and weed (star ratings range from * = worst to **** = best).

Method	Efficacy	Cheapness	Turn-round time	Suit small areas with crop present
Methyl Bromide	****	**	***	No
Dazomet	***	***	*	No
Metam-sodium	***	***	*	No
Steam	****	*	***	**
Pesticides	*	***	****	**
Alternative systems	**	**	****	***
ICM (e.g. mulches)	**	****	****	***

2.7.6 Recent and ongoing research

Most soil sterilisation research in the UK over the last 20 years has been conducted with reference to field strawberries and control of *Verticillium* wilt. There are no comprehensive comparisons of alternative chemical sterilants for use in glasshouse crop production. However, a number of soil sterilisation treatments have been developed and evaluated in recent HDC and HortLINK funded projects, and these provide useful guidance on possible treatments for use under glass:

- Bulbs and cut flowers: development of a combined dazomet and metam-sodium treatment as an alternative to methyl bromide for soil sterilisation (April 2002). HDC project BOF 45.

- Integrated use of soil disinfection and microbial organic amendments for the control of soil borne diseases and weeds in sustainable crop production (August 2000). HDC project CP 6 (HortLINK project 16).

- Field vegetables: assessment of the potential for mobile soil steaming machinery to control diseases, weeds and mites of field salad and related crops (December 1999). HDC project FV 229.

- Larkspur: evaluation of weed control systems in *Delphinium ajacis* and *D. consolidata* grown for flower production outdoors (December 1997). HDC project BOF 40.

- Evaluation of weed control treatments in tree and shrub seed beds and first year outdoor transplants (November 1993). HDC project HNS 31.

- Allium white rot control: soil sterilisation (April 1992). HDC Project FV 4a.

Further details of methyl bromide withdrawal and alternative techniques are given in a MAFF/ADAS Booklet: Alternatives to Methyl Bromide – A Guide for Protected Crops (Reference MB1).

2.7.7 Contacts for further information

Certis UK, 1b Mills Way, Boscombe Down Business Park, Amesbury, Wilts, SP4 7RX
Tel: 01980 676500
Fax: 01980 626555
email: certis@certiseurope.co.uk

Field Irrigation, Asparagus Farm, Court Lodge Road, Appledore, Ashford, Kent, TN26 2DH
Tel: 01223 758780
Fax: 01223 758790
email: sales@fieldfl.co.uk

Igrox Ltd, White Hall, Worlingworth, Woodbridge, Suffolk, IP13 7HW
Tel: 01728 628424
Fax: 01728 627024
email; enquiries@igrox.co.uk

Plumtree Equipment Ltd, The Grange, Station Road, Plumtree, Nottingham, NG12 5NA
Tel: 0115 937 6076
Fax: 0115 937 6222
email: plumtree@farmersweekly.net

Sands Agricultural Services Ltd, Town Road, Ingham, Norwich, Norfolk, NR12 9TA
Tel: 01692 580781
Fax: 01692 582186
email: sas@sasltd.co.uk

UK Sterilizers Ltd, 33 Common Lane, Southery, Downham Market, Norfolk, PE38 0PB
website: www.uksterilizers.co.uk

Wilkie Recycling Systems, Mercury House, Calleva Park, Aldermaston, Berks, RG7 8PN
Tel: 0118 981 6588
Fax: 0118 981 9532
email: jim@wilkierecycling

2.8 Hydroponic production

In 1990, research into closed production systems for alstroemeria was initiated in Holland. The aim was to investigate whether this could be a viable alternative to soil culture to reduce emission of nutrients, pathogens and chemicals to the water and soil. Various substrates were examined with different air and water balance. The substrates examined were:

- Fine perlite (0-1 mm) 65% water/volume;
- Medium perlite (0.6-2.5 mm) 40% water/volume;
- Coarse perlite (1-7.5 mm) 30% water/volume;
- 50/50 mix of polyurethane and rockwood flakes (oxygrow) 20% water/volume.

Production in all of these substrates (15 cm deep layers) was reduced compared with sphagnum peat, and this may have been due to the lower percentage moisture in the substrates compared with peat. Despite much research, hydroponic production is no longer used routinely. The authors visited one Dutch producer who maintained a house on a movable closed 'hydroponic' systems (Plate 2.2).

Plate 2.2. Hydroponic production system on movable benches in Holland.

The benefits of this system were the increase in yield/m^2 due to better utilisation of glasshouse floor space. There was no information available on any yield enhancement obtained from using a different cultural technique in this instance.

2.9 Plant spacing

Young alstroemeria plants are usually propagated by tissue culture but sometimes by dividing plants. The plants are delivered in 9 cm or 7 cm pots. Alstroemerias are planted in two rows running along beds measuring 1.02 to 1.19 m wide. For beds 1.02 m wide, plant spacing is normally 3.1 plants/m^2 of glasshouse space. The distance between plants along a row is 34 to 40 cm depending on the variety and the width of the beds. The distance between the rows should be 40 to 50 cm, depending on how fast the rhizome grows towards the edge of the bed (Table 2.4).

Table 2.4. Planting layout for alstroemeria (2 rows of plants/bed).

Desired number of plants/gross m^2	Distance in cm between plants along the row	Number of plants/10 linear metres of bed (with 2 rows/bed)
3.0	41.6	48.1
3.1	40.3	49.6
3.6	34.7	57.6
4.0	31.2	64.1
4.5	27.7	72.2

In practice, breeders recommend the planting density for producers. In the UK, the density is generally 3-3.8 plants per gross m^2 of bed (5.5 per actual growing area).

2.10 Planting

Rhizomes are shallow planted with the growing points 7-10 cm deep. Beds of alstroemeria are often watered by trickle tubes down the centre of the bed. Only damaged shoots should be removed.

2.11 Crop support

For all varieties, support is necessary. The number of support nets is dependent on the height that the plant can reach. A support net is necessary for every 50 cm of stem length. If most of the crop becomes taller than 150 cm, three support nets are generally used. If a plant reaches 2 m, then a minimum of four nets is required. For this reason, support posts should be sufficiently high to accommodate the anticipated height of the crop.. Depending on the length of the plant, the highest net should be able to be raised to 120-150 cm. Varieties that grow taller than 2 m are sometimes supported to around 180 cm high. The netting is regularly elevated as the plant develops in order to avoid the stems falling over. Nets with openings of 20 x 20 cm are most often used. A smaller opening interferes with harvesting, especially with varieties that are cut.

Alstroemeria does not normally sit heavily in the netting like carnations but during the peak flush of May and June, unless the bed is very well supported with plenty of nets (Plate 2.3), the flowering shoots can fall over. Strong end supports are required and intermediate cross supports should be placed every 5 m along the bed.

Plate 2.3 Support structures for alstroemeria being grown in polytunnels in Cornwall.

2.12 Summary

- Clay and sandy-clay soils are best suited to alstroemeria production, which requires good drainage, an organic matter content of at least 20% and a pH of 6.5.
- Weed control is important and may be achieved through chemical or (preferably) physical control in addition to steam sterilisation.
- Rotavating in the old crop and steam sterilisation are recommended before planting a new crop.
- Soil sterilisation is highly desirable between production cycles, for weed, fungal and nematode control. Different methods have been reviewed.
- Sources of recent UK research and contacts for soil sterilisation are presented.
- Hydroponic production of alstroemeria is possible but few producers use this now.
- Plant densities of 3-3.8 plants/gross m² are generally recommended in the UK.
- The alstroemeria crop requires support as it grows.

3. CROP MANAGEMENT

3.1 Seasonal variation in production

One of the most important factors for selection of alstroemeria varieties is the fluctuation in production output over the year. Breeders generally supply information on this for specific varieties, under defined conditions.

The primary objective of most breeders is to obtain flowering of alstroemeria AYR. Generally, sales to UK florists and local outlets require AYR supply of quality material. UK supermarkets mainly purchase between April and October, and may require second grade material only.

The supply of alstroemeria flowers is affected by many factors: cultivar, soil temperature, air temperature, solar radiation, availability of initiated shoots, and the uptake of the requisite amount of irrigation water. To even the peaks in production, adequate water supply to the initiating buds, cool soil temperature at the level required for the varieties grown, and 16 h days with lighting during the winter months are required. However, this depends on market demand for alstroemeria flowers throughout the year.

Examples of the spread of flowering for modern cultivars are presented in Figs 3.1 and 3.2. Twenty to 25% of a crop may not be in production at any one time, coming in to flower later. In year 1, the crop is becoming established and may produce 150 stems/m^2, for example. In year 2, the quality of flowering stems will improve and the yield may double, to 300 stems/m^2. In year 3, the yield may increase further and yet the quality may decline somewhat. In year 4, the quality may further decline and yet the yield may still increase further, however there may be more work required due to increase in vegetative shoots relative to the number of flowering shoots (A.Cox, D.Hodson, B.Goemans pers. comm.). It may in fact, be optimal to replant after year 3.

Figure 3.1. Number of flowering stems produced monthly by cv. Jamaica in 1999 and 2000.

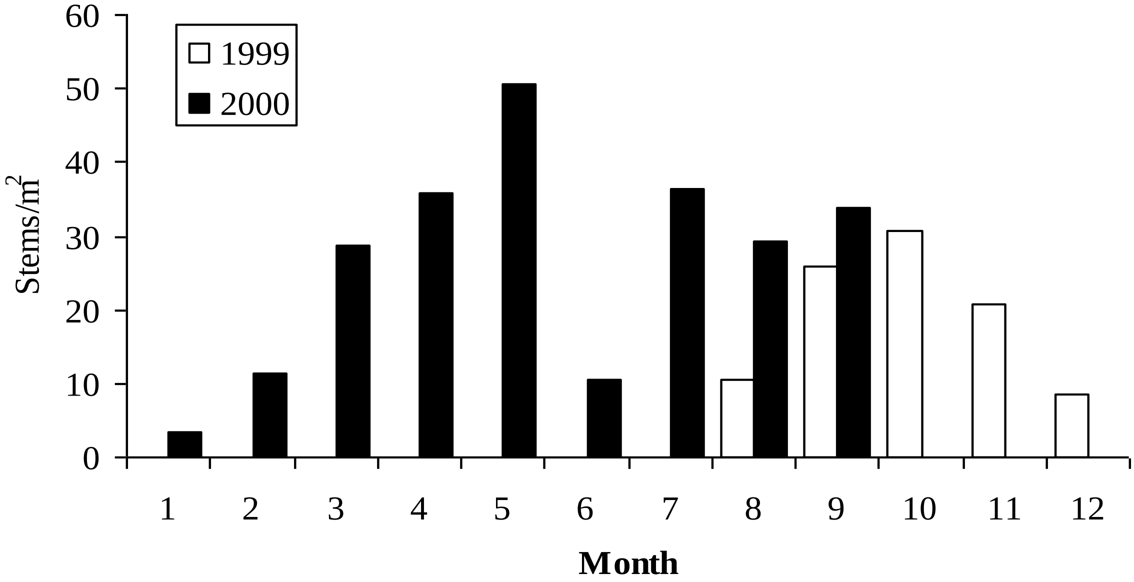
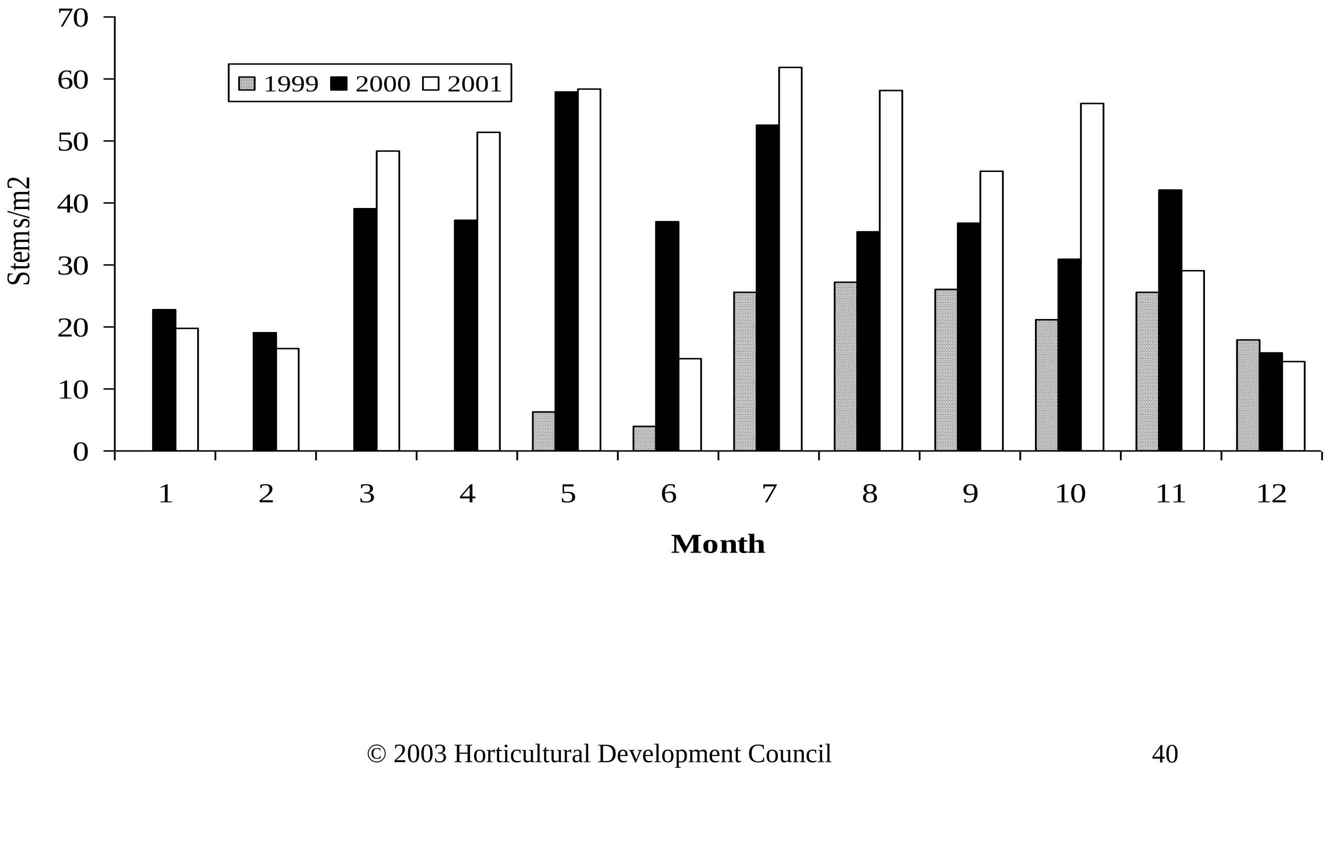


Figure 3.2. Number of flowering stems produced monthly by cv. Saba in 1999, 2000 and 2001 (crop planted in March 1999; data supplied by Mr Alan Cox).



3.2 Control of flowering

The control of alstroemeria flowering is a process that requires a thermophase and a photophase (Healy & Wilkins, 1991). The thermophase requirement must be fulfilled prior to the photophase. Each cultivar has a unique thermophase from 10 to 16°C, both in absolute temperature and duration. The genetics of the cultivar will determine the temperature range and the amount of time at that temperature before rhizome meristems are induced.

Floral shoot development on alstroemeria rhizomes is a complex process. Sympodially branched rhizomes are the receptors of floral-inducing stimuli; the flowering aerial shoots that arise from the rhizomes are not receptors. When temperature and photoperiod conditions are conducive for flowering, all shoots will initiate flowers. When conditions are marginal, only some shoots will initiate flowers, while some will remain vegetative. During non-inducive high temperature conditions of 21-27ºC, plants will remain vegetative regardless of the photoperiod (Healy & Wilkins, 1991).

Summer and autumn planting have been used to accommodate the varieties that have a flush of flowering activity in the spring. With varieties that have almost a continuous flowering schedule, planting can be completed at any time of the year. If such varieties are planted during the late winter to early summer months, flowering will occur more quickly than if they were planted in the late summer to winter months.

3.3 Thinning

Thinning procedures are used to remove weak vegetative stems, to stimulate rhizome branching, and to stagger flowering. However, thinning is performed at different times of the year and in different manners for different varieties. In winter months, they may continue to thin about 15-25% of the vegetative shoots until flowering begins. Thinning AYR varieties is a little different because the 'short stem effect' can be more pronounced. During the autumn and winter months, such varieties are thinned about 15-25% each month until flower initiation has occurred.

Thinning consists of the pinching off or removal of thin and/or blind and/or old shoots from the plant. Flowers that are not harvested should also be removed. Flowers that are left blooming on the plant lead to dormancy of an alstroemeria plant. Thinning increases light perceived by upcoming shoots, and improves the air circulation, thus reducing the risk of *Botrytis*. Thinning enhances shoot growth on seasonally flowering varieties. The amount of thinning required is cultivar-dependent. During thinning, a distinction is made between thinning young and old plants.

3.4 Effect of planting date

From 1990-1993, the HDC funded work (PC 33) on the effect of planting date on eight alstroemeria varieties (Libelle, Zebra, Canaria, Samora, Tiara, Fiona, Carola, Olivia). During trials, the glasshouse was heated to 8°C night and 12°C day with CO_2 enrichment (1000 vpm, far vents at less than 10% open or vpm, far vents at more than 10% open) during the winter period. The cultural practices followed were designed to represent best commercial techniques in consultation with Van Staaveren (now Royal Van Zanten).

Early planting in July enabled the production of an early flush of flowers in the first winter period (November – December), which was not achieved with the September planting date. The proportion of top grade stems and aborted and semi-aborted stems was not significantly influenced by the planting date. In addition, the number of thinnings required was greater for the majority of varieties from planting I (July) than planting II (September) (with the exception of Carola).

3.5 Control of flowering

The challenge for producers is to schedule planting times, and any environmental control used, to enable supply of flowering stems of a suitable colour throughout a specific harvest window.

This requires careful planning given that 25% of a crop is dug out and replanted every 12 months and that this may involve between one and eight varieties. There may be between one and three planting periods during the year to meet this target.

Another difficulty can be estimating the flowering time for new varieties, particularly when they are trialled under different growing conditions in Holland. Many new varieties are trialled in the UK also, and this is very important for UK producers. Planting date effects yield of flowers stem quality. The quality of top grade stems may be maximised by later planting. General responses to environmental conditions are summarised in Tables 3.1 and 3.2.

Table 3.1. Environmental conditions promoting different aspects of alstroemeria growth and development

Vegetative Growth	**Flowering**	**Dormancy**
Short days with high temperatures (31-38ºC)	Long days with low temperatures.	Long days with low temperatures
High light intensity	Peripheral shoots flower earliest	Leaving on shoots and flowers

Table 3.2. Environmental conditions inhibiting different aspects of alstroemeria growth and development

Vegetative Growth	**Flowering**	**Dormancy**
Low light intensity	High soil temperature especially with high air temperature	High air temperatures
Temperatures of 45ºC	-	Removing shoots and flowers
Long days with low temperatures		

The relative effects of different planting dates under UK conditions are summarised in Table 3.3.

Table 3.3 The effect of planting date on alstroemeria production in the UK.

Planting date	First flowers	Comments
Dec-Mar	April to end of May	Slower establishment More uniform production
April-Jun	Early July to September	Increased early production High labour demand
July-Dec	October to March-April	Low light levels, SD and low soil temp Not common practice

3.6 Quality of propagated material.

One of the causes of discrepancy between intentions and results with regard to scheduling is the quality of the material supplied to producers. There may be different specifications for individual end users (pinched back plants, or not, for example), and without clear communication, incorrect material may be supplied. Also, the availability of planting material may severely limit when material can be planted. Long-term planning and working closely with breeders may reduce this problem as batches of plants are ideally raised to order.

Young (12-16 weeks) well-rooted plants are supplied in a 9 cm pot with 3-6 growing shoots (see Plates 18 and 19). Depending on the time of year, plants may or may not be pinched. The principle factors affecting quality are age, growing temperature and watering. When plants remain too long in the 9 cm pot, the roots turn brown and the plant becomes dormant. If small plants are exposed to temperatures exceeding 20°C, the plant becomes vegetative instead of generative. If the small plant has dried out too much, the plant develops large water storage roots and not young hairy roots, resulting in stress flowering.

Plant material should be:

1. Certified free of specified alstroemeria viruses by independent virus testing of laboratory plants stocks.
2. Fully rooted before dispatch and not exceed 240 mm in height.
3. Between 10 and 40 weeks old after potting from a plug.
4. Grown from a plug for 10-15 weeks, trimmed hard back and the foliage re-grown before dispatch to the customer, unless the customer requests a younger plant, in which case the plant is not trimmed before dispatch.
5. Visually inspected one week prior to dispatch to ensure they are free from any sign of pests or diseases and again at dispatch.

Variations from this quality standard should be discussed with the customer before dispatch.

Plate 3.1. Typical alstroemeria plant at youngest dispatch date.

Plate 3.2. Typical alstroemeria plant at oldest dispatch date.

3.7 Summary

- Seasonal production of alstroemeria stems is affected by variety, soil temperature, photoperiod, planting date and other environmental conditions.
- The above factors also influence variation in stem quality and the amount of thinning required.
- It is important to obtain plant material of suitable quality at appropriate times in order to achieve control over timing, production levels and quality of flowers.
- There is a great challenge for UK producers to supply a steady stream of flowers of specific colours AYR, and the importance of UK-specific variety trials and knowledge of the influence of environmental factors on crop production seasonality is crucial.

4. TEMPERATURE REQUIREMENTS

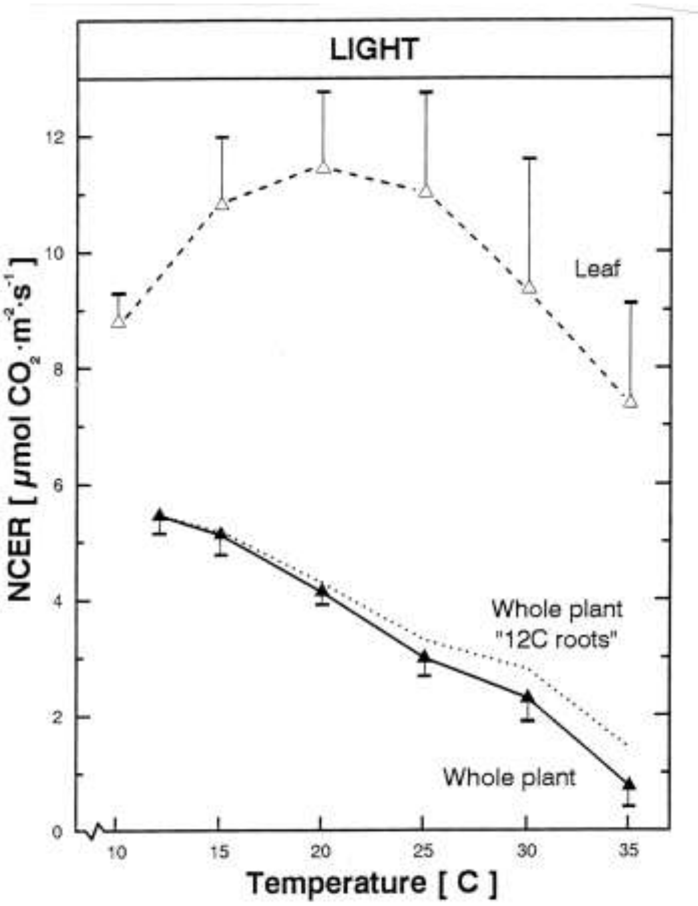
4.1 Air temperature

Alstroemeria is a cool climate crop, well suited to production in The Netherlands, the UK and the mountains of Kenya and Colombia. It is important to distinguish between the effects of soil and air temperatures on growth and development. High air temperatures increase development more than growth, so hasten production but decrease the success of each phase of development. In contrast, high soil temperatures increase wasteful root respiration, thus decreasing growth. Controlling the aerial environment is also important to control relative hmidity, as well as to reduce the risk of damage associated with high aerial temperatures.

4.1.1 Scientific background

At high air temperature (above 15°C), alstroemeria plants respire more energy than they fix by photosynthesis, thus the plants lose energy overall in the form of depleted carbon reserves at increased temperatures (Leonardos *et al*., 1994). This is illustrated in Fig. 4.1, where the net carbon exchange rate (NCER) (the difference between carbon loss though respiration and carbon gain via photosynthesis) is shown to decrease significantly at air temperatures above 15°C (solid line and filled triangle in Fig. 4.1).

Figure 4.1. The effect of air temperature on Net Carbon Exchange Rate (NCER) in alstroemeria: Leaf (unshaded triangle) and whole-plant (shaded triangle) Net C Exchange Rate (NCER).



In the mid 1990's, Baevre and Bakken (1997) studied the effect of air temperature (18°C and 21°C) on flower stem quality and production for four cultivars (Table 4.1).

Table 4.1. The number of harvested flowering stems/m^2 for alstroemeria (average of four varieties) grown at two air temperatures (numbers within each class followed by different letters are significantly different at *P*<0.05).

	Number of harvested stems			
Air temperature	**Class 1**	**Class 2**	**Class 3**	**Total**
18°C	247 a	136 a	32 a	414 a
21°C	196 b	114 b	35 a	344 b

These data indicate that crops exposed to an air temperature of 18°C performed significantly better than those grown at 21°C.

4.1.2 Dutch recommendations

For a period of six weeks after planting the Dutch recommend that air temperature be kept at 13°C during the night and at 14-16°C during the day. A lower temperature produces a slower start for production.

During the summer, an average of 17 to 20°C is an excellent temperature for the growth of alstroemerias. Cool nights and keeping the soil as cool as possible are desirable for high-quality results. It is not known how robust the crop is in terms of temperature fluctuations. Alan Cox of Alpha Nurseries, Chichester , believes the crop can average night and day temperatures; in addition Dutch producers use 7 day temperature averages.

During the late autumn and winter, the temperature is recommended to be kept between l0 and l4°C, depending on the cultivar, the length and quality of the stem required. The more natural and/or artificial light the crop receives, the higher the temperature that can be maintained. Temperatures under 9-10°C lead to very slow development of plants and very low production.

In the early spring (February/March), it is better to heat a little more (13-15°C) or on sunny days to keep the warmth inside the glasshouse by not ventilating too much. This will produce an earlier, more uniform production peak in the spring.

4.1.3 UK grower practice

In the winter in the UK, producers heat to achieve a 9°C night and a 12°C day, venting at 15-18°C. In summer various methods are used to maintain appropriate air temperatures, including shading and free ventilation.

The temperature in lit glasshouses will run a few degrees higher than unlit glasshouses. There is a requirement for improved management and monitoring of aerial temperatures with other variables such as lighting.

4.1.4 Outdoor production

The most vigorous varieties should be chosen that are winter hardy. The foliage will be completely killed by the frost and the root stock should be covered with straw on the most exposed sites. Re-growth starts in April/May with cropping from June to October. The colours are brighter than under glass and the quality better. Since the soil temperatures rarely reach 20°C, production continues until stopped by frost. It is suggested that only the best-drained sites be chosen and that windbreaks are used to stop petal bruising.

4.1.5 Technologies and practices to control air temperature

4.1.5.1 Air temperature

Although alstroemeria production is influenced more by soil temperature than by air temperature, it is still necessary to control glasshouse air temperature within defined limits. The crop does not demand high temperatures, requiring a minimum of 10°C during the night and day. Flowering is encouraged when air temperatures are 10°C plus, in a 12-14 h day. Low air temperatures, short days and high soil temperatures outside of the optimum range discourage flowering. When using supplementary lighting in winter, the air temperature should be kept at 15°C.

To achieve the sort of temperature lift required for alstroemeria does not entail the use of a particularly sophisticated heating system. The energy demand for the UK crop is in the region of 1.5 million kWh/ha per annum. Although indirect or even direct-fired heaters would provide sufficient lift, particularly in the south of England, a piped heating system is preferred to give a more even heat distribution in the glasshouse and enables one to place the pipes where desired to keep the crop dry and maintain the appropriate relative humidity control. To avoid heating the soil unnecessarily, heating pipes are mounted within the crop 10-15cm above the soil.

It may be possible to modify air temperatures in relation to previous or expected weather patterns. Given the ability of the plant to 'integrate' temperatures over several days to maintain an average temperature, it is unlikely that substantial energy (and therefore cost) savings would be made, although no specific work has been done on alstroemeria. However a trial using variable greenhouse temperatures on tomatoes (HDC Report PC 49 – Optimal Control of Greenhouse Climate, 1994) reported a potential energy saving of 15%. Current HDC studies on crops of poinsettia, chrysanthemum and begonia also indicate a saving of this order. With the lower temperatures used for alstroemeria, any savings would be much smaller.

4.1.5.2 Relative humidity

Humidity control in the crop is important for active crop growth and is also relevant in terms of disease control, i.e. prevention of foliar pathogens such as *Botrytis.* While using heat and/or ventilation to keep RH levels below 80%, the effect on soil temperature should not be forgotten.

High humidity may be avoided by:

- expelling moist air at night fall.
- increasing air movement (fans, ventilation)
- ventilating early in the morning
- reducing plant density (in crop appropriate)
- improving irrigation management
- maintaining adequate heating, especially at night (sensor driven heat boosts may be effective and cost effective)
- using a well-designed site and glasshouse.

Most modern climate computers measure and control humidity using Vapour Pressure Deficit (VPD) or Humidity Deficit (HD) rather than relative humidity (RH). Vapour Pressure Deficit (VPD) indicates how easy it is for the air to draw water from a plant and is measured in Kpa (kilopascals). Humidity Deficit (HD) indicates how much additional water the air can take up and is measured in g/m^3. Relative Humidity (RH) indicates how close the air is to saturation (100% RH).These factors are inter-related and temperature-dependent (Table 4.2).

Table 4.2. The relationship between Humidity Deficit (HD), Vapour Pressure Deficit (VPD) and Relative Humidity (RH).

Temperature °C	**25**	**20**	**15**	**10**
Relative Humidity %	80	80	80	80
Humidity Deficit g/m³	4.6	3.5	2.6	1.9
Vapour Pressure Deficit	0.62	0.46	0.34	0.24

4.1.5.3 Ventilation

Keeping air temperatures low in hot weather will help to maintain lower soil temperatures, so any glasshouse used to grow alstroemeria must have exceptionally good ventilation (Plate 4.1). Older glasshouses with ventilators of approximately one sixth of the roof area may be inadequate, and newer designs with 20-25% are more appropriate.

Plate 4.1. Ventilation on glasshouses in southern England.

Ventilation setpoints as low as 12-14°C may be needed to help keep soil temperatures down in summer but when using lights, the ventilation setpoint can be increased to 18°C. Temperatures above 20°C reduce photosynthesis.

In Holland, roof sprinklers are used by some producers on the outside of the glass to cool the internal air, with misting systems on the inside (Plate 4.2) in addition to normal ventilation. Other techniques for cooling include heat exchangers and filtering of infra-red radiation not utilised by plants (the non-PAR wavelengths). HDC Research Report PC 68 (l994) reviewed various techniques, but concluded that heat exchangers and using absorptive chemicals in double-glazed units were likely to be exceedingly expensive, or that chemicals used on open roofs could cause phytotoxicity.

Plate 4.2. Misting systems to cool air temperature in Holland.

4.1.5.4 Screens and shading

To reduce both air and soil temperatures, screens or shading may be necessary. Since energy saving is also an issue with heated glasshouse crops, combined energy/shade screens are most appropriate for alstroemeria production. Screen material affects the energy saving and shading capability - typical values are given in Table 4.3.

Table 4.3. Typical values for energy saving and sun-shading offer by different type of screens (data source: LS Systems Ltd)

Screen type	**Energy saving (%)**	**Sun-shading (%)**
XLS10	47	15
XLS13	49	30
XLS14	52	44
XLS15	57	54
XLS16	62	64
XLS17	67	75
XLS18	72	82
XLS 14 (F)	20	41
XLS 15 (F)	22	50
XLS 16 (F)	25	61
XLS 17 (F)	30	73
XLS 18 (F)	35	81

Shade screens to reduce glasshouse temperatures should be used carefully to avoid excessive loss of light, which can lead to loss of flower colour and lower overall production. It should be noted that all screen installations reduce light levels, even when in the 'open' position. Use of shade screens is more widespread in Holland, probably as a result of growing the crop in modern high-gutter houses with inherently better light transmission. The need for shading to reduce temperatures in summer can sometimes be achieved by using glass shading materials such as Nixol or Hortishade, although once applied to the roof glass they tend to remain effective for some time and may not be needed if weather changes.

Energy-saving screens should also be managed to avoid unnecessary light loss. Use during the day should be avoided, but night use can give substantial fuel savings. Due to rapid movement of cold air above the screen into crop on opening, screens should be opened gradually in steps (most automated screen controls will do this). This allows sufficient air mixing to avoid chilling the plants.

4.1.5.5 Air movement

'Natural' air movement in glasshouses arises from convection currents caused by warm air rising from heating pipes and cooler air falling from ventilator openings. Strong winds also cause some air movement within the glasshouse environment. Still air may cause problems in a glasshouse, especially temperature gradients, but the use of air circulation fans can go some way to improving the environment. Horizontally mounted fans just below gutter height can help to improve heat distribution and eliminate hotspots or cool areas, as well as reducing localised high humidities around plants. This can improve control of some diseases.

4.1.5.6 Environmental control

Accurate and routine monitoring to control climate, including air and soil heating/cooling, ventilation, humidity, shade screens, irrigation and lighting is considered essential.

Although most growers are using their climate computers to control the environment based on past meteorological data (e.g. reducing air temperatures following a period of high radiation to maintain an average temperature), it is possible to control setpoints using predicted weather data. This may be either to enhance crop response or to save energy.

4.1.5.7 Impact of the Climate Change Levy (CCL)

The Climate Change Levy (introduced on 1 April 2001) will significantly increase running and total costs of supplementary lighting. However, because lighting constitutes a relatively small proportion of total production costs, the effects of increased lighting costs due to the Climate Change Levy on the grower's overall margin are likely to be small. The energy tax is 0.43 pence/kWh on electricity and 0.15 pence/kWh on gas, nil on oil.

The addition of this tax to the generalised standard tariff figure for electricity of 5.50 pence/kWh, which has been assumed throughout this section, gives a revised figure of 5.93 pence/kWh, and increase of 7.82%. This percentage figure can be used directly to increase the estimated running costs of supplementary lighting to take account of the energy tax.

4.1.5.8 Energy saving

With the introduction of the CCL and rises in fuel prices (particularly gas) in the last two years, growers are acutely aware of the need for saving energy. Measures can be as cheap and simple as 'good housekeeping' such as always closing doors when not in use, to switching off unwanted lights, to more costly capital investments.

Inaccurate temperature measurement can cost money: a 1°C error in heating can add as much as 10% to fuel bills. Table 4.4 outlines some common ways of saving energy in a glasshouse.

Table 4.4. Summary of glasshouse energy saving options.

Item	Annual fuel saving	Approx. cost/ha	Notes
Windbreak	3-6%	Natural £1250 + labour	Not effective for 4-5 years
Windbreak	3-6%	Artificial £3500 + posts and labour	90m long, 4m high
Bubble lining (sides/ends)	5%	£850 + labour	5 year life. Reduces solar radiation levels
Temporary 'fixed' screen	35% when in use	£4000 + labour	Anti-condensate polyethylene. High humidity
Gutter insulation	5%	£5000 + labour	Polystyrene fixed internally to old Venlo houses
Secondary glazing of side/end walls	5%	£16000	Winter light reduction
Environmental computer installation	5%	£12000	Improved environmental control, alarms & monitoring
Thermal/shade screen (moveable)	20-35%	£60,000	Some light loss. Higher average night temperatures and humidity
Double-skinned structures	34-50%	£300,000	Significant light loss
New glasshouse (single glazed)	7% (depends on what is being replaced)	£250,000	Better light and insulated gutters
Energy efficient lights	20-45%	£110,000	

4.1.5.9 Energy supply and saving

4.1.5.9.1 Combined heat and power units

Combined heat and power (CHP) plants simultaneously generate electricity, heat and CO_2 at the point of use. Their attractiveness to users (and to Government) lies in the fact that they typically give savings of around 35% in primary energy usage, because they enable the heat produced from the generation of electricity to substitute for conventional heating fuels. They also avoid the electricity transmission losses associated with the National Grid. They achieve significant saving in CO_2 emissions compared to power stations and crucially for growers this is 'free'. Typically, a CHP unit will generate 4.5 kW of heat, 3.2 kW of electricity and 1.8 kg CO_2 from each m^3 of natural gas burnt (based on Dutch experience, Ben van Onna, IPC Plant).

The potential benefits of CHPs installed on growers' holdings are, therefore the reduced energy costs, free CO_2 and an improved environmental image that may have implications for Climate Change Levy savings.

In The Netherlands , an estimated 1,500-2,000 glasshouse nurseries out of a total of 12,000 have CHP installations. Use of CHP technology in the UK glasshouse industry has largely been in edible crops, where high temperatures are required and CO_2 can be utilised to boost production. Typical energy cost savings quoted in the Netherlands (Ben van Onna, IPC Plant) are around 40 pence/m^2 p.a. based on a gas price of 8 pence/m^3 and with 48% of the nursery's heating costs provided by the CHP.

In general, a CHP unit of 1MW electrical output will serve 1 hectare of glass for crops such as tomatoes. A 1MW unit is thought to be the smallest economic unit to install. Micro-turbine systems have been introduced into the glasshouse sector more recently, featuring modular generators more suited to smaller nurseries of less than 1 hectare, with modest heat and electricity demand. Units with electrical outputs as low as 200kW can be supplied, suitable for nurseries of 2,000 m^2 of glass. They also produce cleaner exhaust gases than reciprocating engines, for direct CO_2 enrichment. Reciprocating CHP units need exhaust gas scrubbers (a type of catalytic converter) to enable the CO_2 to be utilised.

The cost of putting in connections to the electrical and gas utilities is a major consideration. This factor is directly related to the cost of connecting the CHP and therefore ultimately has an influence on the cost of the project. With supply of these two utilities, the issue of wayleave and access may provide other constraints.

The installation of CHP units, and in particular micro-turbines could be beneficial to alstroemeria producers, but in the current climate of relatively high gas prices and very low electricity costs, there is little financial incentive to pay the capital costs of installation. Salad growers who benefited from large CHP installations on their nurseries owned by the utility companies are now facing the risk of having the generators shut down as it is not economic to run them.

For further information relating to CHP and especially micro-turbines, refer to HDC Grower Guide 'Micro-Turbine CHP Units – Their application in protected horticulture'.

4.1.6 Summary

- Alstroemeria perform best at an air temperature of less than 15°C. Above this temperature, carbon loss through respiration exceeds carbon gain through photosynthesis.
- Dutch recommendations are for 13°C night and 14-16°C day temperature after planting; followed by 17-20°C (day) maximum during production. Maintenance of RH at 80% is recommended.
- UK producers heat to achieve a 9°C night and a 12°C day in winter, and strive to keep the temperature down to less than 20°C in the summer by venting etc.
- Productivity and quality of alstroemeria grown at 18°C air temperature produced 20% more stems than those exposed to 21°C.
- Although alstroemeria production is influenced more by soil than air temperature, flowering is encouraged when air temperatures are 10°C plus in a 12-14h day.
- The energy demand for the crop is in the region of 1.5 million KWh/ha/annum.
- The energy saving potential of temperature integration needs to be evaluated for Alstroemeria.

- Ventilation, roof sprinklers and misting can be used to maintain air temperatures at suitable levels.
- Although smaller micro-turbine types of combined heat and power (CHP) units may have benefits, including reducing energy costs, the current energy supply and price situation make the investment look unattractive.

4.2 Soil temperature

4.2.1 Background

The temperature of the soil is critical for growth and development in alstroemeria, since the main part of production occurs in the rhizome. Alstroemeria is a cool temperature plant, and many varieties thrive best in a *constant* soil temperature of 14ºC. When additional assimilation lighting is used, the soil temperature can be slightly higher (15-16ºC). The yield advantage from optimum soil temperature control is 10-15%.

Under conditions of high light and high soil temperatures, new shoots and rhizomes may still develop, but many of these shoots will be blind, or vegetative. This increases the labour requirement for thinning. Another advantage of soil temperature control is a reduction in plant height. Reductions of 50 cm are common. This makes management of the crop easier.

For many varieties, there is also a spread of flowers from 'traditional' times of peak flowering to later in the year. This contributes toward achieving AYR supply.
Thus, the benefits of soil temperature control are:

- increased flower yield/m^2 of 10-15%
- decreased numbers of blind shoots
- shorter crop height
- more even spread in the flowering period

4.2.2 Scientific research

There is a considerable body of research from 1975 to the present on soil temperature and alstroemeria production. Only work done post 1990 is considered in detail here. Much of the early work showed that alstroemeria cultivars were very sensitive to low soil temperatures. However many of the modern varieties perform well under higher soil temperatures.

Baevre & Bakken (1997) studied four cultivars grown at two soil temperatures (14 and 18°C). In this study, plants were exposed to 40 W/m² for 20 hours/day with CO_2 at 0.6 vpm. The results are presented in Table 4.5. The cultivars clearly responded differently to soil temperatures. King Cardinal and Amanda produced more stems at 14ºC, whereas Helios and Cinderella produced more stems at 18ºC. This type of work is essential to aid in cultivar selection for individual growing systems.

Table 4.5. The number of harvested flowering stems/m^2 from four alstroemeria cultivars grown at two soil temperatures from September 1993 until April 1995.

	Number of harvested stems							
	Class 1		**Class 2**		**Class 3**		**Total**	
Cultivar	**14ºC**	**18ºC**	**14ºC**	**18ºC**	**14ºC**	**18ºC**	**14ºC**	**18ºC**
King Cardinal	316	200	212	79	33	18	561	297
Amanda	252	252	137	113	48	36	437	374
Helios	175	254	204	149	57	36	436	439
Cinderella	172	179	50	52	19	21	242	252
P value	0.014		<0.001		0.014		0.005	

Further work on the effect of soil temperature is summarised in Table 4.6.

Table 4.6. Summary of research on soil temperatures.

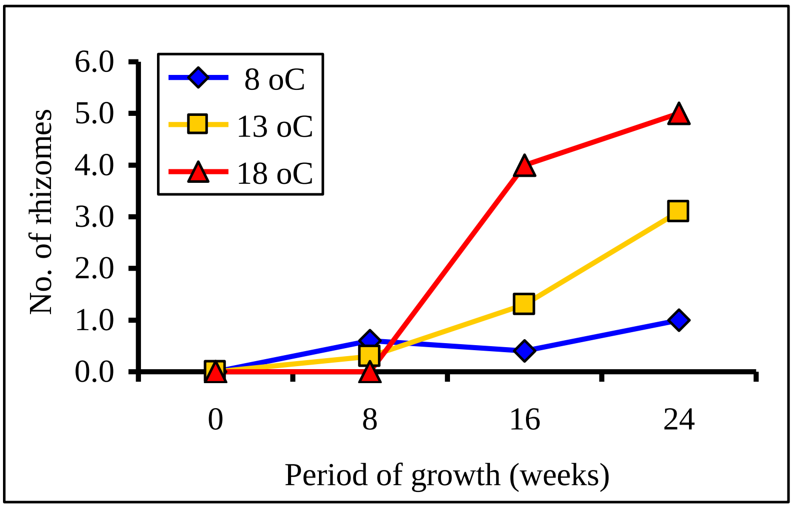
Variety	Soil temperature	Other factors	Main response
King Cardinal (a)	14, 18ºC	+ Supplement-	Increased flowering at 14ºC
Amanda (a)	14, 18ºC	ary light (20	Increased flowering at 14ºC
Helios (a)	14, 18ºC	hrs + CO_2)	Increased flowering at 18ºC
Cinderella (a)	14, 18ºC 22ºC		Increased flowering at 22ºC
Annabel (b)	13-15ºC	+ 400 W/m²	13-15ºC increased %
Mona Lisa (b)	compared with	Supplement-	flowering shoots.
Yellow King (b)	uncontrolled	ary light, air	
Red Sunset (b)	(16-22ºC)	temp 14°C	Increased total shoots
Valiant (c)	8, 13, 18ºC	-	18°C optimum for lateral rhizomes, shoots and tubers
Parade (c)	8, 13, 18ºC	-	13ºC optimum for lateral rhizomes, shoots; 18ºC for new tubers.
Butterfly (c)	8, 13, 18ºC	-	13ºC optimum for lateral rhizomes shoots; 18ºC for new tubers.
Red Sunset (d)	16ºC constant vs	-	No effect on total production.
Rio (d)	non- controlled	-	Ratio of total spring and
Rosario (d)		-	summer to autumn and winter
Rosita (d)		-	production changed from 3.1 to 2.2. Non-controlled 16ºC.

(a) Baevre & Bakken, 1997
(b) Van Labeke & Dambre, 1993
(c) Bond & Alderson, 1993
(d) Blom & Piott, 1990

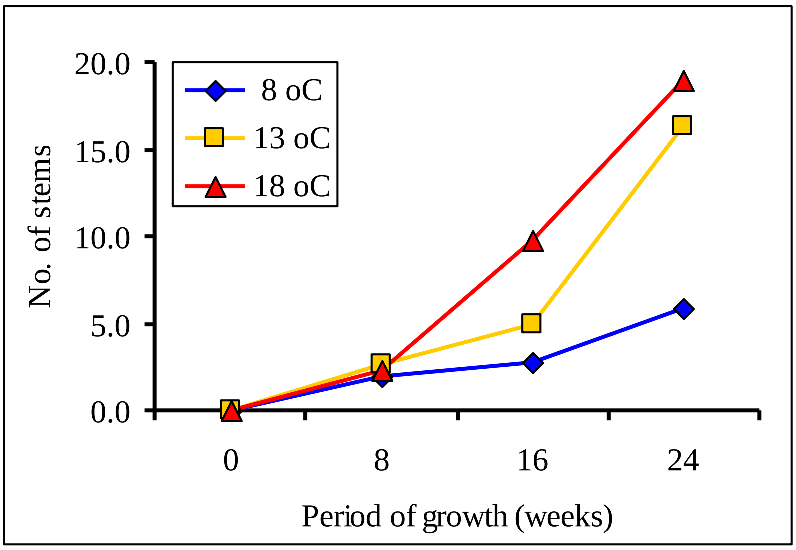
Work by Bond & Alderson (1993) investigated the effect of three soil temperatures (8°C, 13°C, 18°C) on lateral rhizomes, number of aerial shoots and number of tubers. Results for two cultivars are presented in Fig. 4.2a-f. Although the differences between treatments were not consistent, the greatest number of shoots relative to lateral rhizomes occurred at 13ºC for cvs Parade and Butterfly (not shown), and at 18ºC for Valiant.

Figure 4.2. Effect of soil temperature on lateral rhizome, aerial shoot and tuber production in cvs Valiant and Parade

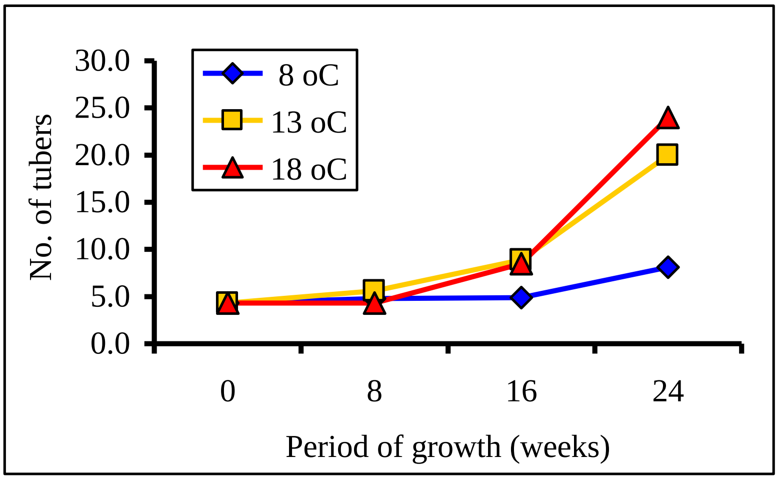
a) Valiant – lateral rhizomes



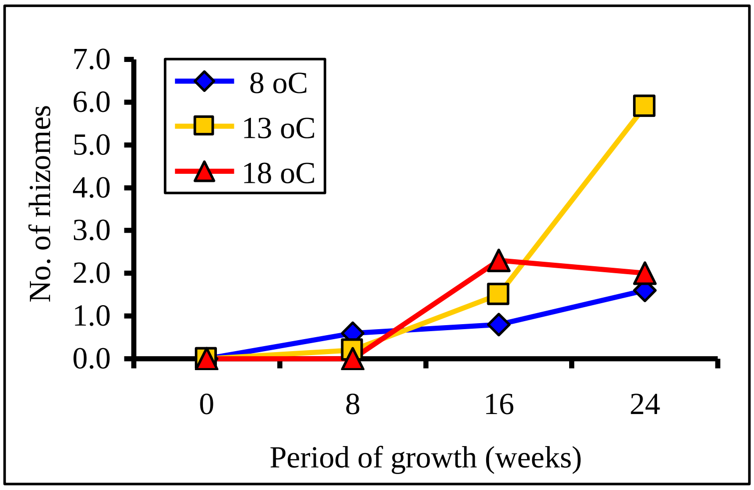
b) Valiant – aerial shoots



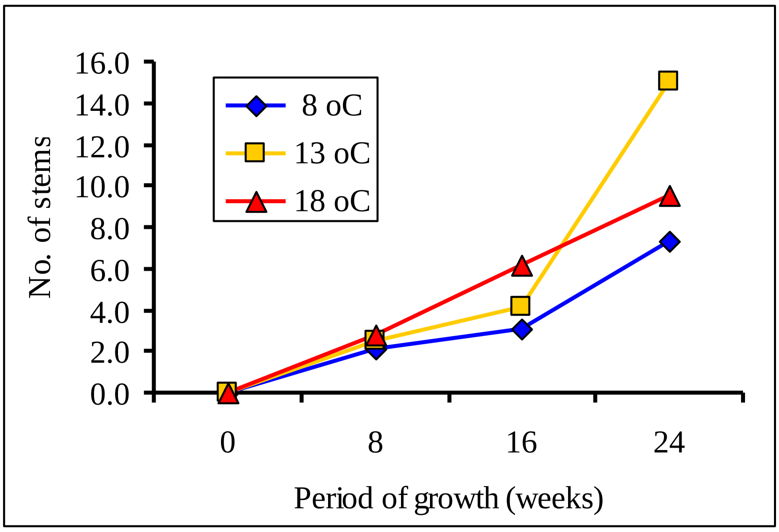
c) Valiant – tubers



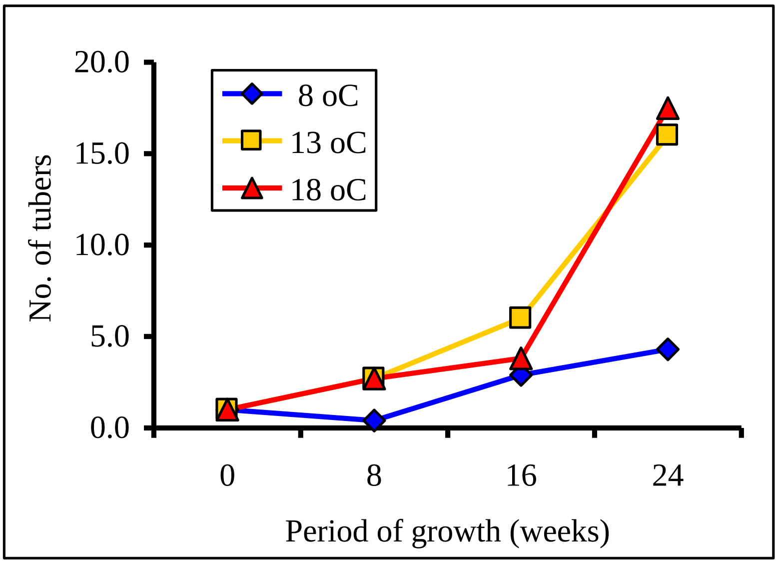
d) Parade – lateral rhizomes



e) Parade – aerial shoots



f) Parade - tubers



Van Labecke & Dambre (1993) illustrated the effect of lighting (high pressure sodium lighting) with and without soil cooling on the spread of flowering in two cultivars (Figs 4.3 & 4.4). The greatest production over the longest time occurs with the lighting and soil cooling combination.

Figure 4.3. The effect of soil cooling and supplementary lighting on the spread of flowering in cv. Regina. (from van Labeke & Dambre, 1993).

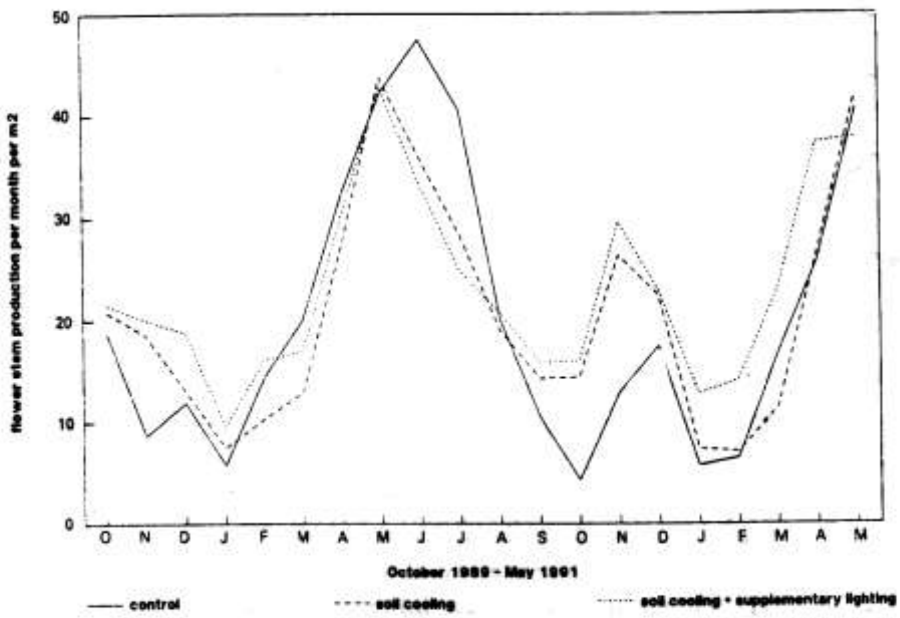
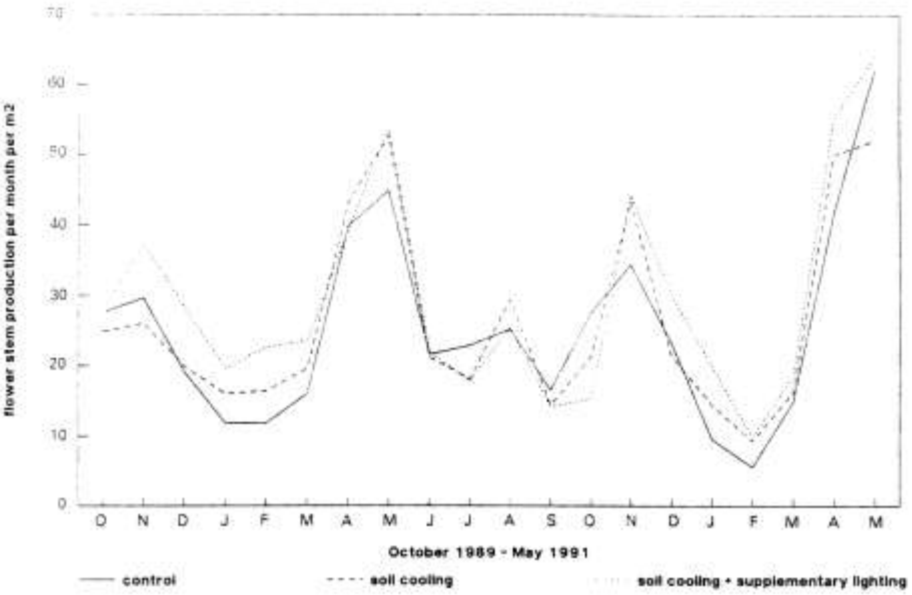


Figure 4.4. The effect of soil cooling and supplementary lighting on the spread of flowering in cv. Libelle (from van Labeke & Dambre, 1993).



4.2.2.1 Rhizomes and temperature

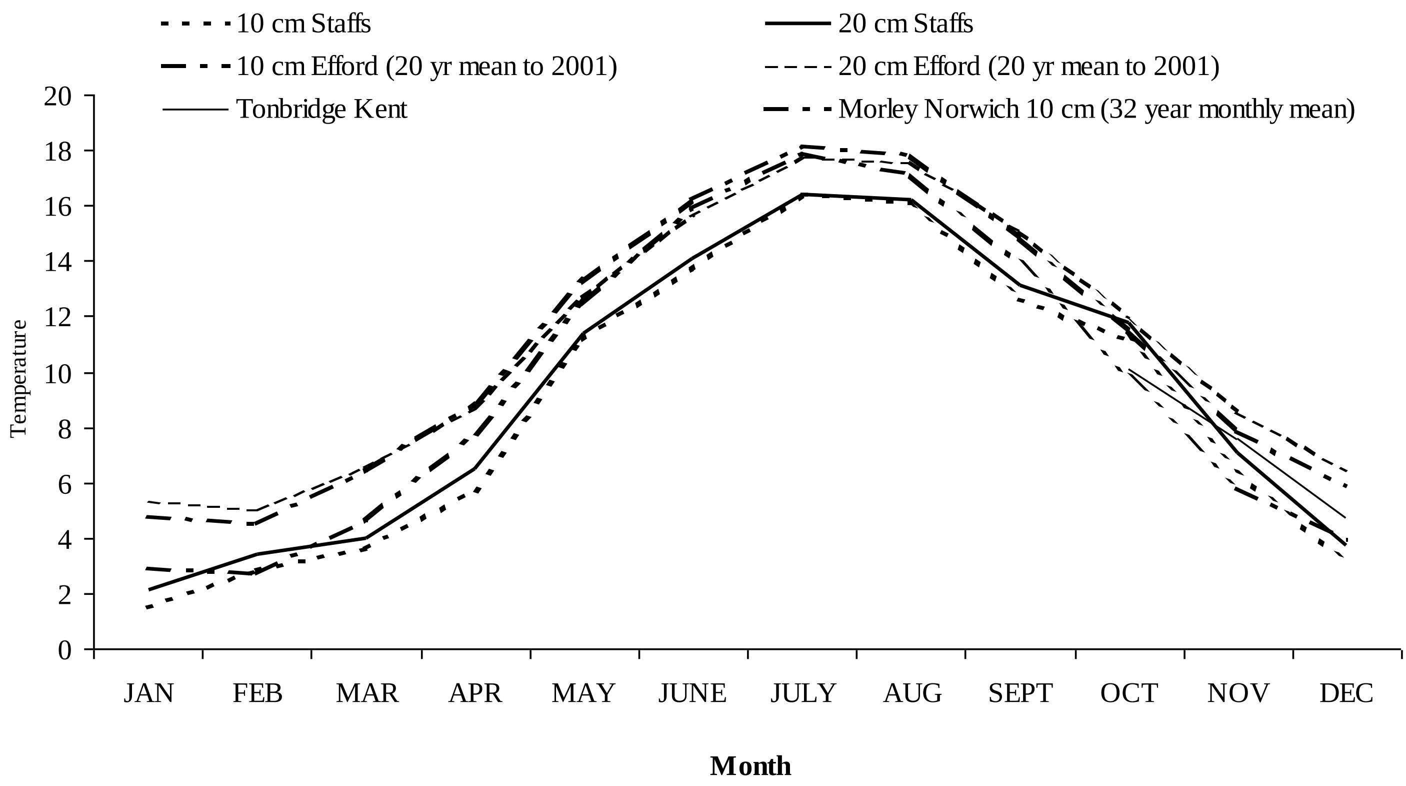
Low temperatures at the rhizome level promote flowering in alstroemeria. Research has investigated the effect of low temperature treatment (10ºC) of rhizomes during propagation (Cervilli & Zizzo, 1992). Rhizomes (6-7cm with young vegetative shoots but no storage roots) were potted into 11cm pots with soil. This was found to promote earlier flowering and increase earlier product. Low temperature treatment of rhizomes also promoted flower induction in underground shoots that had shown signs of being vegetative shoots (had already differentiated many leaves). In contrast, such shoots in untreated rhizomes remained in vegetative shoots. Other work suggests this is an annual requirement, which thus limits its usefulness for the traditional four-year growth cycles for alstroemeria unless soil can be cooled to such levels at appropriate times. Time to flowering was inversely related to the number of weeks (up to 8) alstroemeria plants remained at 5ºC (a vernalising temperature) compared with 13ºC (a vernalising as well as a forcing temperature) (Healy & Wilkins, 1982). The role of temperature in controlling flowering may be related to gibberellin production, but further research has not focused on this.

Research has showed that high intensity lighting promoted the speed of flower development from cold-treated rhizomes (Cervilli *et al.*, 2000). Protocols for one-year production cycles were proposed, especially for varieties such as Yellow King.

4.2.3 UK soil temperatures

The soil temperature in the UK is quite variable, depending on season, soil type and geographical location (Fig. 4.5). On average, the temperature is below 12ºC for more than seven months of the year, and does rise above 18ºC in any of the soils presented. The soil temperatures in the glasshouses may be significantly higher than this due to the higher aerial temperatures.

Figure 4.5. Annual variation in soil temperature at selected sites in the UK.



The effects of low soil temperatures slowing rhizome development are more likely to be of concern to UK producers than high soil temperatures. There may be value in installing soil pipes through which water at controlled temperatures is pumped - cooling (when necessary) in summer and heating in winter – with the objective of achieving a constant soil temperature of 12-15ºC, depending on the variety. In Holland, growers are recommended to keep the soil at between 14-15ºC all year round. There may also be benefits in applying various mulches that either reflect the suns rays away from the soil (e.g. Perlite, sawdust) or those that absorb radiation and warm the soil. Anecdotal evidence showed that application of peat, perlite and wood shavings to a depth of 5 cm made no difference to the 15 cm soil temperature (D.Hodson, pers.comm.).

One of the main difficulties associated with the use of soil pipes may be the large number of different alstroemeria varieties grown. These are likely to have different soil temperature requirements.

A Dutch survey in the late 1980s concluded that the benefits from spreading perlite mulches were insufficient to cover the costs of the material used. Soil cooling had a cost:benefit ratio of less than one for only some varieties, indicating it was not always worthwhile. Some UK producers have found Perlite mulches enable over-watering.

4.2.4 Dutch research and recommendations

Much research has been done on soil temperature and alstroemeria production in Holland. It is estimated that more than 90% of producers in Holland use soil cooling. Certainly most trials on other aspects of production such as lighting use soil cooling as a basic husbandry practice. An example of the results obtained from breeders is illustrated in Table 4.7, which shows the production of 14 varieties at four soil temperatures.

The benefits of a soil temperature of 14ºC compared with 16 and 18ºC can be seen for all of these 14 varieties, either in the form of an increase in total numbers of stems and a decrease in the number of blind shoots, or both.

Table 4.7. Average yields (flowering stem:blind shoot) in year two of several varieties grown at various soil temperatures (Royal Van Zanten).

	Soil temperature							
	Ambient		**18°C**		**16°C**		**14°C**	
Variety	**No. stems**	**No. blind shoots**	**No. stems**	**No. blind shoots**	**No. stems**	**No. blind shoots**	**No. stems**	**No. blind shoots**
Ilona	291	12	293	11	285	8	303	8
Rebecca	266	34	280	26	283	15	329	12
Sacha	247	11	247	15	266	8	277	8
Pink Triumph	246	81	255	83	275	33	300	11
Irena	213	33	244	36	263	30	268	22
Belinda	213	29	215	26	226	8	238	6
Delilah	212	60	218	36	194	24	257	29
Laura	211	13	206	11	202	2	232	6
Tiara	195	47	185	49	215	45	218	17
Cinderella	186	28	171	25	202	5	205	1
Rosita	183	98	212	92	237	53	275	17
Yellow King	175	112	168	100	209	68	303	24
Diamond	171	78	177	54	200	22	255	13
Sabina	139	8	130	6	127	3	132	1

Trials in the early 1990s aimed to keep the soil at a constant 15ºC between weeks 10-41 (March to October), in combination with a 13-hour day from the end of March until mid-September. This resulted in a 30% increase in production, mostly due to soil cooling. In 1994, a longer day (14 h) from week 19 to 30 was trialled, which increased yield by a further 6%. The costs of controlling photoperiod by blackout screen are greater than the benefits achieved, thus research has since focused on optimising soil temperature for each variety. Some of the results of these trials are illustrated in Tables 4.8 and 4.9

Table 4.8. Soil cooling trials with cv. Wilhelmina planted in November. Totals (yields and blind stems) are cumulative to September in year two.

Temperature (ºC)		**Yield (stems/ m^2)**		**Blind stems/m^2**
Greenhouse	**Soil**	**May to Sept, year 2**	**Total from planting**	**Total from planting**
	Ambient	250	662	76
12	14	260	688	49
	17	258	641	150
	Ambient	256	654	217
15	14	260	720	67
	17	250	647	312
	Ambient	188	535	377
18	14	259	706	88
	17	192	535	349

Dutch research has shown that generally, high summer soil temperatures negatively affect those varieties that produce more blind shoots between autumn and winter. Magic Red, Yellow Dream and Valencia responded well to soil cooling in summer.

Crops that flower in autumn and do not produce excessive blind shoots without soil temperature control may become taller and produce later and less uniformly, thus requiring more labour to manage.

Table 4.9. Effect of soil cooling and controlled photoperiod on production (yield of stems/m^2) from 10 varieties.

Variety	**Control**	**Soil cooling only**	**Controlled day length**	**Combined**
Amanda	188	224	187	259
Amor	126	171	164	195
Diamond	202	245	201	278
Fiona	237	337	256	342
Helios	204	247	205	229
Madonna	229	235	211	226
Pink Triumph	185	280	212	292
Rebecca	222	318	252	327
Yellow Libelle	229	283	242	269
Yellow King	136	206	144	202

Current recommendations are that if there is sufficient vegetation and the rhizome is actively forming new shoots, keep a constant soil temperature of 14-16ºC after week 20 (depending on variety). If there is insufficient vegetation and there are few new shoots, it is better to wait a few more weeks before going to the desired soil temperature. Cooling could start at 17ºC to allow the rhizome to develop faster, then slowly decrease the temperature to achieve a temperature of 14 or 15ºC. Napoli and especially Jamaica are varieties that respond well to this.

The costs of fuel in the Netherlands in recent times have meant that producers are heating to lower air temperatures in winter than previously. This increases the risk of humidity-related *Botrytis* developing, and reduces production. Breeders are recommending that soil temperatures should be raised to 14-15ºC in February/ March, even despite cooler glasshouses, to maximise appropriate rhizome growth and development.

4.2.4.1 Soil temperature control options

Pumping chilled water through flexible plastic tubes is efficient but expensive. Up to four tubes are buried at 10 cm soil depth, to maintain soil temperature at 15ºC at a depth of around 7 cm. The annual cost of this is around £1.50/m^2 in an average summer. Dutch producers tend to grow one variety per glasshouse, which makes setting and maintaining the optimum soil temperature an easier exercise compared with the UK.

Dutch producers may pump bore hole water through the pipes in the soil, which is significantly colder than mains water. Alternatively, they may chill water prior to circulating it. The former option is less expensive than the latter. The costs that need to be considered are the borehole, pump, pipes, electricity, labour costs for laying and relaying between crops.

4.2.5 Technical information

UK soil temperatures can be affected by soil type, solar radiation, plant canopy cover, shading, soil mulching (wood shavings, Perlite), refrigeration and irrigation. In the summer months, shade screens can reduce incoming light particularly if they are on a diagonal plane close to the glass. In such cases, solar radiation can be reduced considerably and screening may only be necessary from the south side of the roof and vent.

Horizontal screens can, in low glasshouses, increase the temperature under the screen over and above what it would have been without screening, by impeding convectional currents that draw cooler air down from the roof. Thus it is probably better to provide a gap in such screens to allow the convection air currents to prosper. Misting (not fogging) systems are also used in glasshouses to reduce the ambient temperature and keep soil temperatures low.

High canopy cover in the crop will shade the soil. In summer after large flushes, canopy cover is likely to be light and thus allow the penetration of solar radiation to the soil. Mulches of Perlite will reflect the light away from the soil, but will be expensive, and may have other side effects. The use of pine wood shavings layers 5-10 cm deep and kept moist may help to keep the soil cool and maintain weed control until it disintegrates. Some UK producers are installing drip irrigation pipes below such a mulch to great benefit.

4.2.6 Summary

- A constant soil temperature of 14-16°C is generally recommended for alstroemeria, to maximise production and minimise thinning and other management costs.
- Correct soil temperature control increases flower yield/m², decreases the number of vegetative shoots, reduces crop height and spreads the flowering window more evenly AYR. More class I stems *may* be produced.
- Cultivars respond individually to soil cooling, and some respond negatively.
- Supplementary lighting and soil cooling together spread the flowering window wider and increase production at otherwise low times of the year.
- Low temperature treatment of rhizomes and subsequent high intensity lighting increased the spread of flower development, although the practicalities of using this may be slim.
- Soil temperatures in the UK may be **cooler** than desirable for much of the year thus, rather than soil 'cooling', the term 'constant soil temperature control' may be more descriptive of this key objective.
- Any economic advantage from soil temperature control needs to take into consideration the varieties being grown, market demands and the environmental factors controlled, such as supplementary light.
- Photoperiod and soil temperature control also act in a combined way to increase productivity; however, most of the benefit is due to soil temperature control.
- Pumping cool borehole or chilled water through pipes to cool soil is used in Holland.
- As the canopy grows, reflectance from the crop or mulches reduce radiative heat absorbed by the soil. In addition, fogging and ventilation to reduce air temperature reduces soil heating.
- Improved monitoring of UK glasshouse soil temperatures throughout the year will be required to assess the need for improved soil temperature control, potentially via heating. The costs and benefits of this will need to be assessed.

- There is a lack of knowledge on soil temperature fluctuations under relevant UK conditions. There is a recommendation to monitor the soil temperature to assess the costs and benefits, and the effects on varieties.

5. IRRIGATION TECHNIQUES

5.1 Background & Introduction

Alstroemeria develops a considerable leaf mass and thus plants lose a lot of water by evapotranspiration. Irrigation is of paramount importance, and the aim of irrigation is to keep the moisture level at the required level around the rhizome crown to maximise the number of shoots formed. Over-watering can cause significant stunting and reduced production and increases problems due to rots. The optimum volume to irrigate depends on the cultivar, the temperature, the condition of the crop, the soil type and the time of the year.

Traditionally, irrigation was overhead; more recently low level spray lines or trickle lines or a combination of all three have been employed. Yield increases of 12-15% have been observed in the UK by improving irrigation systems. Recent research into irrigation techniques has focussed on irrigation based on plant requirements, more even watering and more frequent watering. A better understanding of the irrigation requirements of UK-grown Alstroemeria crops is required to optimise productivity, quality and scheduling.

5.2 Irrigation Systems

5.2.1 Types of irrigation

Irrigation systems can broadly be divided into overhead or low level, with low level further divided into sprayline or drip/trickle systems. Many glasshouses have been equipped with overhead spraylines for multi-crop applications. These are usually of the "Dutch Pin" type of nozzle mounted in a rigid plastic pipe, giving a 360^{o} coverage. Traditionally the lines were placed under the ridge of Venlo type houses and above head height. These overhead lines are capable of applying a coarse spray over a fairly wide area, and nozzles delivering up to seven litres per minute are available. Other nozzle types are available but overhead watering is generally not recommended for alstroemeria production (except to help in plant establishment and in soil preparation) as fertigation may scorch the foliage. Using overhead spraylines also leaves the foliage wet which may encourage disease problems.

Low level spraylines, often using nozzles which give a “fan-shaped” output through 180°, can be used near bed level. It is usual for nozzles to be mounted on two rigid plastic lines running either side of each cropping bed, and the spray directed into the bed. Such a system is less likely to leave wet foliage compared with overhead mounted lines, but penetration into a dense bed of stems may be inadequate.

Another low level system uses “layflat” flexible lines which are laid between rows. Water is emitted from the lines either through small perforations in the tube or the holes where the lines are stitched together. Although cheap, this system has the disadvantage of uneven water distribution along the length of the line and deposits of lime or fertiliser, or root growth, may easily block the holes and/or perforations.

The major problem with all sprayline systems is the very high water application rates. Systems that deliver in excess of 50 litres/m^2/h make effective irrigation difficult, as the difference between irrigating and flooding the crop is only a matter of minutes. To overcome these issues, growers in Holland and more recently in the UK have looked towards drip irrigation. Conventional drip systems that have been in use for many years for soil-grown crops, consist of low density polyethylene (LDPE) feeder lines with capillary leads and stakes. The type of nozzle at the end of the capillary may have an output of between 1 and 4 litres per hour. Earlier types, especially those with very fine capillaries such as Volmatic, were very prone to blocking. There were also problems with the lines draining down and needing re-filling at every irrigation.

This created a certain lack of uniformity, so growers started looking at non-leakage drippers, primarily the Netafim PCJ. Non-leakage drip systems, CNL (Pressure Compensating Non-Leakage) and PCJ (Pressure Compensating Junior) drippers were developed for substrate culture where many short irrigation cycles are required during the day. A diaphragm contained in the dripper seals the output as pressure drops, preventing “afterdrip” and making the system ideal for sloping sites. Manufacturers claim 99% uniformity of output along the dripline in a wide pressure range. This facilitates pulse irrigation because as soon as the valve is opened all the drippers begin to work instantaneously and when the valve is closed all the drippers stop instantly.

The PCJ system has been installed by some Dutch alstroemeria growers, but its biggest limitation is that as it is made of drippers inserted in PE (polyethylene) tube and it is very difficult to work with in a standing crop. Around two years ago Netafim Uniram was produced. Uniram has all the attributes of the PCJ dripper but is integral with the PE tube and thus much easier to work with. Since its release, all new sales into the Alstroemeria market have been with Uniram where drip has been chosen. Typically two lines are used per alstroemeria bed, with 25 cm spacing between drippers.

Growers who have changed over from low level spraylines to drip systems report production increases of 10-15%, and fewer peaks and troughs of production. Flower quality is also improved in the second and third years of production.

5.2.2 Measuring moisture levels in the soil

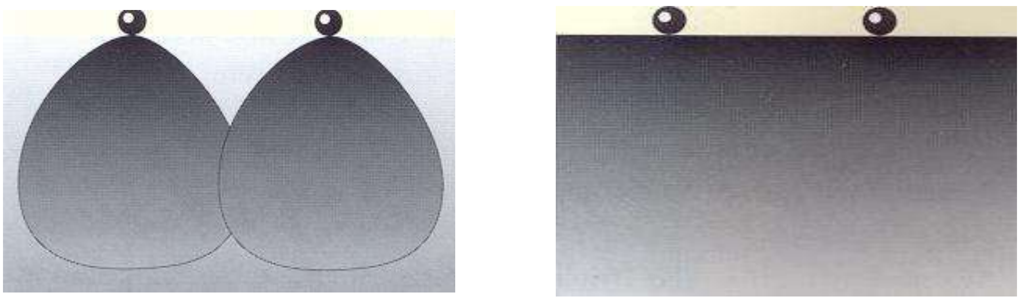
When using drip irrigation, soil moisture monitoring is crucial to gain maximum benefit. 95% of growers will over-water, thus allowing excessive drainage and wastage of not only water but nutrients.

Various soil moisture 'Data Collector Systems' are available that measure soil dielectric properties (ability of the soil to conduct an electrical charge, which is dependent on moisture levels in the soil). Most operate on a capacitance probe system (i.e. use an oscillator to generate an AC field which is applied to the soil to detect changes in dielectric properties linked to variations in soil water content), with several sensors (each consisting of a pair of electrodes), which can be read automatically or linked to a PC. The electrodes form a capacitor with the soil acting as the dielectric in between. This capacitor works with the oscillator to form a tuned circuit. Changes in soil water content are detected by changes in the operating frequency. Systems such as the Enviroscan cost in the region of £5,000. There are currently four in use in the UK on Alstroemeria crops. Alternative systems with probes plus a controller to feed into a solenoid or irrigation panel can be purchased for around £200 - £300 and added to as time goes on.

Frequency Domain (FD) and Time Domain Reflectometer (TDR) sensors are similar systems based on soil dielectrics. The sensors measure electrical capacitance of a soil/air/water mixture to detect changes of water content, allowing growers to monitor moisture movement minute by minute. Sensors are used in threes, with one placed in the root zone, one below the depth of water penetration (50-60 cm) and one in air. Devices on the market include Delta-T's ThetaProbes and ML2 sensor.

Tensiometers can also be used to measure soil moisture. A soil tensiometer consists of a porous pot, normally sited 150 mm below the soil surface between plants. The pot is connected to a vacuum gauge. Water diffuses in and out of the pot in accordance with the soil moisture tension, causing changes in the vacuum measured by the gauge. At field capacity, a low vacuum (tension) of approximately 4 kPa is measured, and this increases as the soil dries out. The point at which irrigation is applied will depend on the stage of the crop, but may be at levels of between 8 kPa and 16 kPa. Tensiometers are delicate and not appropriate for all soil types but they can be connected to dataloggers to provide a constant record of soil moisture. Tensiometers, such as those available from Skye Instruments Ltd., cost around £100 each. A typical production area may require a number of tensiometers to ensure the soil moisture status across the whole area is taken into account. These can be connected to a central datalogger, which would cost around £600. Tensiometers are used routinely with on tensiometer station per 1000 m^2 of production area. In general, use of tensiometers results in a much more even pattern of water distribution that can be achieved through visual control (Fig. 5.1.).

Figure 5.1. The water distribution profile in the soil where irrigation is controlled visually or by tensiometers (from Royal Van Zanten).



Visually controlled irrigation

Irrigation controlled by tensiometers

5.2.3 Irrigation control systems

Irrigation control may be by i) a simple timer device, through a sequence controller or irrigation panel, which opens solenoids in turn, or ii) linked to an environmental computer. Whether a stand-alone controller or computer is used, account should be taken of soil moisture levels and weather conditions, particularly solar radiation, in determining the amounts and timings of the irrigation applied. While many substrate-grown glasshouse crops rely on a certain radiation-sum to trigger an irrigation start, soil moisture measurements are more appropriate for alstroemeria. The time that the irrigation runs will depend on various factors including age of crop, type of glasshouse, output of the irrigation system etc.

5.3 Research Studies

Table 5.1. The effect on flowering of different applied water volumes in two alstroemeria cultivars. Means followed by the same letter are not significantly different at 95% probability (data from Lisiecka & Szczepaniak, 1992).

Characteristic	Cultivar	Volume of water/plant weekly (litres)			
		0.5	1.0	1.5	2.0
Number of inflorescences per plant	Orange Beauty	12.0	15.4	21.5	23.3
	Regina	10.6	14.8	20.4	19.5
	Mean	11.3c	15.1b	21.0a	21.4a
Length of stem (cm)	Orange Beauty	40.4	40.0	48.2	53.5
	Regina	46.9	48.8	53.8	54.1
	Mean	43.7b	44.4b	51.0a	53.8a
Number of umbel branches per inflorescence	Orange Beauty	3.3	3.1	3.1	3.2
	Regina	4.9	4.8	4.7	4.8
	Mean	4.1a	4.0a	3.9a	4.0a
Number of flowers per inflorescence	Orange Beauty	7.2	7.2	7.7	8.7
	Regina	8.8	9.4	9.9	9.6
	Mean	8.0a	8.3a	8.8a	9.2a

Lisiecka & Szczepaniak (1992) used data gathered in the early 1980s to study the influence of irrigation on flowering in two varieties, Regina and Orange Beauty (Table 5.1). There was clearly a response to increased irrigation on various floral attributes. One and a half litres of water per week per plant was found to be the optimum water requirement and there were no significant improvements in the number of inflorescences/plant and stem length above this volume. There was no information provided on the weight, depth or volume of soil to enable comparison with other work.

The HDC and UK alstroemeria growers funded research in 1991/1992 to examine the effect of two simple irrigation regimes on the production of alstroemeria cvs Eleanor and Carmen (HDC project PC 33a). Irrigation was controlled either by tensiometer or subjectively by hand assessment of soil moisture content. Table 5.2 illustrates the different water volumes (l/m²) applied in the different treatments with tensiometer control reducing water usage by 28% in 1999 and 5% in 1992. Whilst both of these varieties are now outdated, the work did also demonstrate improvements in stem quality via tensiometer-controlled irrigation.

Table 5.2. Water application (litres per m^2 of production bed) applied to alstroemerias via subjectively controlled and tensiometer-regulated irrigation (HDC project PC 33a)

Year	Subjective irrigation control	Tensiometer regulated irrigation
1991	353	219
1992	414	433

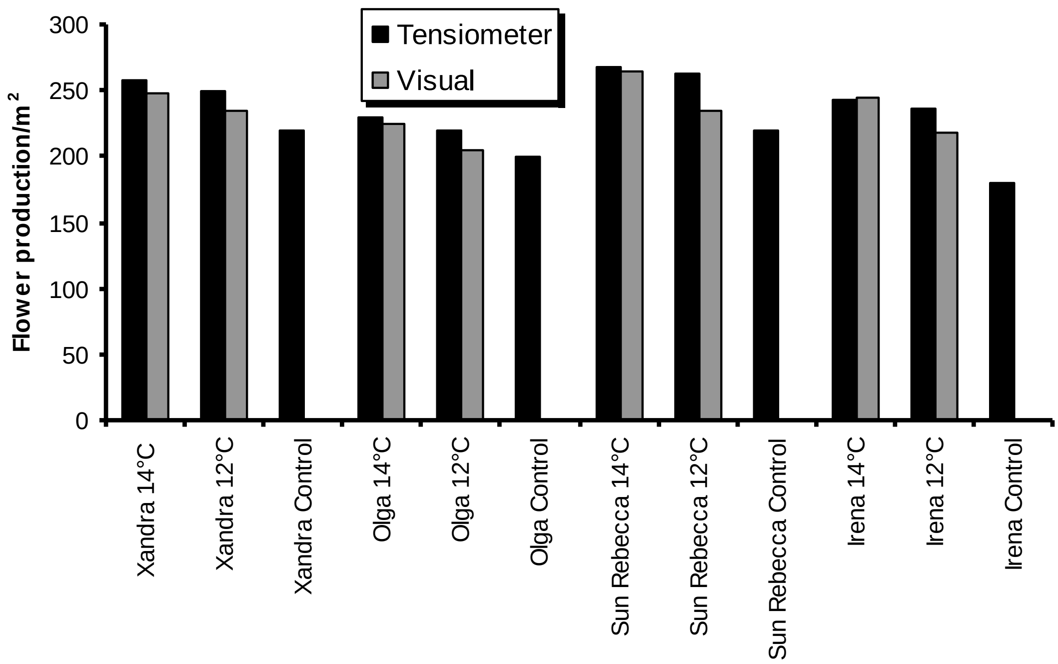
In 1999, RVZ studied the effect of the two irrigation systems on four varieties (Olga, Sunny Rebecca, Irena and Xandra) planted across 2000 m^2 in week 23. The treatments included:

1. Pressure compensated self-closing drip-line in combination with tensiometers.
2. Traditional drip lines with visual control of irrigation timings (subjective, grower-manager assessment).

3. Soil cooling at 12ºC vs 14ºC, plus no soil cooling, or ambient soil temperature (control).

The effect on flower number per m^2 is presented for all varieties in Fig. 5.2.

Figure 5.2. Flower number per m^2 for Xandra, Olga, Sunny Rebecca and Irena grown under soil temperatures of 12ºC and 14ºC and ambient soil temperature (control), irrigated with either tensiometer or visually controlled irrigation (Source Royal Van Zanten) (no data available for visual irrigation control in control treatments).



Tensiometer controlled irrigation led to an increase in production in all cultivars, with the greatest response at a soil temperature of 12ºC. There were some varietal differences in the responses. Tensiometer controlled irrigation also resulted in reduced water use, averaging 10% across the trial (see Table 5.3).

Table 5.3. Water usage during the trial period presented in Fig. 5.2 (source: RVZ).

Soil temperature	**12ºC**	**14ºC**
Tensiometer controlled	450 l/m^2	464 l/m^2
Visually controlled	515 l/m^2	503 l/m^2

From this and other trials, Royal van Zanten concluded that the benefits of tensiometer-controlled irrigation are (i) higher production, (ii) improved quality, (iii) less fungal diseases, (iv) less fertiliser use, (v) more controlled watering and (vi) less weeds. The economics of this will need to be considered in the light of installation expenses, water costs and productivity improvements in the presence or absence of soil cooling.

In 1998-2000, Alpha Nurseries in the UK conducted further tests of the potential of improved irrigation systems to enhance production and quality of alstroemeria (the work was done on the behalf of Könst). The trial objective was to compare low-level spray lines with drip lines, and to evaluate simple timed irrigation starts (see Table 5.4 for a list of treatments). The drip system was not used until the plants were established, approximately 6-8 weeks after planting. The work was done on the varieties Andorra and Fantasy.

The low level spray-lines were regarded as the conventional irrigation system. Two irrigation periods were implemented per week and the length of the watering period was judged by the grower. This was usually 5 to 15 minutes per start. Irrigation control using the drip lines was implemented using a simple time clock, and limited to a maximum of three starts per day. The duration of the irrigation period was influenced using information from an 'EnviroScan' soil moisture meter but was usually 90 seconds to two minutes per start. EnviroScan meter measurements of soil moisture were made at 10, 20, 30 and 50 cm depth.

Total stems per cropped area, stems per m^2 and stems per plant were assessed throughout the first complete year (Table 5.5). The distribution of stems throughout some of the year for variety Andorra is presented in Fig. 5.3.

Table 5.4. Treatments used in irrigation trials conducted by Alpha Nurseries for Konst in 1998-2000.

Irrigation System	**Name**	**Type**	**Lines per 1m bed**	**Nozzle/dripper spacing**	**Approx. output per nozzle**	**Total output/30m bed length**
Low level spray-line	T-Dop green/red bow nozzle	Conventional bow nozzle with oval, dished spray pattern on ground level 32mm PVC sprayline	1	75cm	124 litres per hour @ 2 bar	4960 litres per hour
Low level spray-line	Green bow nozzle	Conventional bow nozzle with flat spray pattern on ground level 32mm PVC sprayline	1	75cm	124 litres per hour @ 2 bar	4960 litres per hour
Drip line	Pressure Compensated Dripper	Pressure compensated labyrinth nozzle inserted in 20mm LDPE tube	3	30cm	3 litres per hour @ 1.5 bar	900 litres per hour
Drip line	Streamline 80	Internal labyrinth dripper welded into lightweight layflat hose	3	10cm	1 litre per hour @ 0.85 bar	900 litres per hour

Table 5.5. Yield results for the varieties Andorra and Fantasy from Year 1 (1998/99, 365 days from planting) for the irrigation trial at Alpha Nurseries

	Andorra		**Fantasy**	
	Drip	Low level sprayline	Drip	Low level sprayline
Total stems	5321.0	4033.0	8908.0	7413.0
Stems/m²	118.2	89.6	198.0	164.8
Stems /plant	36.7	27.8	61.4	51.2

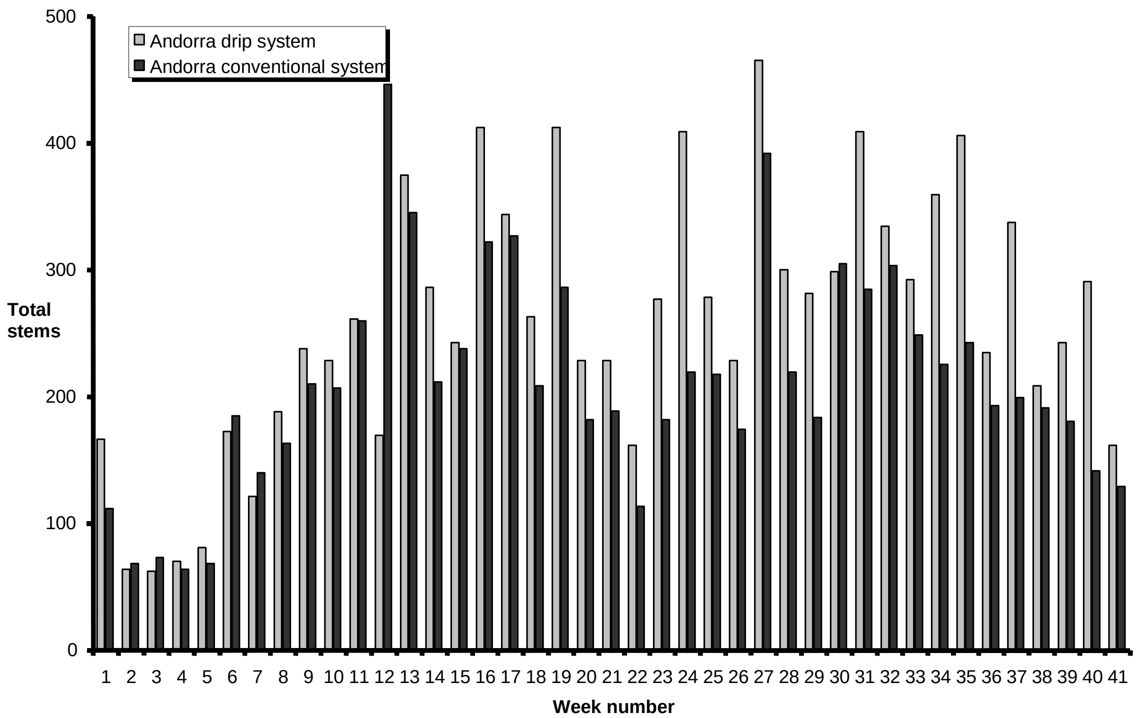


Figure 5.3. Distribution of total number of stems per week in the cropped area throughout 41 weeks of Year 1 (1998/99) for the variety Andorra.

The implementation of drip irrigation led to a substantial increase in yield for both varieties, Andorra and Fantasy, when compared with plants grown using low-level spray lines. Andorra showed consistently higher yields with the drip system, with a particularly marked improvement in summer production. Stem quality was also improved, resulting in a higher percentage of class one stems. Yield increased by an average of 26% over the first two years. The variety Fantasy also showed higher yields with a 20% increase in the first year alone. However, the difference was reduced to 12% in later years. It was also noted that stem quality was improved especially during summer months.

How the crop is treated in the early months after planting sets the pattern of growth for the first years of its life. From the EnviroScan system, it became apparent that for the first 12 months the active root was taking water up primarily from the 10 cm level (Alan Cox, pers. comm.). As the crop matured, the roots in the 20 cm level became more active. There was no significant effect of the irrigation regime on soil temperature.

5.4 UK grower practice

While most Dutch growers are now using modern drip irrigation for alstroemeria, in the UK low level watering by either lay flat drippers or spraylines is used on most alstroemeria units. On some units overhead spraylines are used. Some producers, who use wood shaving mulches, incorporate seephoses underneath the wood shavings to maintain a more consistent soil water content and improve weed control (Plates 5.1 and 5.2). Wood shavings will give the added advantage of preventing fern growth.

Plate 5.1. Three irrigation lines placed under sawdust mulch in the UK.

Plate 5.2. Low level spray line in a UK crop of alstroemeria.

5.5 Further information and contacts

CMW Horticulture, Stonepit Road, South Cave, East Yorkshire HU15 2BZ
Tel: 01430 422222
Fax: 01430 422264
email: info@cmwhorticulture.co.uk

Growquip Ltd, 1a Green Lane, Fordingbridge, Hampshire SP6 1HT
Tel: 01425 650200
Fax: 01425 650041
email: sales@growquip.com

LS Systems Ltd, 184 Blackgate Lane, Tarleton, Preston, Lancashire PR4 6UU
Tel: 01772 815080
Fax: 01772 815417
email: sales@lssytems.co.uk

Revaho UK Ltd, Penketh Place, West Pimbo Industrial Estate, Skelmersdale, Lancashire WN8 9QX
Tel: 01695 556222
Fax: 01695 556333
email: info@revaho.co.uk

Brinkman UK Ltd, North Moor Lane, Cottingham, East Yorks, HU16 4JW
Tel: 01482 842123
Fax: 01482 840444
e-mail: sales@brinkmanuk.co.uk

Hortisystems UK Ltd, West Chiltington Road, Pulborough, West Sussex, RH20 2PR
Tel: 01798 815815
Fax: 01798 815816
e-mail: sales@hortisystems.co.uk

Priva UK, Bredon Road, Tewkesbury, Gloucestershire, GL20 5BX
Tel: 01684 293081
Fax: 01684 297990
e-mail: technical@priva.co.uk

Van Vliet Automation Ltd, 42 Stockbridge Road, Elloughton, East Yorkshire, HU15 1HN
Tel: 01482 668676
Fax: 01482 665293
e-mail: vlambert@vanvliet.co.uk

5.6 Summary

- Irrigation is one of the key factors regulating growth and ultimately productivity in alstroemeria. Yield increases of 12-15 % have been observed in the UK by improving irrigation systems.
- Monitoring of soil moisture (e.g. using tensiometers) is necessary to prevent overwatering and also to ensure uniform water distribution throughout the cropped area.
- Productivity and quality of alstroemeria can be improved with more attention to management of soil water content and with the use of low level irrigation systems such as drippers.
- Control over irrigation in the early months sets the pattern of growth in the early years. Appropriate irrigation can lead to yield increases of up to 20% in the first year, together with improved stem quality.
- More UK relevant information is required for irrigation of alstroemeria in order to improve uniformity productivity and quality.

6. Crop nutrition

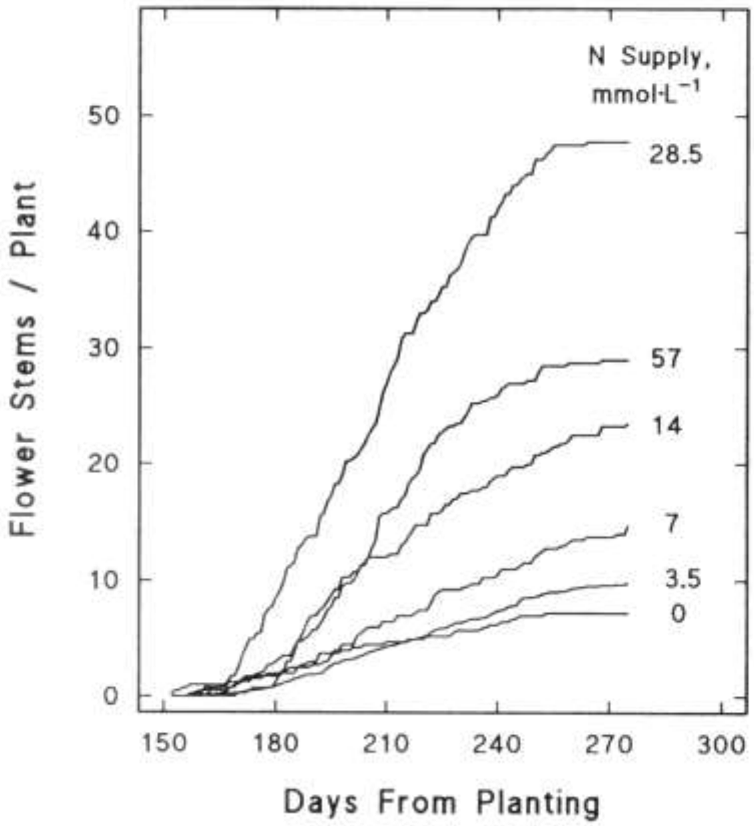
6.1 Background and Introduction

Alstroemeria plants require correct nutrition throughout the production period. Without correct nutrition, crop yields are not optimised, and the quality and vaselife of flowering stems can be negatively affected. Prior to planting, the soil may be amended with organic matter, limestone to increase pH, and base fertilisers. Throughout production, fertilisers are generally applied with the irrigation water (fertigation). Alstroemeria is sensitive to high salt concentrations, thus the application of fertilisers during production needs to be little and often.

6.2 Research Studies

Bik & van den Berg (1981) demonstrated that the optimum ratio of N to K_2O was between 1:1 and 1:1.4. In comparison with lower ratios, this ratio significantly increased the number of flower stems per plant, stem length and stem fresh weight. In addition, Brigden *et al.* (1987) showed that the NH_4^+:NO_3^- (ammonium:nitrate) ratio of N fertiliser does not affect flower production in alstroemeria. Smith *et al*. (1998) showed that flower production was not affected by Ca supply (NO_3^{2-} or Cl^-) between 0 and 12 mmol/L. However, they did find that flower production was maximised when leaf tissue N was maintained close to 4.5% (Fig. 6.1). This can be achieved by applying total N at 30 mmol/L.

Figure 6.1. The effect of N (mmol/L) in leaf tissue on the number of flower stems/plant throughout flowering (from Smith *et al.*, 1998).



The time to flowering can be reduced by at least 15 days by optimum N nutrition. Dinova *et al.* (1988) found that N levels significantly above those required, promote the development of vegetative and blind shoots at the cost of flowering shoots.

Dutch research has examined the production benefits from increased soil oxygen. Tests in practice demonstrated that soil aeration increased yields, and approximately 5 ha of alstroemeria production in the Netherlands is equipped with a soil aeration system.

UK trials funded by the HDC in 1993-1996 (HDC project PC 33b) investigated the response of four cultivars of alstroemeria to standard and high rates of nutrition. The treatments used are summarised in Table 6.1.

Table 6.1. 'Standard'' and 'High' N:K_2O ratio treatments and appropriate varieties used in HDC project PC 33b.

Treatment	**Varieties**	**Nutrient levels**
Standard: October - March	Samora	150 mg/l N: 200mg/l K_2O
Standard: March - October	Wilhelmina	200 mg/l N: 200 mg/l K_2O
High: October - March	Libelle	200 mg/l N: 200 mg/l K_2O
High: March - October	Cavalier	350 mg/l N: 200 mg/l K_2O

The baseline seasonal production for each variety was examined initially, with Samora and Wilhemina producing higher numbers of marketable stems with no evidence of a decline in yield with time. The results were variety specific but the general trends were that the higher nutrition regime favoured production for the varieties Libelle and Samora. Full data is available from the relevant HDC report.

6.3 Fertigation Systems

Alstroemeria is a long-term crop and thus fertilisers need to be added over a long growing period, and cannot all be added in the base fertiliser (base fertiliser application is described in Chapter 2). Adding fertiliser in solid form would be impractical in alstroemeria production, so fertilisers are added to the irrigation water – a process known as fertigation.

The simplest way of supplying fertigation is by using a single stock tank of concentrated fertilisers (typically 100 times or 200 times required strength), which are then diluted before applying to the crop. This can be done using a displacement-type dilutor (barrel dilutor) or a water-driven proportional dispenser such as a Dosatron. Both types operate without any electrical inputs. Dosatron types are generally preferred over barrel dilutors as they give a more precise dose and their calibration is less likely to drift.

Another system of dilution relies on measuring and controlling the electrical conductivity (EC) of the mixture. This method has advantages over mechanical systems in that the dilution rate is more quickly and easily varied. Controlling by conductivity is more appropriate on nurseries with climate control computers, and gives the advantage of varying EC according to weather conditions, radiation levels etc.

Single tank systems work well where a limited number of fertilisers are used in the mix and where there is no risk of precipitation. However, most nutrient recommendations for alstroemeria, especially those from Holland, contain a blend of all major and minor nutrients, similar to hydroponic production in substrates or nutrient film technique (NFT). Such mixtures cannot be contained in concentrated form in a single tank because calcium (from calcium nitrate) will precipitate with sulphate and phosphate, thus reducing active concentrations. If a single tank is used, a much less concentrated stock mix must be used to prevent precipitation. Many growers use a feed controller with a two-tank system to keep the calcium separate from sulphates and phosphates. Nutrients from the “A” tank and “B” tank are drawn in equal proportions and mixed either in-line or in a mixing tank to produce the feed of the desired EC level. In some cases a third (acid) tank is used to regulate the pH in the resulting mixture. More generally acid is added (usually nitric acid) to one or both of the “A” and “B” tanks. This not only corrects the pH but also aids the dissolving of some of the fertilisers. Most of the companies listed in section 5.7 supply suitable dilution and feeding control equipment, ranging from mechanical dilutors to computer-linked fertigation rigs.

A typical example of a Dutch feed recommendation for fertigation of alstroemeria is shown in Table 6.2.

Table 6.2. Standard alstroemeria liquid nutrient feed profile (source: SGS Laboratory Services B.V., The Netherlands).

Tank A (1000 litres)		Tank B (1000 litres)	
Nutrient	**Amount**	**Nutrient**	**Amount**
Ammonium nitrate	5.4 kg	Copper sulphate	12.5 g
Calcium nitrate	27.2 kg	Magnesium sulphate	20.4 kg
Iron chelate EDTA 13%	0.5 litres	Manganese sulphate	85.0 g
Nitric acid 68%	0.3 litres	Mono potassium phosphate	6.8 kg
Potassium nitrate	11.4 kg	Nitric acid 68%	3.0 litres
		Potassium nitrate	10.0 kg
		Sodium borate (Borax)	95.0 g
		Sodium molybdate	12.1 g
		Zinc sulphate (23%)	86.3 g

The recipe above is suitable for **mains water**. The fertiliser recommendation is set up for an installation consisting of two mixing tanks (A and B) with a volume of 1000 litres and 2 injection pumps with dilution rate 1:100. Both mixtures are injected in the main pipeline of the drip system in equal proportions. Check and adjust (if necessary) the EC to 1.0 and the pH to between 5.5 and 6.0.

Note that different water supplies will need adjustment to the mixtures. An analysis of the raw water supply (mains or roof/reservoir water) will be needed. If calcium levels in the water and soil (combined) are high enough, there is no need to add calcium nitrate to the feed.

A shortage of micronutrients is very rare in soil-grown crops as only a very small amount of these nutrients is required. Occasionally boron is required (Borax). Deficient micronutrient symptoms may appear if the root system is not functioning correctly, or if the pH is too high.

6.4 Monitoring nutrient levels

Since alstroemeria plants require correct nutrition during the production cycle in order to optimise productivity and quality, routine analysis of the soil nutrient levels and monitoring of the liquid feed solutions is essential. There is a greater level of knowledge of the nutrition requirements of alstroemeria crops in the Netherlands and hence most of the UK producers have their soil analysed regularly at laboratories there.

6.4.1 Soil sampling and sampling techniques

The principle is to ensure that a representative soil sample is taken from the place where the roots grow. To sample:

- use an auger of minimum 25 cm long. The auger, a half open pipe, should have a diameter of approximately 2.5 cm.

- Use strong plastic bags or the special bags supplied by the laboratory to send the samples for analysis.

To ensure that a representative sample is taken:

- Gather soil-cores from 40 places, spread around the glasshouse. Sample the layer of 0-25 cm depth. If the roots grow deeper you can decide to take an extra sample of a deeper layer. Gather from places where the soil is moist and where water fertilisers are added.
- Take material from at least 8 rows or 8 beds, equally spread over the glasshouse.
- If no crop is present, take samples across the glasshouse in X or W shapes.

The Analytical laboratory needs half a litre or 700 grams of soil to make adequate extractions and follow the quality rules of the laboratory. Growers will be asked to provide details of fertigation systems to the sampling laboratory

6.4.2 Soil testing laboratories

Anglian Soil Analysis Ltd, The Laboratory, One Way Street, Sutterton, Boston, Lincs. PE20 2JG. Tel 01205 460590

BLGG Laboratories, Zuidweg 42, Postbus 98, 2767 MN Naaldwijk, The Netherlands.
Tel 00 31 174 626624; Fax 00 31 174 620065

Direct Laboratories, Woodthorne, Wergs Road, Wolverhampton, WV6 8TQ.
Tel 01902 743222

SGS Nederlands Groep, Postbus 200, 3200 AE Spijkenisse, The Netherlands.
Tel 00 31 181 693333; Fax 00 31 181 623566

6.4.3 Interpreting soil nutrient analysis information

UK growers generally send soil samples to the Netherlands for analysis and recommendations specific for alstroemeria. Laboratories such as SGS and BLGG use specific extraction procedures for analysis and send a relevant interpretation back to the grower. It is important that growers provide details of their fertigation system to the soil testing laboratories.

Dutch laboratories report nutrient levels in mmol/l for major nutrients and µmol/l for minor nutrients. UK laboratories report in mg/litre, but most will also convert to mmol/l and µmol/l on request (a conversion table is given in Appendix 2). Some laboratories report nutrients in the soil, and others, what is available to the plant. Typical levels of nutrients in the soil are shown in Table 6.3. Reported levels should be between the minimum and maximum figures.

Table 6.3. Target ranges for soil pH, electrical conductivity (EC) and nutrient concentrations for alstroemeria production.

Nutrient/factor	**Min**	**Max**
pH	5.5	6.5
EC (ms/cm)	0.8	1.6
NH_4 (mmol/l)	0.1	0.4
K (mmol/l)	1.5	4.0
Ca (mmol/l)	1.7	2.8
Mg (mmol/l)	1.0	2.0
No_3 (mmol/l)	3.0	6.0
So_4 (mmol/l)	1.0	3.5
H_2PO_4 (mmol/l)	0.15	0.25
Fe (µmol/l)	3.5	15.0
Mn (µmol/l)	0.5	4.0
Zn (µmol/l)	1.5	4.0
B (µmol/l)	10.	30.0
Cu (µmol/l)	0.5	2.5

The nutritional requirements of alstroemeria change as the crop develops; guidance for fertigation is also calculated to allow for 30% leaching through the soil profile. To get plants off to a good start, the concentration of salt (the electrical conductivity or EC) should not be too high at planting time, especially in the summer.

If the pH of the soil is too high (pH 7 or higher), iron or manganese deficiency may occur. A lack of iron can be treated by providing 6-8 g of EDDHA per m^2 or by providing this regularly in irrigation water, but it will not always solve the problem.

Yellowing of the leaves can be a frequent problem with certain varieties. Yellowing can appear after a high production period when the plants have lost some active roots. Yellowing may also occur at the end of the winter when the plants have fewer roots due to low light conditions, or lack of iron after a flush. A cold soil (10-12^{o}C) and too much water prolongs the problem. The AYR producing varieties display fewer problems in this regard. Supplementary fertilisation should be discontinued a number of weeks prior to and during the period of dormancy.

With regard to electrical conductivity (EC), general recommendations are that the fertigation solution is usually 1.1 mS/cm. If the EC value rises above 1.5 mS/cm there may be an impediment to growth in some varieties. This manifests as the number of stems that are harvested and the weight per stem. The number of flowers per stem is less influenced.

Table 6.4. Percentage decrease in production per 0.1 increase in EC in the water supplied to plants over a threshold of 1.5 mS/cm (i.e. an increase of EC from 1.5 to 1.6 will reduce total number of stems by 10%).

Characteristic	**% decrease**
Total weight	15
Number of stems	10
Number of flowers per stem	2
Stem length	5
Weight per stem	8

Salt tolerance has been studied in alstroemeria using solutions with EC ranging between 0.2 and 4.0 mS/cm at 25°C, on soil-grown plants (Sonneveld, 1988). Alstroemeria is a salt-sensitive crop, with a salinity threshold value of 0.8 mS/cm, above which there are a reduced number of cymes/inflorescence and less weight/cyme. The negative influence of salt in fertigation for alstroemeria is shown in Table 6.4. As a guide, the maximum levels of EC, Sodium (Na), and chloride (Cl) in water for the cultivation of alstroemeria are shown in Table 6.5. If the sodium, chlorine, or EC levels of the irrigation water are higher than the value given, the water may not be used for alstroemeria , and alternative supplies must be found.

Table 6.5. Maximum levels of EC, Na, and Cl in water for the cultivation of alstroemeria.

Production method	**EC (mS/cm, 25°C)**	**Na (mmol/l)**	**Cl (mmol/l)**
Soil culture drip system	1.5	4.5	4.5
Soil culture spray lines	1.5	3.0	3.0
Substrate Culture	1.0	3.0	3.0

6.4.4 Diagnosis of nutrient disorders

Diagnosing nutritional disorders in alstroemeria is sometimes difficult due to the confusion of continual death (with associated chlorosis) of blind shoots, and the buffering effect of a long-term storage rootstock on overall plant health. In addition, viral symptoms can sometimes resemble nutritional disorders.

The most essential requirement for recognising disorder symptoms is a thorough knowledge of the plant itself and its normal appearance at all stages of growth. It is not always possible to distinguish between the symptoms caused by a deficiency of one element and the symptoms caused by the relative excesses or imbalance of the other elements. If in doubt, laboratory analysis of soil, feed or plant tissue should be carried out. Leaf analysis can be used to monitor crop nutrition levels but is generally used to assess problems for diagnosing crop nutrient disorders. A typical leaf analysis for alstroemeria is shown in Table 6.5.

Table 6.5. Typical leaf analysis for nutrients in healthy alstroemeria leaves, expressed as % dry matter or as ppm (mg/l) dry matter

Nutrient	Concentration
Nitrogen	4.0 - 4.5 %
Phosphate	0.30 - 0.35 %
Potassium	3.5 - 4.0 %
Magnesium	0.25 - 0.35 %
Iron	170 –199 mg/l
Boron	18 – 23 mg/l
Copper	3.8 - 8.0 mg/l
Manganese	4.4 –16 mg/l
Molybdenum	3.9-6.7 mg/l

Sometimes, an excess of one element may interfere with the utilisation of another element to the extent that acute deficiency symptoms appear even though there is an adequate supply of the other element. Examples of well known ion-competitions are: iron/ manganese, potassium/calcium, potassium/magnesium and phosphorous/ magnesium.

6.5 Summary

- Since alstroemeria is a long-term crop, regular addition of fertilisers over a long growing period is required. Fertilisers are applied with irrigation water (fertigation), usually in a two stock-tank system similar to hydroponic production systems.
- Regular soil nutrient analysis is advised for optimal production, since the nutritional requirements of alstroemeria change as the crop develops. It is important to ensure that soil samples representative of the cropping area are used for analysis. Leaf tissue analysis can provide extra back-up for diagnosis of problems.
- Optimal N:K ratios of 1:1 – 1:1.4 significantly increase the number of flower stems/plant, stem length, fresh stem weight and number of flowers/stem.
- Soil pH should be in the range 5.5 – 6.5. Higher pH values can lead to iron or manganese deficiency.
- Alstroemeria is a salt-sensitive crop. General recommendations are that electrical conductivity should be maintained below 1.5 mS/cm at 25^{o}C, with a maximum of 4.5 mmol/l each of sodium and chloride. Negative effects on yield can occur above these levels.
- Leaf tissue analysis is useful for diagnosing symptoms of toxicity or deficiency, which can otherwise be difficult to distinguish from physiological or virus symptoms.

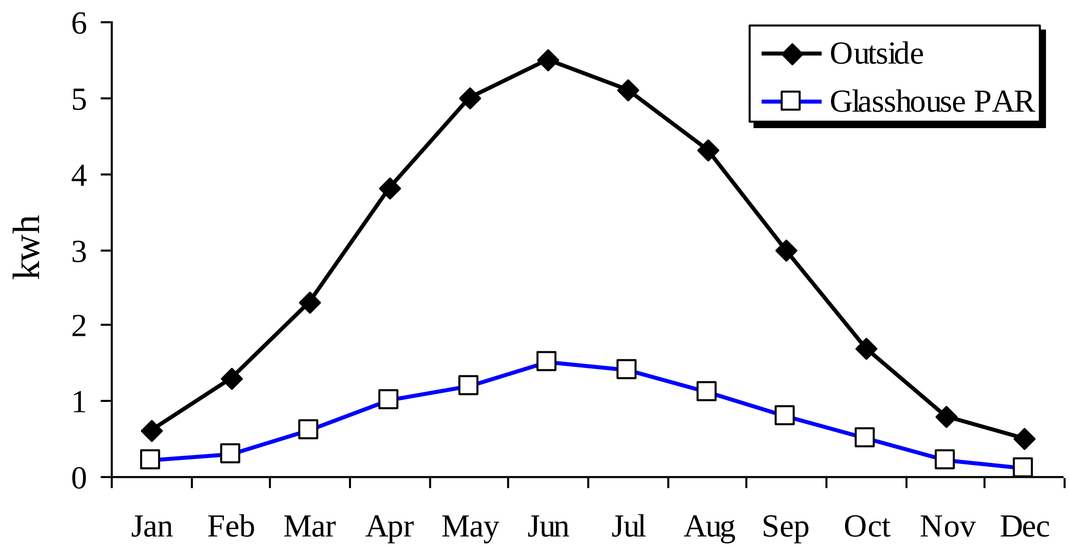
7. Supplementary lighting

7.1 Natural light

In most growing areas in the world, seasonal changes in day-length result in substantial differences in the number of hours of natural light per day and thus in the light sum per day. In Western European conditions, the difference between day length in winter (8-9 hours of day light per day) and summer (15-16 hours of day light per day) is about eight hours.

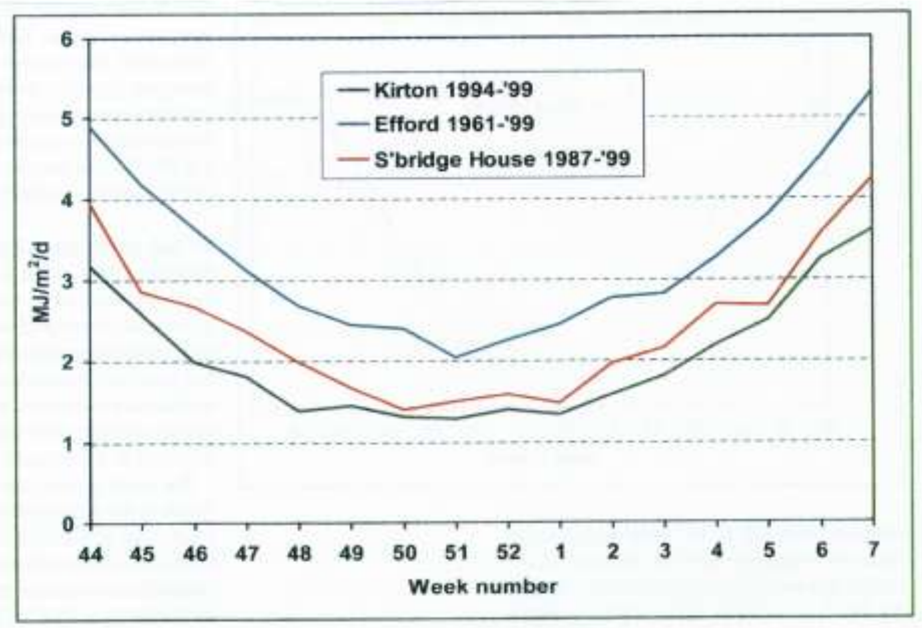
The combination of this, with more cloudy skies and the lower solar angle in winter results in 'poor light conditions' in the winter season. The light originating from solar radiation (natural light) varies in wavelength between 300 and 3,000 nanometers (nm) of which only 45% (wavelength between 400 and 700 nm) is available for photosynthesis. From this light, 25-40% is intercepted by greenhouse constructions. This means that only 15-20% of the natural light (Photosynthetically Active Radiation, PAR) is available for plant growth in greenhouses (Fig. 7.1). Thus, light is the limiting growing factor in the winter season.

Figure 7.1. Availability of photosynthetically Active Radiation (PAR) outside and within glasshouses throughout the year in the UK.



Average daily solar radiation integrals ($MJ/m^2/d$), recorded in the open in winter in the UK, are only about one tenth of those in summer. It is vital that any grower planning to invest in or upgrade his supplementary lighting takes account of how much solar radiation he can expect to receive in his locality. The magnitude of the differences to be expected between localities is illustrated in Fig. 7.2.

Figure 7.2. Average daily integrals for Efford (50°44'N), Kirton (52°55'N) and Stockbridge House (53°50'N) during the winter period (weeks 44-7).



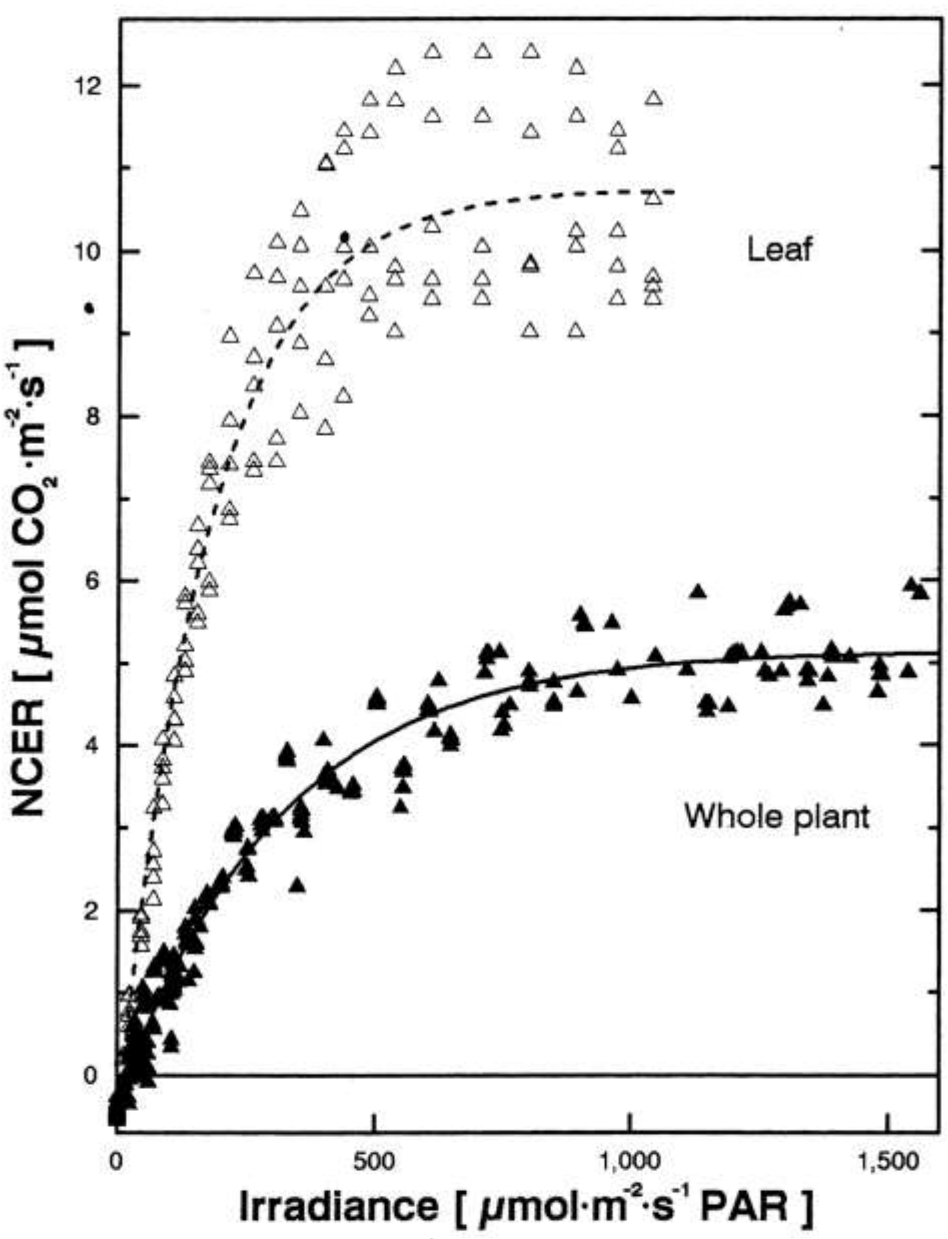
The average outdoor daily integral over this period at Efford is 3.3 $MJ/m^2/d$ but the integrals at Stockbridge House and Kirton are respectively about 27% and 38% lower.

Information on how growers can estimate average daily radiation levels can be obtained from 'Supplementary Lighting, A Grower Guide' published by HDC. The highest solar radiation integrals can be expected in the Channel Islands, along the south coast and on the Cornish and Welsh peninsulas.

7.2 Response to light

Alstroemeria is very sensitive to light, the dominant factor regulating photosynthesis. The effect of increased light on whole plant photosynthesis is illustrated for cv 'Jacqueline' grown at 17^oC with ambient CO_2 in Fig. 7.3.

*Figure 7.3***.** Effect of irradiance on alstroemeria leaf and whole plant Net Carbon Exchange Rate (NCER) at 17°C, 333 ppm CO_2 (data from Leonardos *et al*., 1994).



The data in Fig. 7.3 illustrate that at increasing light levels (up to 600 µmol/m²/s) the increased photosynthesis outpaces carbon losses as a result of respiration. Above this light intensity, photosynthesis does not increase linearly as it has become saturated. Thus no further benefits for the plant to accrue (at least for cv. Jacqueline, in this example).

Crop thinning increases within-canopy light levels, which enhances subsequent flower production. As more light penetrates the canopy, apical dominance is reduced and lateral rhizome growth is promoted, thus increasing photosynthesis of young emerging shoots. Exposure to a long-day regime and to high-intensity lighting may induce a new growth response dependent on enhanced photoassimilate production, which results in earlier flower production and increased flower yield.

To improve light levels, it is important that the glasshouse is constructed to enable maximum light penetration (with clean glass), with appropriate venting and use of screens to maintain good control of air temperature. If the temperature gets too high, bud formation will be negatively affected. In autumn and winter, buds may dry out due to insufficient lighting. This is why varieties may respond so well to winter lighting. Levels of at least 2,000 lux are sufficient for shoots to develop; extra light enables more shoots to develop.

7.3 Daylength responses

There are two types of illumination:

- Illumination to increase growth = assimilation lighting (High Pressure Sodium lamps, HPS)
- Daylength control lighting = control lighting (incandescent light bulbs).

Alstroemeria is a facultative long-day plant i.e. a day length of more than 13 h is required to promote flowering. Thus, a short day (SD) is less than 13 h. Some growth may occur during these conditions, but the number of flower stems is markedly less than during the long day (LD) period (and the flowers take longer to develop). Also, the proportion of non-flowering stems is correspondingly higher at day lengths of less than 13 h.

Buds are induced less rapidly with a 12-13 h day than they are with a 15-16 h day, but the number of flowers in the inflorescence is increased. This results in an improvement in flower quality.

Investigations into the effect of lighting on alstroemeria have been done in Holland since 1970. The Research Stations and breeders have collected many data on the effect of light on alstroemeria physiology. The mechanisms involved are not completely understood, but there are a number of rules that are generally applicable:

- Too long a day (>14 h) results in a reduction of the total number of shoots.
- Too long a day results in a reduction of the number of flower pedicels in the inflorescence.
- Prolonging the day (to 13-14 h) in the spring and autumn promotes bud formation on the shoots.
- Prolonging the day results in fewer blind stems.
- Winter-flowering varieties do not require additional light.
- Prolonging the day with lamp bulbs does not prevent dying out.

7.3.1 Spring illumination – festoon lighting

This illumination is given to young autumn and previous year's plants when the natural length of the day is less than 13 h. Spring illumination is intended to advance the flowering of the plants. This will result in improved prices and earlier re-growth.

The plants should be growing vigorously before beginning the illumination treatment. The shoots should be appearing regularly above ground, preferably at intervals of about 10 days, with about three to four shoots per plant. In general, this stage will be reached in December/January. If the crop is not yet at the required stage, then it is better to delay supplementary lighting or production losses may be incurred. Illumination is stopped when the natural length of the day has reached 13 h, or when insufficient numbers of new shoots are being formed.

7.3.2 Autumn illumination

The objective of autumn illumination is to increase and advance the production of the flower stems, and to reduce the production of blind stems on some varieties. Both young plants planted in June and the previous year's plants can be illuminated. The plants must be at the right stage with three to four good shoots per plant. Illumination should begin in about mid-July, and should be discontinued in about mid-November for young plants. Previous year's plants should receive a few weeks extra illumination. The day length in Holland varies from 8-10 h between January and February, 11-14 h between March and April, 15-16 hours between May and June, 16-15 h between July and August, 13-10 h between September and October, 9-8 h between November and December.

Illumination in the spring and autumn makes it possible to spread the crop flowering over a longer period of time. This is influenced by factors including the variety, the previous history of the crop, the temperature, and the type of greenhouse. The development of the crop during the period of illumination should be given particular attention, as there is a risk that incorrect application will result in a diminished crop, both in the number of flowers and in the quality.

The critical day-length at which the flowers are formed and the formation of shoots is barely inhibited, is in the order of 12-13 h, depending on the variety. Two to three hours illumination will be required with a 10 h day. The illumination can be either continuous or cyclical. There are two methods:

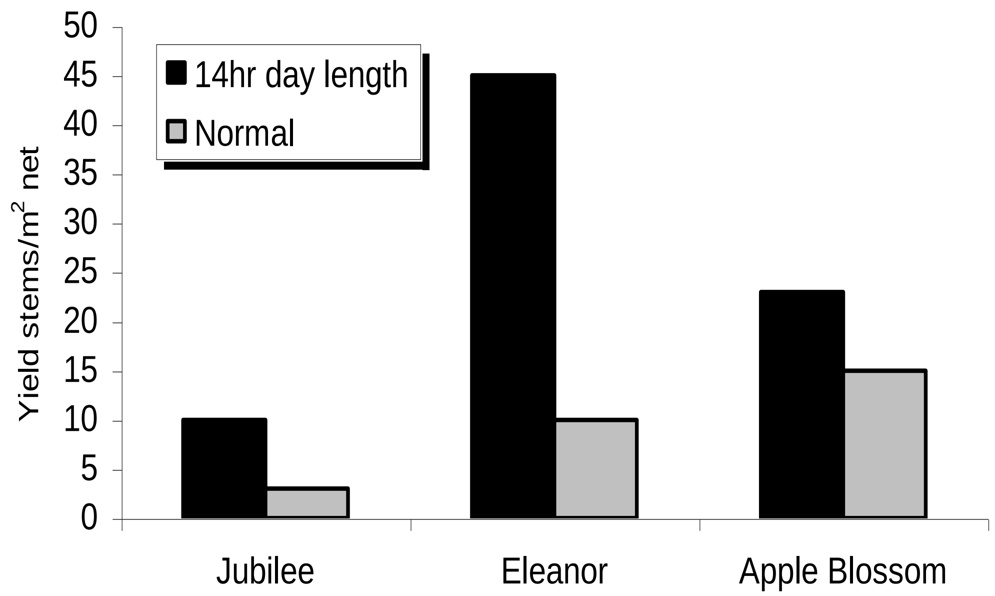
1. immediately preceding or following the day, i.e. prolongation to the required length of the day before dawn or after sunset;
2. in the middle of the night. The night is then interrupted for the required period of illumination.

Both methods can be carried out using continuous or cyclical illumination, with the same result. With cyclical illumination, the lighting is only turned on during about 35% of the illumination period. This results in savings of about 65% of the costs of electricity. One hour cyclical illumination is then 10 min lights on, 20 min lights off, and than a further 10 min lights on and 20 min lights off. The rule is that one hour continuous illumination is equivalent to one hour cyclical illumination. The intensity of the light should be between 30 and 40 lux, which is equivalent to 10-15 Watt/m^2. Light bulbs are usually used to provide the illumination.

7.4 Varietal response

The response of individual varieties to both photoperiodic and assimilation lighting needs to be verified before application by growers. Several studies have investigated the response of different cultivars to day length, with predictably variable results (Fig. 7.4). There are even varieties that will yield well in winter without additional lighting.

Figure 7.4. Yield of three alstroemeria varieties (Jubilee, Eleanor, Apple Blossom) grown under a 'normal' and 'enhanced' (14 h day length) lighting.



7.5 Assimilation lighting

In the early 1980s, research at the University of Guelph, Canada, examined high pressure sodium lighting on the production of 15 varieties over three years (Table 7.1).

Table 7.1. The production (stems/m^2) of 15 alstroemeria varieties subjected to high pressure sodium (HPS) lighting compared with control (no supplemental lighting) over three years.

	Difference (stems/m^2) between HPS lighting and Control		
	Year 1	**Year 2**	**Year 3**
Alsaan	1.0	19.4	20.2
Cyprus	0.2	11.2	16.5
Jacqueline	52.5	42.1	25.0
Jubilee	9.8	11.2	8.3
Mona Lisa	16.5	25.1	23.7
Ontario	16.8	10.2	-4.5
Oscar	21.8	13.8	1.0
Paloma	-5.9	-1.3	8.3
Parano	13.4	25.8	40.8
Pink Triumph	3.2	30.9	28.5
Rio	-5.0	2.4	7.5
Rosita	-7.2	-9.6	-1.1
Samora	31.7	48.6	25.3
Sonja	4.2	17.8	16.2
Vanitas	5.6	10.4	11.0

This is a typical number of varieties produced on one site in the UK, and represents the challenge to producers: Some varieties will respond to supplementary lighting, and some won't.

7.6 Lighting and soil cooling

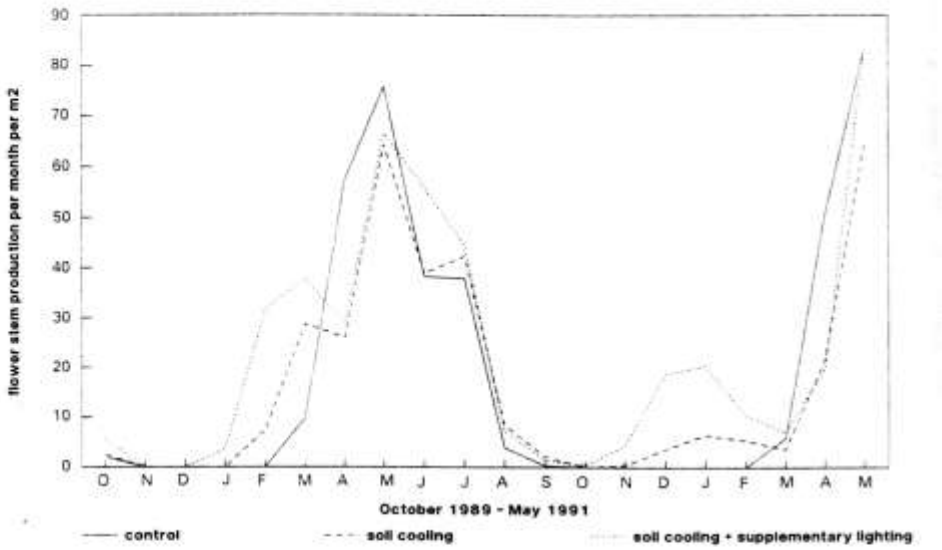
Recent research around the world has considered the benefits of altered lighting regimes with soil cooling and CO_2 in addition. Soil cooling in particular affects how varieties perform. Thus, it is most interesting to discern the effects of supplementary lighting alone. Van Labeke & Dambre (1993) considered the effect on five cultivars of uncooled soil, soil cooling (13-15^oC), and soil cooling and lighting levels. The varieties used reflected a range of types. These were Annabel (AYR variety), Mona Lisa and Libelle (periodic flowering) and Yellow King and Red Sunset (both spring flowering). The results are presented in Table 7.2 and Fig. 7.5.

Table 7.2. The effect of soil cooling with and without supplementary lighting on five alstroemeria varieties (n/e = no effect).

	Cultivar				
	Annabel	**Mona Lisa**	**Libelle**	**Yellow King**	**Red Sunset**
Soil cooling	Lower total shoot number.	Lower total shoot number	n/e	Lower total shoot number	
	Increase % flowering shoots	Increase % flowering shoots	n/e	n/e	Increase % flowering shoots
Soil cooling and lighting	Increase % of flowering shoots	Increase % of flowering shoots	n/e	Increase % of flowering shoots	Increase % of flowering shoots
	Increased total number of flowering shoots	Increased total number of flowering shoots	Increased total number flowering shoots	Increased total number of flowering shoots	Increased total number flowering shoots
	n/e	Increased number of cymes per inflorescence	n/e	Increased No. cymes per inflorescence	Increased No. cymes per inflorescence

Annabel, Mona Lisa and Red Sunset responded to soil cooling with an increased percentage of flowering shoots (less blind shoots) with the addition of lighting , an increased total number of flowering shoots also occurred, as well as bigger flower heads (Mona Lisa, Yellow King, Red Sunset).

Figure 7.5. Effect of soil cooling and supplementary lighting on flower stem production in alstroemeria 'Red Sunset'.



Flowering was primarily controlled by soil temperature regardless of air temperature or photoperiod. However, a higher % of flowering shoots were associated with higher root and rhizome dry weights, which were promoted when soil and air temperatures were 13^{o}C and the night period was interrupted.

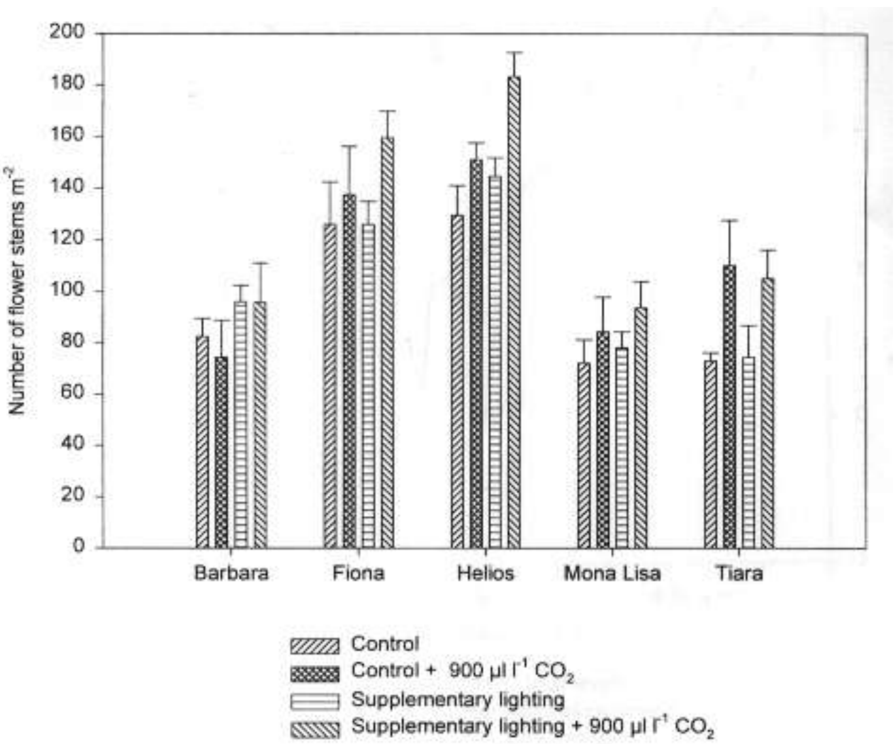
7.7 Supplementary lighting and CO_2

As with soil cooling, trials with supplementary lighting often incorporate the addition of CO_2. CO_2 enrichment up to 900 ppm alone increased the number of flower stems and stem quality regardless of the use of supplementary lighting (van Labeke & Dambre, 1998). Supplementary lighting alone enhanced both factors to a lower extent than CO_2. The combination of both supplementary lighting and CO_2 enrichment resulted in superior flower production for cvs Fiona, Helios, and Mona Lisa and flower stem quality for Barbara, Fiona, and Mona Lisa (Table 7.3; Figs. 7.6 & 7.7).

Table 7.3. Effect of three CO_2 levels on the mean flower production and the mean flower stem weight of five alstroemeria cultivars (Period: 1 January-30 April 1992, all plants received supplementary lighting). Means followed by the same letter are not significantly different at $P = 0.05$ (Tukey's Test).

	CO_2 setpoint (ppm)	**Barbara**	**Fiona**	**Helios**	**Mona Lisa**	**Tiara**
Number of flower stems m^2	Ambient	55.3b	84.7b	81.3b	33.7a	47.2b
	600	76.0a	91.2b	128.0a	45.6a	63.6a
	900	65.8ab	101.3a	126.4a	56.6a	74.5a
Stem weight (g/100 cm)	Ambient	77.6a	63.5a	72.9a	93.4a	86.1a
	600	81.6a	64.6a	67.4b	88.5ab	81.1a
	900	76.6a	60.0a	67.4b	82.3b	81.7a

Figure 7.6. Influence of supplementary lighting and CO_2 enrichment on the total number of flower stems/m^2 of five varieties. Values represent mean and standard deviation of two growing seasons (source: Van Labeke & Dambre, 1998).



The addition of CO_2 to otherwise non-enhanced production conditions increases production slightly, especially varieties that probably reach maximum rates of photosynthesis at ambient light conditions (e.g. cv. Tiara, Fig. 7.6). If light is enhanced (alone) the plants rarely respond with increased production, as one of the main components of photosynthesis (CO_2) may be limiting. With both enhanced light and CO_2, all varieties responded with increased production, although there is a maximum level attainable, which will vary between varieties.

Figure 7.7. Measured CO_2 concentration (µl/l = ppm), photosynthetic photon flux density PPFD (light intensity, leaf level) and leaf net photosynthesis of cv. Mona Lisa. The supplementary lighting is switched on at 6.50 a.m.

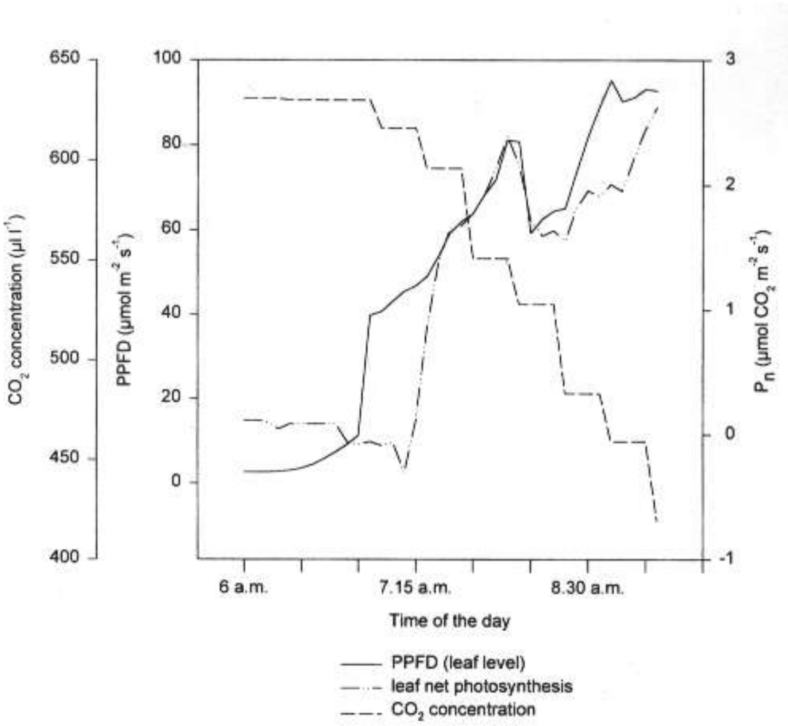


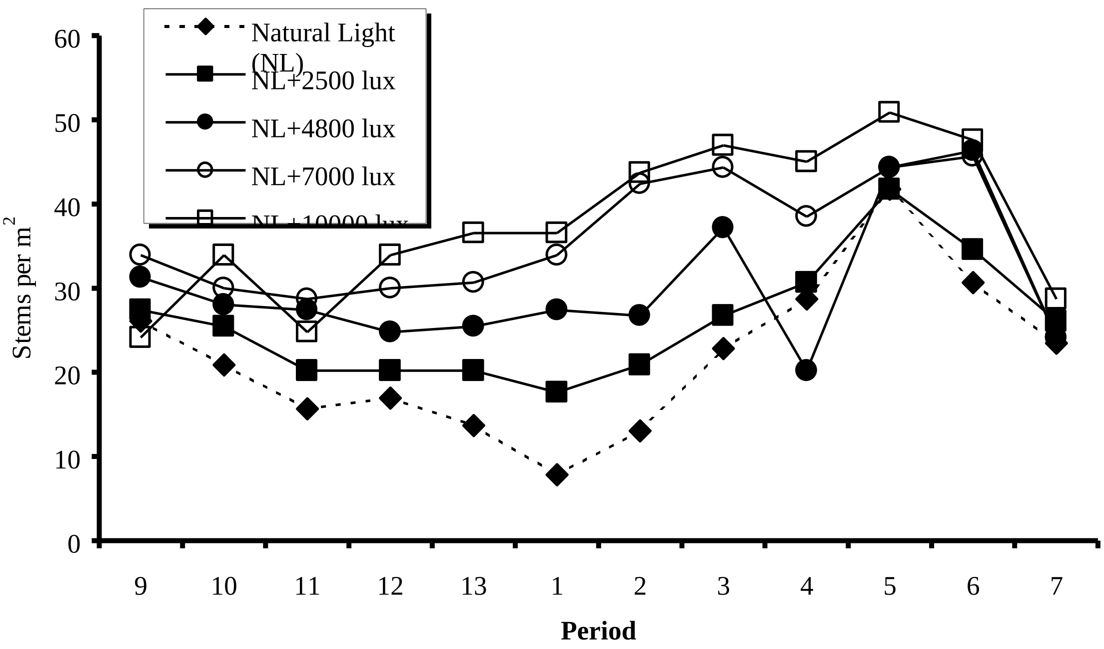
Fig. 7.7 illustrates the flux in light intensity (PPFD), leaf net photosynthesis (Pn) and CO_2 concentration through the morning, highlighting the deficit in CO_2 that occurs early in the day. These data illustrate the challenge of maintaining optimum CO_2 concentrations whilst venting.

Thus, there are clear benefits from maximising the rate of photosynthesis (energy, or carbon gain) and reducing excess respiration at high temperatures (energy or carbon loss), to optimise carbon available for flower production. UK producers can do this by selecting varieties that achieve good production at relatively low light and CO_2 levels, or by improving light and CO_2 through clean glass, leaving waste leaves/stems lying on the ground (to produce CO_2), optimising venting and heating balance, and by installing lights and adding CO_2 to responsive varieties.

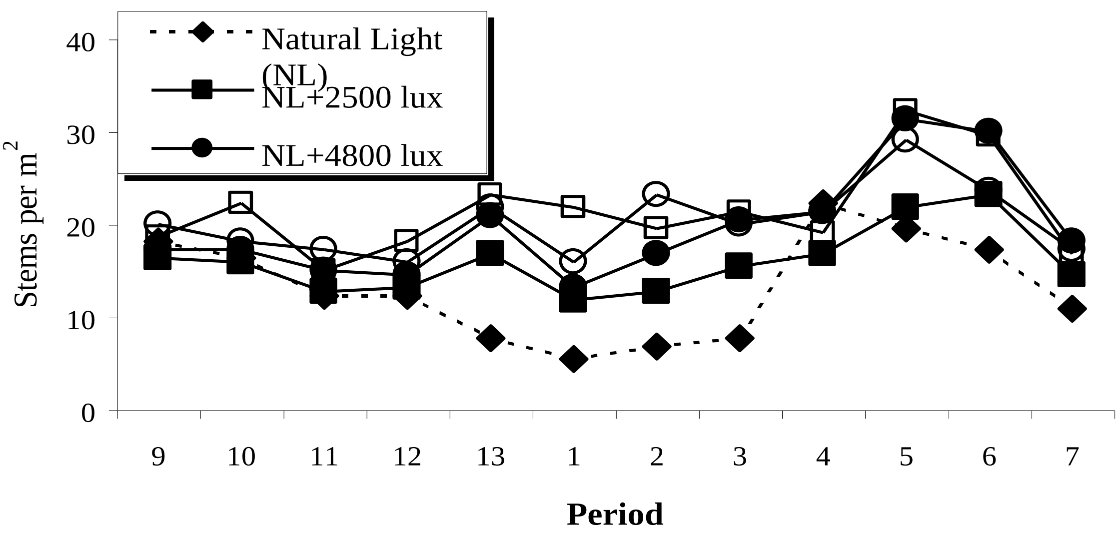
Cultivars Granada, Olga, Jamaica, Fiorella and Flamboya were examined under five different light intensities: natural, natural + 2,500, natural + 4,800, natural + 7,000 and natural + 10,000 lux, with or without additional CO_2 (Fig. 7.8). The results showed increased winter and early spring production (20%) at up to 7,500 or 10,000 Lux, with varietal response differences. Extra light on Olga (Fig. 7.8a) and Granada (Fig. 7.8b) led to increased production at all levels, mainly in the winter months, and early spring.The plants were in a better condition after winter, with additional light. CO_2 further enhanced production and quality: an increase of 10% in stem weight.

Figure 7.8. Effect of assimilation lighting on the flower yield (stems/m^2) of two alstroemeria varieties (periods are months; period 1 = January).

a) Cv Olga

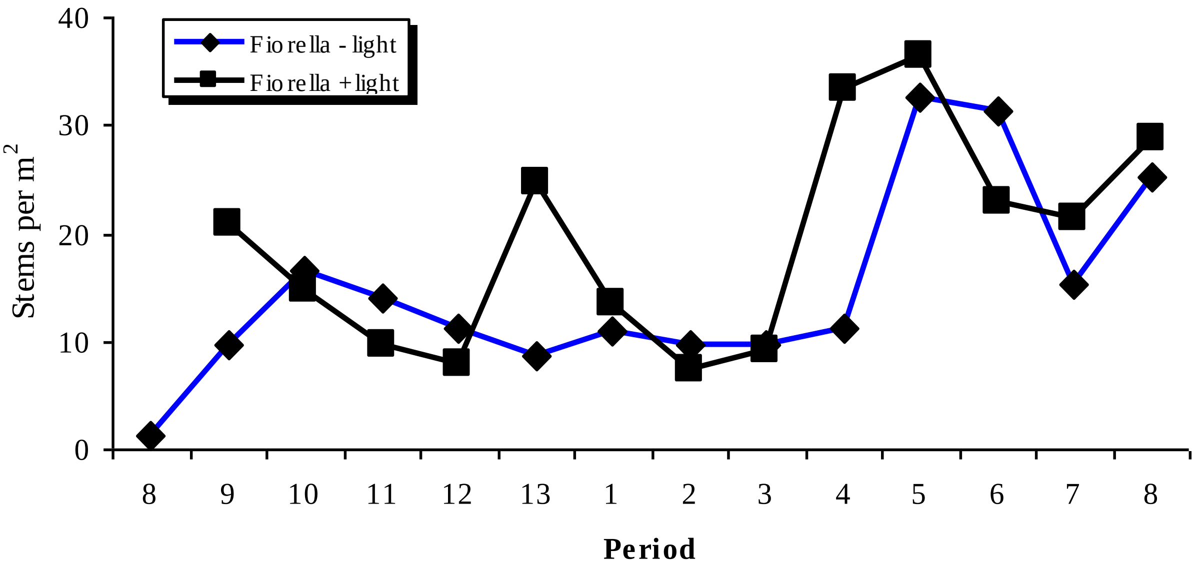


b) cv Granada



A further experiment with Fiorella and Flamboya under ambient light (AL) and AL + 5600 lux showed production was increased by about 20% under light (Fig. 7.9).

Figure 7.9. Effect of assimilation lighting on the flower yield (stems/m2) of cv. Fiorella (periods are months, period 1 = January).



7.8 Dutch practice

In Holland, the area of alstroemeria under lighting has increased significantly in recent years. Now 65% of producers use supplementary lighting. Lighting improves the quality of alstroemeria in winter months, making output more consistent all year round. Lighting also reduces leaf development near blooms which improves the colour impact of alstroemeria in bunches. Although increased light often equates to improved flower production, the financial aspect needs to be considered. Increased light levels may also increase air and soil temperatures, thus deleteriously affecting quality.

7.8.1 Photoperiod

In the Netherlands, supplementary lighting starts in September/October with a 14 h day length (3,000 to 3,500 lux) and ends in February with a 12 h day length. Due to the reduction in shoot formation caused by long days (especially in combination with soil temperatures of 14^oC and lower), lighting is restricted to 12 h in January/February. Maintaining a longer day length will result in insufficient numbers of new shoots in December/January, and less vegetative growth in March/May. The peak in production in spring will also be delayed and reduced. The number of young shoots (up to 10 cm in length) from a sample of plants should be counted every week as a check on crop development.

With more lamps (4,000 + lux) and higher soil temperatures, it is possible to maintain a day length of 16 to even 20 h, although little experience has been acquired with these artificial day lengths. Jamaica, for example, appears very susceptible to problems caused by the combination of a long day created by assimilation lighting and low soil temperatures. After a period of higher production in September to December, maintaining long day lengths and low soil temperatures gives a reduction in production and quality during the January to March period.

7.8.2 Assimilation lighting

Although current practice in the Netherlands is for, on average, an additional 4,000 lux, there is research ongoing on the benefits of increasing light levels to 7,000 lux. Artflor B.V. are studying the effect of this on the varieties Napoli and Fuego. Thus far the vegetation of Napoli has not been significantly altered, whilst Fuego underwent rapid initial growth with long stems; this has moderated since week 6, 2002 (Table 7.4, Plate 7.1).

Table 7.4. Effect of assimilation lighting on stem number per m² between weeks 1 and 12, 2002.

Variety	**Stems/m^2 4,000 lux**	**Stems/m^2 7,000 lux**	**Percent increase (7,000 lux vs 4,000 lux**	**Increased stems per m^2**
Napoli	79.2	100.6	+27%	21.4
Fuego	51.4	66.8	+30%	15.4

Plate 7.1. Trials with lighting at Könst alstroemeria, the Netherlands.

When using supplementary lamps, it is important to ensure that the soil temperature does not drop below 14-15°C in the winter. This is especially crucial when the day length is more than 14 h per day. With soil cooling and lighting, some varieties perform better with a warmer soil temperature (15-17°C) for several weeks in September. The warmth helps the plant develop a stronger rhizome. The formation of the rhizome in weeks 36-40 is important, because it forms the basis for the shoot production in week 50 and the weeks to follow. This is the case for varieties such as Jamaica, Santana and Napoli and possibly for many others as well. It is unknown what the effect of a higher soil temperature in September has on varieties which easily form blind shoots.

A huge difference in heating and air temperature occurs among growers with and without supplementary lighting during the season. Those without supplementary lighting will heat less and the temperature in the air will be lowered to approximately 12-13°C; where lamps are used, temperatures will be 2-3°C higher.

The Dutch growers with supplementary lights even use these to maintain day lengths of 16-17 h per day. Most growers have stepped back from lighting with a maximum of 4,000 lux for 18 or more hours a day, which was a normal practice in 2001. This is because the longer day did not significantly improve quality of winter production. It seems that a day length of more than 16 h for the duration of several months, improves the production until January but that the quality in subsequent months suffers. This is definitely the case when the soil temperature is lower than 14^{o}C for several weeks during the winter. For example, cv. Jamaica cannot tolerate day lengths longer than 13-14 h in October and November. Jamaica produces fewer newer new shoots under these conditions. Thus, the quality and production in January will be reduced.

There are obviously extreme differences between varieties. In general, a crop with a high production of new shoots (more than 20 new shoots per 10 plants a week) can thrive better with additional lighting than a crop that is poorly producing. It is therefore recommended by breeders, that growers section off a test area of 10 plants per variety to closely control and monitor the generation of the new shoots.

7.9 UK practice.

Only some UK growers use supplementary (≥ 2,500 lux) or photoperiodic lighting to maintain winter production.

Plate 7.2. Alstroemeria production in polytunnels in the UK.

Plate 7.3. Alstroemeria production in glasshouses in the UK.

7.10 UK research

There has been no UK research on the effects of supplementary lighting on alstroemeria production. Two documents have been produced on behalf of The HDC on the subject: 'Supplementary lighting: A grower guide', and an evaluation of the efficiency of production of winter pot chrysanthemums at two levels of supplementary lighting (HDC Project PC 92d). These documents should be consulted for further information.

7.11 Economics of supplementary lighting

Supplementary lighting has to be cost-effective for a grower using it to stay in business. Accordingly, all lighting treatments used in HDC-funded trials since 1991/92 (PC 13b) have been costed. This section outlines the procedures that have been followed to do this, and attempts to provide a framework to enable any given lighting regime to be costed. Actual costs of a given treatment will inevitably vary from grower to grower since installation charges, the costs of borrowing money and electricity costs vary widely.

Costings given in this section assume continuous lighting during the daily lighting period and make no allowance, for example, for switching off when the solar radiation reaches some specific value. Continuous daily lighting has been the practice in all HDC-funded trials as the most cost-effective way of exploiting an expensive, but essential, capital asset. Running costs will be reduced if lights are switched off for periods during the lighting season, but this will inevitably diminish the benefits of supplementary lighting unless deleterious effects on production from a prolonged photoperiod ensue.

7.11.1 Supplementary lighting: running costs

Running costs per unit area for a given level of irradiance depends on:

a. the area lit by a single 400 W or 600 W SON/T lamp (m^2/lamp) = A (see Table 7.5)
b. the electrical energy used in 'burning' the lamp (kWh/week) = B (see Table 7.6)
c. the cost of electrical energy (pence/kWh) = C (5.50 pence per kWh)
   Running costs (pence/m^2/week) are calculated as (1/A) x B x C.

Table 7.5. Glasshouse area lit by a single SON/T lamp for a range of irradiances (m^2/lamp).

Irradiance	400W SON/T lamp	600W SON/T lamp
4.8 W/m^2 (2,000 lux)	22.5	-
7.2 W/m^2 (2,000 lux)	15.0	24.3
9.6 W/m^2 (2,000 lux)	11.2	18.2
12.0 W/m^2 (2,000 lux)	9.0	14.6

Table 7.6. Estimated annual and weekly capital costs of installing lighting.

	Lamp Wattage			
	400W SON/T lamp		**600W SON/T lamp**	
Irradiance W/m^2	**£/m^2/year**	**Pence/m^2/week**	**£/m^2/year**	**Pence/m^2/week**
4.8	1.66	3.20	-	-
7.2	2.50	4.80	1.54	2.96
9.6	3.34	6.43	2.06	3.96
12.0	4.16	8.00	2.56	4.93

600W and 400V lamps are now available which use 25% less energy and produce more photosynthetically active radiation per unit cost.

7.11.2 Capital costs on a unit area basis

Lighting installation costs vary greatly, depending on factors such as the area to be lit, electrical supply issues and the wattage of the lamps chosen. For the sake of illustration, however, a cost of £150 per lamp (installed) has been assumed. Amortizing this cost weekly over 5 years at 9 % annual interest gives an annual cost per lamp of £37.44 (Amortization calculator, http://ray.met.fsu.edu/~bret/amortize.html). Dividing this figure by glasshouse area per lamp (see Table 7.5) gives capital costs (£/m^2/year) as shown in Table 7.6. Capital costs are also given in pence/m^2/week.

There is a clear financial incentive to install 600 W lamps, but the proviso is that there has to be sufficient headroom to enable this.

7.11.3 Contribution of lamps to glasshouse heating costs

Only about 27% of the 453 W of electrical energy required to light a 400 W SON/T lamp is actually converted to light (PAR). The larger part, about 330 W (or 0.33 kW) of electrical energy is actually dissipated as heat into the glasshouse, and this reduces the glasshouse heating demand in winter. The comparable figure for heat generation from a 600 W lamp is about 450 W (or 0.45 kW), a slightly smaller proportional contribution to heating costs because these lamps are more efficient at converting electrical energy into light. These heat savings need to be taken into account in arriving at 'true' running costs. As a rule of thumb, it is generally accepted that there is a gain of as much as 1°C for each 2.4 W/m^2. The costs of this calculated on the basis of oil or gas as the heating fuel are given in the fuel document.

7.11.4 Economics of Supplementary lighting

The costs of lighting calculated above take no account of additional alstroemeria flowers produced over the year as a whole as a consequence of less blind shoots developing. This has to be taken into account when overall benefits of lighting are assessed. Given the variability in variety in response to lighting and the large number of different varieties grown, calculations of the cost/benefit analysis for alstroemeria have not been undertaken.

The HDC has funded the production of a booklet: 'Supplementary lighting of pot chrysanthemums, a grower guide'. This booklet outlines the calculations required to assess the cost of operating supplementary lighting. There are a few studies comparing the economics of supplementary lighting in alstroemeria. For example, cultivated cv. Virginia one year under two lighting regimes:

- 7,000 lux for 20 h
- 3,220 lux for 14 h

The increased light led to an increase in production of 18 shoots/m^2, with an average 3.5 grams/shoot greater weight. The auction price at the time equated to £2.30/m^2. This was not considered worthwhile. In Holland, assimilation lighting, at 4,500 lux/m^2 for 3,300 h/year on a 1 ha nursery, costs £18.63/m^2 to establish and £6.88/m^2

to run. At current prices, this would require an additional 86 shoots/m^2 per year or that the price should be increased by 16 pence each.

In the UK, for 1 ha of glass, lit to 4,000 lux for 15 h a day using 400 W SON/T lamps, the running costs would be:

(1/A) x B x C = pence/m^2/week (see page 122 for definitions of A, B and C)

For example:

(1/11.2) x 47.56 x 5.50 = 23.35 pence/m^2/week or £12.14/m^2 per year

This assumes assimilation lighting is on 12 months of the year for 15 h, which it may not be. It could be used 6-9 months/year, for day extension or set to come on after a critical day light level only. This could potentially halve the cost, and would bring it to similar levels compared with the Dutch.

The UK capital costs would be £3.34 m^2/year (Table 7.6) which appears to be less than that quoted for Holland. However, different calculation methods and assumptions may have been made to arrive at these two figures.

7.12 Summary

- The level of incident photosynthetically active radiation (PAR) on alstroemeria crops under glass may be significantly less than the crop requires for optimum production, especially in winter.
- Alstroemeria in very sensitive to irradiation - both to photoperiod and intensity.
- Alstroemeria is a long day (LD) plant and a daylength of ≥ 13h is required to promote flowering. There are varieties that will yield well under relatively sub-optimal lighting conditions.
- Additional assimilation lighting may increase productivity, depending on the variety. Breeders recommend trials be undertaken by producers before regimens are consolidated in to general practice.
- Further productivity benefits are obtained through assimilation lighting + soil cooling and assimilation lighting + CO_2.

- Productivity improvements include an increase in the number of flowering shoots, an increase in the % of flowering shoots and an increase in the number of cymes per inflorescence.
- Dutch producers routinely use 4,000 lux for 13-14 h, with 500 ppm CO_2. There may be benefits for increased light levels beyond this, but no cost:benefit analysis has been done.
- Additional benefits of HID lighting (assimilation lighting) are reduced heating costs (gain of 1°C/2.4 W/m²).
- Substantial UK research has investigated the economics of supplementary lighting; 600W lamps are preferred over 400W lamps.
- For a given lighting regime, UK running costs are approximately twice that for a similar situation in Holland although in reality common sense practice and the better light levels in Southern England would reduce the costs.
- There is a need to assess the incident PAR levels throughout the year under glass and to assess the cost:benefit of supplementary lighting in various situations in the absence of CO_2 and soil cooling .

8. CARBON DIOXIDE ENRICHMENT

8.1 Background

Carbon dioxide is a requirement for photosynthesis. As the quantity of CO_2 captured by plants increases, it exceeds the quantity lost by respiration, and thus energy is available for growth, development and storage.

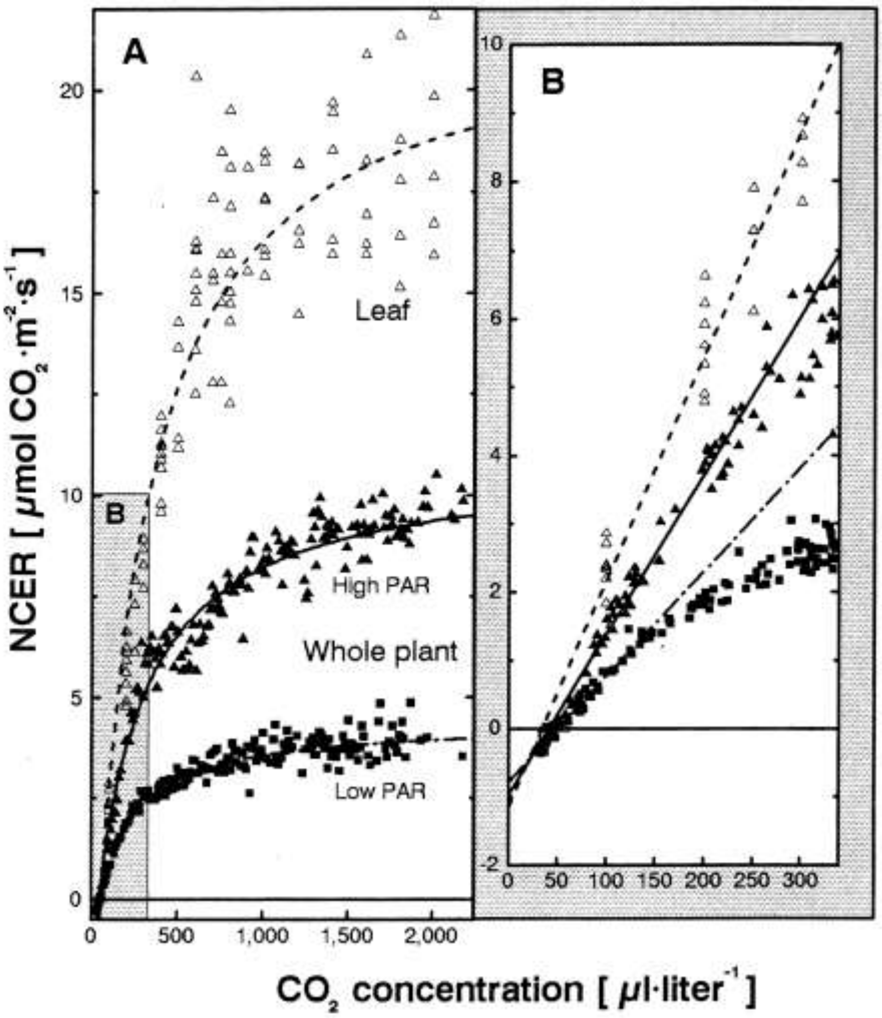
Under conditions of high growth rates (as is the aim with supplementary lighting), optimum fertilization, irrigation and soil cooling, CO_2 availability may limit alstroemeria production. Nowadays, all producers in The Netherlands supplement alstroemeria with CO_2, aiming for approximately 500 ppm (parts per million) in summer, despite venting. Although research has been undertaken on specific varieties, there is a general principle that yield will be increased by 10-15% in all varieties with additional CO_2.

8.2 Scientific information

Since the early l990s, research has been undertaken on the effects of CO_2 enrichment on the production of alstroemeria. Few (if any) of surveyed producers in the UK supplement with CO_2.

Under ambient CO_2 (350 ppm), whole-plant photosynthesis was saturated at 260 Watts per m^2 (Leonardos *et al*., l994). When the CO_2 content was increased to 1,500-2,000 ppm CO_2, whole plant net carbon exchange rate (NCER) doubled (Fig. 8.1). NCER declined above 12°C, due to high respiratory rates.

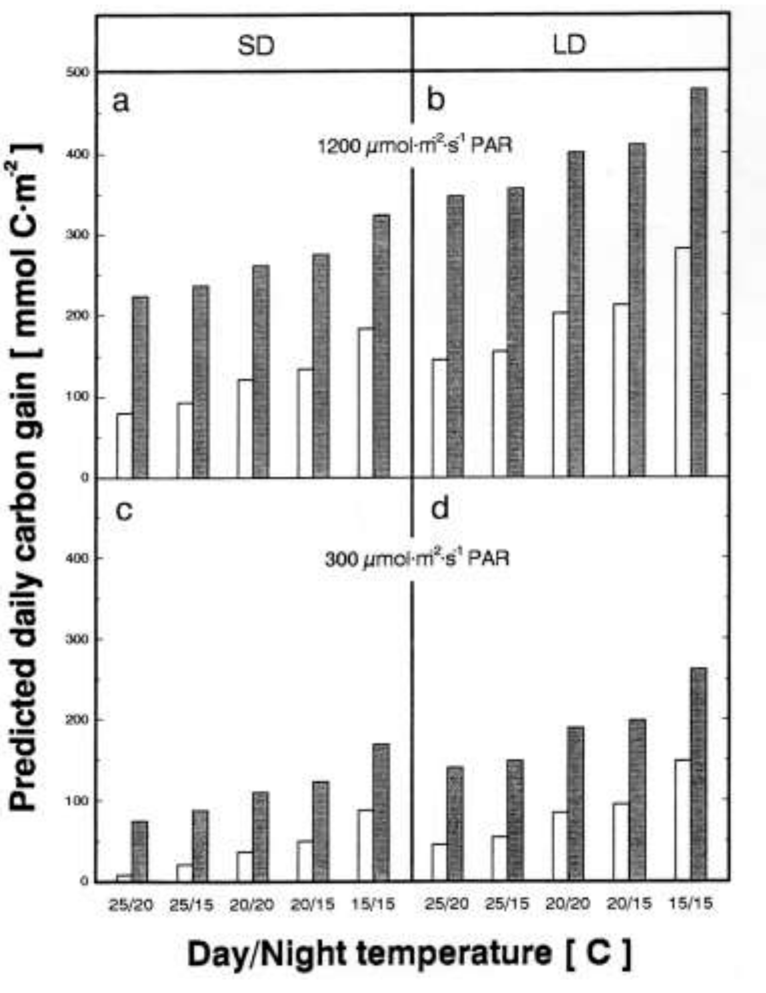
Figure 8.1. Effect of CO_2 concentration on net carbon exchange rate (NCER) on alstroemeria leaf (unfilled triangle) and whole plant (filled triangles at high PAR; and whole plant at low PAR (filled squares) at 18°C. The shaded area in A, (appearing as a larger scale in B) shows NCERs below ambient CO_2 concentrations. (from Leonardos *et al*., 1994).



Note that 1000 ***μ***l. litre^{-1} = 1000 ppm

At ambient CO_2 (approx. 350 ppm), the increased energy captured by alstroemeria plants (as measured by NCER) at higher light intensities is clearly demonstrated (Figure 8.1). These benefits are even greater with both additional CO_2 and light. For example, Leonardos *et al*. (1994) predicted the daily carbon gain at different day and night temperatures with two light levels under short day and long day photoperiods for the cv. Jacqueline. The data clearly demonstrated the benefits of additional CO_2 when the crop was grown at constant 15°C with a long day regime (Fig. 8.2).

Figure 8.2. Predicted daily carbon gain at several day and night temperature regimes for alstroemeria cv. Jacqueline. At ambient (unshaded bars) and saturated CO_2 levels (shaded bars). Reproduced from Leonardos *et al.*, (1994).



CO_2 enrichment increased the number of total and flowering shoots in four out of five varieties studied by van Labeke & Dambre (1998). There were variable effects on stem weight and small (or negligible) effects on the flowering percent, number of cymes/inflorescence and stem weight (Table 8.1).

Table 8.1. Main effects of CO_2 enrichment on mean production per m^2 and flower stem quality in five alstroemeria cultivars. The data are means for the two light levels and the two growing seasons for the period November-April.

Means followed by a different letter within columns are significantly different at *P* =0.05 (Tukey's test). Data from van Labeke & Dambre (l998)

Cultivar	CO_2 enrichment	Total shoot Production (m^2)	Total number of flower stems (m^2)	Flowering percentage	Average stem weight (g/100 cm)	No. of cymes per inflorescence
Barbara	-	120.3a	89.2a	74.3a	67.4b	5.3b
	+	120.2a	85.0a	70.8a	70.6a	5.4a
Fiona	-	254.2b	125.9b	50.0a	49.5a	4.3a
	+	299.0a	148.5a	50.5a	50.6a	4.3a
Helios	-	171.7b	137.1b	79.9a	57.2a	3.7a
	+	216.8a	167.2a	77.3a	56.2a	3.8a
Mona Lisa	-	205.8b	75.1b	36.5a	62.2b	4.9b
	+	235.3a	89.0a	38.2a	63.7a	5.0a
Tiara	-	134.3b	73.6b	56.8a	61.5a	4.7b
	+	180.5a	107.5a	60.0a	62.3a	4.8a

Supplementation with 600 ppm CO_2 was sufficient for the yield improvement observed in all varieties except Fiona, which continued to improve with 900 ppm.

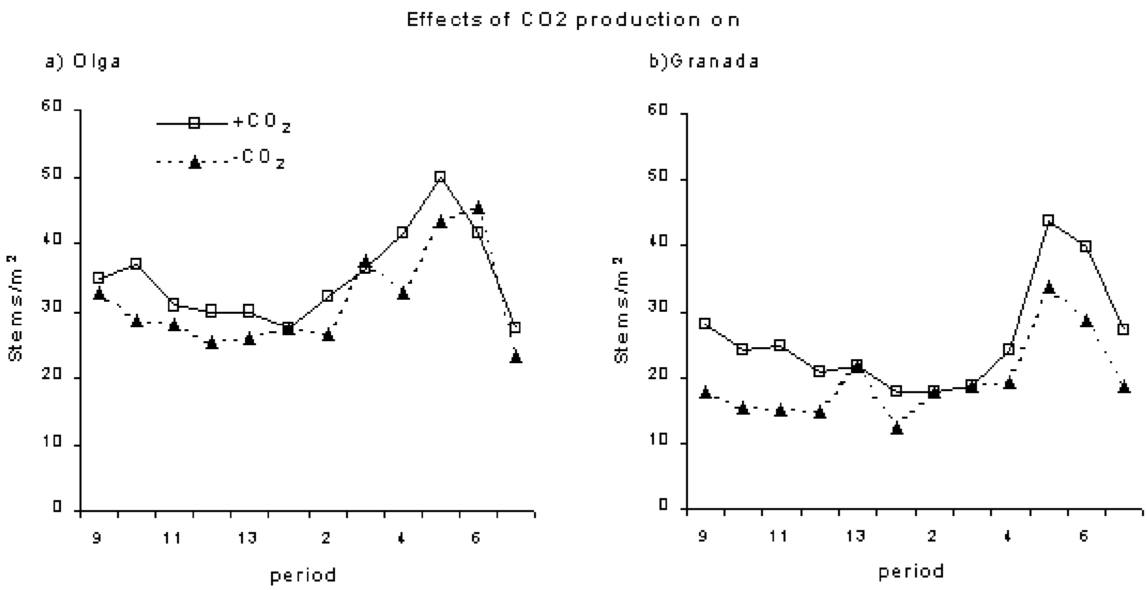
8.3 Dutch recommendations

All large Dutch producers supplement their alstroemeria crop with CO_2 (Plate 8.1). Standard recommendations are to aim for 350–500 ppm in summer (windows/vents 20% open) and 600-800 ppm in winter. Higher concentrations are not harmful to plants, but are not effective.

Plate 8.1. Soft pipe delivering CO_2 into an alstroemeria crop

The increase in production with CO_2 supplementation occurs throughout the year (Fig. 8.3), and can also result in an increase in stem weight of 4-8%.

Figure 8.3. Effect of CO_2 enrichment on the yield (stems/m2) of two alstroemeria cultivars (data from Royal Van Zanten).



Dutch producers supplement CO_2 by means of a:

- a central measuring system;
- a number of CO_2 heaters in the greenhouse;
- a system of thin hoses for administering pure CO_2.

8.4 Sources of CO_2

In the UK, glasshouse CO_2 enrichment is usually achieved by burning hydrocarbon fuel (natural gas, kerosene or propane) or injecting pure CO_2 gas from a bulk tank (the burning of hydrocarbons may raise the glasshouse air temperature by 2-3°C, which may be undesirable for alstroemeria in the summer). In recent years, the introduction of small Combined Heat and Power (CHP) units has had an impact on CO_2 provision .

Propane burners are now little used, due to the relatively low CO_2 output, the high cost of the fuel and the risk from crop damage from leaking pipework. Kerosene burners tend to be larger, but can cause physical damage to the crop if incorrectly placed. The sulphur content of some grades of kerosene may also be unacceptably high resulting in crop damage. A list of 'acceptable' levels of aerial pollutants is given in Table 8.2. There is no direct information available relating to levels tolerated by alstroemeria

Table 8.2. Thresholds limits for aerial pollutants produced by kerosene combustion.

Pollutant gas	**Threshold (vpm)**	**Comments**
Propylene (C_3H_6)	<5	Can be smelt at over 50 vpm.
Sulphur dioxide (SO_2)	<0.05	
Carbon monoxide (CO)	<20	Over 50 vpm it is harmful to humans. No smell.
Oxides of nitrogen (NOX)	<0.1	Chrysanthemum and some pot plants are tolerant to NOX.
Nitrogen dioxide (NO_2)	<0.05	
Ethylene (C_2H_4)	<0.01	Prevents bud initiation in chrysanthemum.
	<0.05	Most other ornamentals (carnations, orchids and Antirrhinum are unaffected).

Many bulk CO_2 storage tanks were installed on nurseries in the 1980s, but the gas tank requires refrigeration. Distribution in the glasshouse is via small-bore rigid plastic tubing or layflat tubes. Tank purchase and upkeep can be costly, and the preference for pure CO_2 in bulk has been superseded by the use of natural gas as a source.

Natural gas is a relatively pollutant-free source of CO_2 for enrichment, although safety checks on the flue gases, especially for carbon monoxide, must be in place. Incomplete combustion from badly maintained burners may give rise to unwanted levels of ethylene or oxides of nitrogen (NOX). Whether from a boiler flue or a CHP unit, combustion products must be diluted with air, and preferably cooled before being distributed in the glasshouse. Because of the high volumes of blended air and CO_2, large diameter rigid plastic nursery distribution mains are needed, together with moderately-sized flexible plastic pipework within the glasshouse.

Whichever CO_2 production system is used (apart from pure CO_2 supply), the combustion products will also contain water. This may cause condensation problems in the distribution system, or increase relative humidity in the glasshouse environment.

The use of gas systems for glasshouse heating has enabled larger quantities of CO_2 to be introduced, even when ventilation levels are significant, as the gas is largely a bi-product of heat generation. Although CO_2 levels of up to 1500 ppm have been successful with other crops, particularly glasshouse salads, there is very little experience of high CO_2 levels for alstroemeria in the UK. There is a possibility of using moderate CO_2 levels in combination with ventilation or shading to reduce air temperatures during the summer. However, unless the heat produced by burning gas could be stored (e.g. in buffer or 'dump' tanks) or utilised elsewhere on the nursery, it could prove costly. Much depends on the price of gas in determining whether enrichment would be an economic proposition.

8.5 Summary

- With enhanced control over environmental conditions in the form of soil and air temperature, supplementary lighting and optimum fertigation, CO_2 would be limiting for alstroemeria production in the UK.
- Almost all Dutch producers use supplementary CO_2 to 500 ppm, combined with supplementary lighting, benefiting from a 10-15% productivity increase across all varieties.
- It is suggested that research be undertaken to assess the efficiency of photosynthesis *in situ* on various sites in the UK, which have better light than Holland, to assess the need for supplementary CO_2. For those producers who have supplementary lighting, the need will similarly need to be assessed.

9. PESTS AND DISEASES

9.1 Fungal pathogens

A range of fungal pathogens have been reported to cause disease on alstroemeria in the UK (Baker, 1972; C. Lane, CSL; C. Prior, RHS Wisley; T. O'Neill, ADAS; & T. Pettitt, HRI Wellesbourne, pers. comm). The principle diseases recorded are given in Table 9.1.

Table 9.1. Pathogens known to affect alstroemeria.

Pathogen	**Disease or symptom type**
Helicobasidium brebissonii (formerly *H. purpureum*)	Violet root rot
Phytophthora sp.	Foot rot
Botrytis sp.	Leaf and flower spotting
Thanatephorus cucumeris (*Rhizoctonia solani*)	Stem rot, plant collapse, damping off
Pythium sp.	Root rot
Colletotrichum sp. (1 report only)	Plant collapse

Growers in the UK are generally in agreement that fungal diseases are not a major constraint to alstroemeria production. Of the pathogens listed above, however, root rots caused by *Rhizoctonia*, *Phytophthora* and *Pythium* are considered the most problematic. Root rots caused by *Sclerotium rolfsii* (not established in the UK) and a pathogen complex (*Fusarium oxysporum*, *Pythium ultimum* and *Rhizoctonia solani*) on alstroemeria have also been reported in Canada (Chang *et al*., 1993; Chang & Mirza, 1994).

9.1.1 Cultural practices to manage fungal diseases

Fungal diseases on alstroemeria can generally be managed at economically acceptable levels using the following cultural practices:

- Soil sterilisation is widely used to eliminate the soil-borne fungal pathogens that cause root and basal rots of alstroemeria. As root infection by fungal pathogens may be facilitated by nematode damage on roots, control of nematodes through soil sterilisation can also help to reduce fungal disease.
- Ensure sanitary procedures are implemented at the time of planting.
- Soils should be well drained and not over-watered to avoid the development of root rots.
- Avoid fluctuations in soil temperature.
- If there is a history of root rot problems, select less susceptible varieties for cultivation.
- Crop and glasshouse hygiene is particularly important for minimising the development of *Botrytis* (Section 9).
- Manipulate environmental conditions (temperature, relative humidity and leaf wetness duration) to minimise *Botrytis* development (Section 9).

9.1.2 Chemical control of fungal diseases

Growers consulted in the UK said that they generally rely on soil sterilisation and management of the glasshouse environment, rather than fungicides, in order to contain disease. Protectant fungicidal drenches on young plants are used but routine fungicide sprays are rarely practised, except in situations where the soil has not been sterilised and/or the grower is aware that glasshouse conditions may be conducive for disease development. Information on fungicide products that can be used safely on alstroemeria is sparse but the general advice is that products should be used with care as the tender young leaves can easily be damaged.

Under the Long Term Arrangements for Extension of Use (2002), any fungicide Approved for use on any protected crop may be used on protected alstroemeria, although the commercial risk is entirely the responsibility of the user. All safety precautions and statutory conditions relating to use (which are clearly identified in the statutory box on the product label) together with any conditions relating to the use of a specific off-label approval, must be observed. Further information can be obtained from the website of the Pesticides Safety Directorate (www.pesticides.gov.uk).

9.1.3 Rhizoctonia solani

Stems of alstroemeria infected with *Rhizoctonia* become rotten at soil level and are constricted at this point. The rotting may spread into the rhizome and if no effective control treatment is applied or if it is delayed, the plants exhibit retarded growth and may take six months or more to recover. The disease may occur on a localised basis and the first symptoms are usually observed after the dormant period, particularly in young plants. Orchid varieties are particularly susceptible to *Rhizoctonia* and it is also reported that root damage by the nematode species *Pratylenchus bolivianus* and *P. penetrans* may facilitate entry of soil-borne pathogens such as *Rhizoctonia*. No information on which anastomosis groups (AG) of *R. solani* are pathogenic on alstroemeria is available.

9.1.3.1 Cultural control

R. solani is a soil-borne pathogen and so soil sterilisation (Section 7) is an important preventative measure. The disease mainly occurs under warm and moist conditions and substantial fluctuations in soil temperature may encourage spread. If hot weather is anticipated in spring and summer, temperature may be kept under control by ventilating or installing a screen.

9.1.3.2 Chemical control

There are few actives now remaining for the control of *Rhizoctonia*. The approval for Terraclor (quintozene) was recently withdrawn. Basilex (tolclofos-methyl) can be used as a drench or a spray, but following the review of anti-cholinesterase compounds, products containing tolclofos-methyl cannot now be applied through hand-held applicators. If symptoms of *Rhizoctonia* are observed, Rovral WP (iprodione) has some eradicant activity against the pathogen. However, if soil sterilisation has not been practised, a single prophylactic spray treatment with Rovral in the spring may be advisable. Ensure that the fungicide penetrates to the stem base.

Amistar (azoxystrobin) has shown good activity against *Rhizoctonia* in some crops (e.g. celery), and although the product now has approval for use on a small number of protected crops (e.g. tomato, SOLA 168/01; celery, SOLA 1041/00), there is no information available on safety to alstroemeria or efficacy against the pathogen at permitted rates.

9.1.4 *Pythium* root rot

This disease is occasional and mainly reported to be a problem during propagation. It can also occur in a mature crop especially under conditions of stress (Plate 9.1). *Pythium* may attack orchid varieties in particular because of rooting difficulties. One UK grower also reported that certain yellow varieties seemed more susceptible to *Pythium* root rot. On plants infected with *Pythium*, the cortex of the roots and rhizome may become glassy in appearance and later rot away, while the vascular cylinder in the roots remains intact. There are no UK records of the species of *Pythium* that are implicated.

Plate 9.1. Alstroemeria infected with *Pythium* sp. (courtesy of T. Pettitt, HRI Wellesbourne).

P. ultimum has been implicated as part of a root rot disease complex of alstroemeria in Canada, co-existing in roots with *Fusarium* spp. and *Rhizoctonia solani* (Chang *et al*., 1993). Diseased plants showed symptoms of dark brown stripes along leaf margins, leaf chlorosis, plant wilting, browning or rotting of basal stem, rhizome, and storage and fibrous roots. Pathogenicity tests with *P. ultimum* showed that the inner tissues of rhizomes inoculated with the pathogen turned brown and appeared water-soaked and the rotten tissues extended into the upper portion of the storage roots. Under very wet conditions, mycelia occasionally appeared on the root surface.

9.1.4.1 Cultural control

As for other root rot pathogens, soil sterilisation is an important method for control of *Pythium* spp. While little information is available on cultural practices to control *Pythium* on alstroemeria, HDC-funded work on AYR chrysanthemums (Projects PC 97a and PC 157) showed that in unsteamed, contaminated soil, the moisture status greatly influenced disease severity; the wetter the soil, the more severe the root rot (HDC, 2001). Results also showed that two 'growth promoter' products had potential for delaying post-sterilisation re-colonisation of soil by *Pythium* spp. Soil treatments with either GlioMix (a powder formulation of dried *Gliocladium* spores) or Agralan Revive (a liquid formulation of *Bacillus subtilis*) immediately following steam sterilisation were effective in excluding pathogenic *Pythium* propagules for more than 70 days.

9.1.4.2 Chemical control

Fungicide drenches at or immediately prior to planting may be effective in reducing *Pythium* root rot. Products with known activity against *Pythium* and that are used by some UK growers with no reported problems of crop damage include:

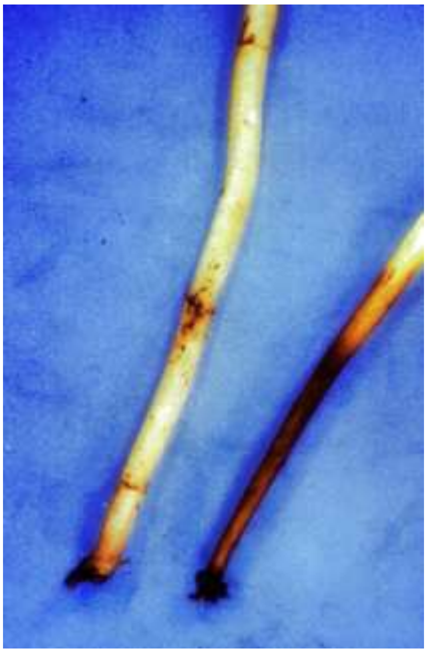
- Aaterra WP (etridiazole);
- Filex and Proplant (propamocarb hydrochloride);
- Fongarid (furalaxyl) (N.B. fungal resistance to furalaxyl has been reported).

Aliette (fosetyl aluminium) should also be effective but no grower experience of its use was encountered.

9.1.5 Phytophthora foot rot

There have been occasional reports of alstroemeria foot rot caused by *Phytophthora* sp. (Plate 9.2). Like *Pythium*, *Phytophthora* is a soil-borne oomycete fungus. Disease development is favoured by waterlogged or poorly drained soils, and warm temperatures. Cultural practices and chemical control described for *Pythium* are also relevant to *Phytophthora* sp.

Plate 9.2. Symptoms of *Phytophthora* foot rot on alstroemeria
(courtesy of T. O'Neill, ADAS)



9.1.6 Botrytis sp.

Botrytis is capable of attacking plants at almost any stage in their growth and of affecting all plant parts. The disease appears initially as a white growth but soon darkens to grey as dispersal spores (conidia) are formed. On alstroemeria, small brown spots on leaves and flowers are the most common symptoms, but if environmental conditions are conducive for pathogen development, then damage such as leaf rot, stem dieback and plant collapse may occur. Affected tissues often develop a characteristic furry, grey-brown mass of spores. The disease is reported to be more problematic on varieties of the orchid group, particularly after leaf tip scorch. *Botrytis* can attack crops throughout the year but is most common in cool humid conditions, when air-flow is restricted by a thick canopy. While literature describing the biology and control of *Botrytis* specifically on alstroemeria is limited, recent HortLink studies (DEFRA project HL0107; HDC project PC/HNS 121) have provided useful information on *Botrytis* management in glasshouses (O'Neill *et al*., 2002).

Conidia, produced in high numbers on affected tissues, are spread by air currents or splashing water. The spores can germinate and invade plant tissue immediately or may remain dormant on plant surfaces for about three weeks. Germination and infection are favoured by high humidity (>95 %) but can occur over a wide range of temperatures (5-25^{o}C). Once infection has occurred, symptoms may develop within hours, or the infection may remain dormant and symptomless (latent infection) until it becomes active days or even weeks later. *Botrytis* is a relatively weak pathogen and generally needs a food source before it can invade healthy tissues, other than flowers. In addition to conidia, infection may arise from fungal strands (hyphae) growing, for example from infected flowers or leaves that have fallen onto healthy tissue.

9.1.6.1 Cultural control

Implementation of good nursery hygiene, crop cultural practices and the prevention of prolonged high humidity are key practices in managing *Botrytis* and can also increase the efficiency of fungicide treatment. Glasshouse hygiene (e.g. removal of weak, thin and blind shoots) is important because the fungus survives in and sporulates on plant debris and the stubble from cut stems. When routine shoot removal is carried out, stems should be cleared up immediately. Careful plant and flower handling is required to avoid damaging plant tissues. Plants that are severely affected with *Botrytis* should be disposed of into covered bins or skips, taking care not to spread the spores. Periods of high humidity (>95%) for more than 3 h and prolonged leaf wetness can increase the risk of *Botrytis* infection and should be avoided, for example, using appropriate heating, venting and watering regimes. When monitoring for the disease, check especially leaves growing close to the soil surface and plants in areas of the glasshouse where air-movement is poor.

9.1.6.2 Chemical control

Fungicide sprays are a valuable tool for *Botrytis* control and a preventative spray programme may be of importance for susceptible varieties. With respect to crop safety, it is reported that Rovral (iprodione) can cause fading in red flowers if applied too heavily.

Fungicides recommended for *Botrytis* control on other crops include Scala (pyrimethanil), Bravo 500 (chlorothalonil), Amistar (azoxystrobin), Frupica (meponipyrim) and Rovral WP (iprodione). Resistance has been confirmed in *B. cinerea* to carbendazim (Bavistin DF) and iprodione (Rovral WP). Recent trials on various pot plants have found good results with Scala and Frupica. There have also been isolated reports of resistance to Elvaron WG (dichlofluanid). Where resistant isolates are present, treatment will provide little or no disease control.

9.1.6.3 Prevention of fungicide resistance in Botrytis

The following measures are recommended to reduce the risk of resistance development:

- Only use fungicides when needed;
- Use no more than two sprays of the same fungicide, or fungicide group, in sequence, then use a completely different fungicide group;
- Use no more than 50 % of the total sprays of the same fungicide, or fungicide group, per crop;
- Follow the label recommendations carefully and keep to the manufacturer's recommended dose rate;
- Do not rely on fungicides alone for disease control.

9.1.7 Violet root rot (Helicobasidium brebissonii)

This disease was first reported in 1959 on *Alstroemeria aurantiaca* imported from Holland. The disease can result in stems becoming dried and withered and the plants failing to grow successfully. Decaying roots may show the violet colouration, fungal hyphae and sclerotial structures typical of the disease. *H. brebissonii* is a soil-borne pathogen which can survive in the soil as sclerotia (long-term fungal survival structures) for up to 15 years. Although the disease is not particularly infectious or rapid in its spread, it is widely distributed and has many hosts, including sugar beet, potatoes and parsnip. There is no specific fungicide treatment for violet root rot so, if the disease is suspected, then the soil should be sterilised or an alternative site should be found.

9.1.8 Sclerotium rolfsii

S. rolfsii was isolated from diseased rhizomes of greenhouse grown alstroemeria in Canada in 1992 (Chang & Mirza, 1994). The underground portions of the plants were attacked, resulting in leaf chlorosis that started on the lower leaves and gradually moved upwards. The pathogen attacked mainly the underground parts of alstroemeria including basal stems, rhizomes, roots and storage roots, resulting in leaves and flowers that were smaller than normal. Leaves on the upper portion of the stem were often twisted and curled inward from the margin. Infection on the stem was limited to the basal portion connected to the rhizome 1-2 cm below the ground. White mycelium and dark brown sclerotia developed on the underground portion of the plant. It was noted that because of the wide host range of the pathogen, the suitability of greenhouse conditions for its establishment and the persistence of sclerotia in the growing medium and decaying debris, *S. rolfsii* has the potential to seriously affect the greenhouse tropical and subtropical plant industry in Canada. This fungus is not established in the UK although it has occasionally been intercepted, for example on imported onions and ornithogalum.

9.1.9 Viruses

Virus diseases appear to be the most important pathological problem for alstroemeria cultivation. Viruses infecting alstroemeria have been described in Denmark, the UK, the Netherlands and Italy. Table 9.2 shows the viruses that have been found in alstroemeria in Europe. The symptoms associated with virus presence can affect leaves (malformation, chlorosis, yellow flecks, mosaic, mottle, chlorotic and necrotic ringspots) and flowers (deformation, colour-breaking and stripes on petals). While various symptoms of virus infection affecting plant quality have been described, there are no reports available in which the effects of viruses on alstroemeria yield have been quantified.

The most recent survey of viruses infecting alstroemeria in the UK was done in 2000 (Spence *et al*,. 2000). A total of 203 alstroemeria samples including many varieties, were collected from protected crops and from an outdoor field trial, with the majority produced by vegetative propagation. Alstroemeria mosaic virus (AlMV) (Plate 31) and closely related strains of Alstroemeria streak virus (ASV), Alstroemeria carlavirus (AlCV), lily symptomless virus (LSV), Cucumber mosaic virus (CMV), and Tobacco rattle virus (TRV) were detected singly or in combination in 67.5 % of samples. The majority of samples in which virus was detected were infected by at least one potyvirus, with AlMV being the most common (reflecting results from surveys in other European countries). Some infected plants were symptomless but more usually there was a mild leaf streak; a chlorotic streak was often associated with CMV.

Plate 9.3. Symptoms of Alstroemeria Mosaic Virus (AlMV).

In UK surveys reported in 2000 and 1986 (Phillips & Brunt, 1986; Spence *et al*., 2000), the tospovirus Tomato spotted wilt virus (TSWV) was not detected, despite reports of the virus in alstroemeria in other European countries. More recently, TSWV has been confirmed in the UK crop with severe leaf symptoms on alstroemeria including necrotic rings (elliptical in shape as typically found in monocotyledons), lines and spots (I. Barker, CSL York, pers. comm.). In Italy, it was reported that alstroemeria plants infected with TSWV showed yellow ringspots (Bellardi *et al*., 1994). Symptom differences could be due to cultivar, environmental conditions, or the developmental stage of the symptoms observed. The related tospovirus, Impatiens necrotic spot virus (INSV), has not been confirmed on alstroemeria in the UK. However, the virus has been detected on the crop in other European countries and is known to be becoming more prevalent on other ornamental hosts in the UK (Bennison *et al*., 2001). Western flower thrips (WFT) is an important vector of the tospoviruses TSWV and INSV.

Table 9.2. Viruses detected in alstroemeria in Europe. *Viruses detected in alstroemeria in the UK.

Virus	Virus group	Details
Alstroemeria mosaic virus (AlMV)*	Potyviruses	Most widespread virus, transmitted by aphids and knife harvesting. Often develops at turn of season (summer/autumn). Produces leaf chlorosis, flower colour breaking and mosaic but sometimes symptomless. • AlMV and ACaV together led to chlorotic leaf mosaic. • AlMV and ArMV led to stunting, malformation and necrotic spots on the leaves. • AlMV and FMV were symptomless or with chlorotic leaves.
Alstroemeria streak virus (ASV)*		Closely related to AlMV
Cucumber mosaic virus (CMV)*		Transmitted by seed and aphids. Can cause yellow mosaic and stunting, often in a period of slow growth.
Tobacco streak virus (TSV)*		Inconspicuous leaf chlorosis.
Lily mottle virus (LMoV)		-
Freesia mosaic virus (FMV)		Inoculated plants showed deformed and faintly chlorotic leaves but symptomless flowers.
Ornithogalum mosaic virus (OrMV)		Dark-green vein banding, necrotic spots and flower colour breaking.
Alstroemeria carla virus (AlCV)	Carlaviruses	AlCV is though to be a host-adapted strain of LSV. Transmission probably by aphids. May be symptomless, or chlorotic mosaic on the leaves and malformed flowers. Also reports of barely visible leaf variegation, plus leaf curling and striping in cool conditions.
Lily symptomless virus (LSV)		Closely related to AlCV. Chlorotic and malformed leaves, and symptomless flowers.
Tomato spotted wilt virus (TSWV)*	Tospoviruses	Transmitted by western flower thrips. Necrotic rings, lines and spots (UK). Yellow ringspots (Italy).
Impatiens necrotic spot virus (INSV)		Closely related to TSWV. Transmitted by western flower thrips.
Tobacco rattle virus (TRV)*	Tobravirus	Concentric marks (‘ringspots’) on the leaves. Malformed leaves. Can be severe. Transmitted in soil by free-living nematodes.
Arabis mosaic virus (ArMV)	Nepovirus	Leaves showed chlorosis and necrotic spots. Stunted flowers had green stripes on the petals. Spread by nematodes.

9.1.9.1 Diagnosis

As a combination of different viruses can occur in alstroemeria, it can be very difficult to attribute specific symptoms to individual viruses by visual examination. For example, it is reported that the combination of CMV with AlMV, AlSV, AlCV or other viruses can induce different symptoms (necrosis, red stripes, yellowing) which could depend upon environmental conditions, alstroemeria cultivar and growth stage at which infection occurs. Virus symptoms may also be confused with those in plants affected by physiological disorders.

Virus identification can be done by specialist laboratory testing. In addition, straight forward on-site diagnosis of TSWV, INSV or CMV can be done by growers or consultants using Pocket Diagnostic™ kits. Further information on these is available from CSL York (Tel. 01904 462328, www.csl.gov.uk). These kits have been shown to give equivalent results to laboratory testing in studies carried out to date.

9.1.9.2 Control

Virus-free seed: reproduction through seed is now usually used only for alstroemeria breeding purposes. It is known that CMV-infected plants can produce infected seeds and that this virus in combination with others can induce severe damage to alstroemeria crops (Bellardi & Bertaccini, 1997). For this reason, virus-tested seed should be used for breeding. No other viruses have been detected in alstroemeria seed.

Vegetatively propagated planting material: as the crop has been propagated vegetatively for many years, it can harbour a high incidence of viruses. The most widespread viruses on alstroemeria (potyviruses including AlMV) can now be eliminated through micro-propagation (meristem tip culture) to produce clean stock. Breeders supply guaranteed virus-free planting material to producers.

Rogueing: plants showing viral symptoms should be removed and destroyed, to minimise the risk of the virus being transmitted to other plants.

Harvesting: certain viruses may be transmitted to other plants on cutting knives at harvest. Periodic knife dipping in disinfectants may help to minimise this method of transmission.

Weeds: weeds may act as hosts for either the viruses or the pests that transmit them and so should be removed.

Control of insect pests: AlMV and other potyviruses can be transmitted by aphids, while tospoviruses such as TSWV and INSV are spread by western flower thrips. Control options for these pests, to help prevent virus transmission, are discussed in Section 9.2.

Control of nematodes: Tobacco rattle virus (TRV) on alstroemeria is transmitted by free-living nematodes in the soil, such as *Trichodorus* sp. Control of this nematode is achieved by soil sterilisation (Section 2.7).

9.2 Pests

The main pests occurring on UK alstroemeria crops are presented in Table 9.3.

Table 9.3. Principle pests recorded on alstroemeria in the UK.

Pest	Common name	Scientific name
Whitefly	glasshouse whitefly	*Trialeurodes vaporariorum*
Aphids	peach-potato aphid	*Myzus persicae*
	glasshouse and potato aphid	*Aulacorthum solani*
	potato aphid	*Macrosiphum euphorbiae*
	melon and cotton aphid	*Aphis gossypii*
	black bean aphid	*Aphis fabae*
Thrips	western flower thrips	*Frankliniella occidentalis*
Spider mite	two-spotted spider mite	*Tetranychus urticae*
Caterpillars	carnation tortrix	*Cacoecimorpha pronubana*
	light brown apple moth	*Epiphyas postvittana*
	diamond-back moth	*Plutella xylostella*
	cabbage moth	*Mamestra brassicae*
Leafhoppers	glasshouse leafhopper	*Hauptidia maroccana*
	green leafhopper	*Empoasca decipiens*
Slugs and snails	species unconfirmed to date	
Nematodes	root lesion nematode	*Pratylenchus bolivianus*

Not all the pests listed in Table 9.3 cause problems on all alstroemeria crops. Pest incidence often depends on the history of pest species and other crops grown on or adjacent to individual nurseries. Further details on each pest and control measures are given below. For each pest, both biological and chemical control measures are given.

Several of the pests occurring on alstroemeria crops are resistant to many of the available pesticides. For this reason, together with increasing retail demands for ornamental produce grown with minimal use of pesticides, biological control within Integrated Pest Management (IPM) programmes should be considered as the first option if practical. Options are given for pesticides that are compatible with biological control agents within IPM, and also for pesticides incompatible with IPM but which may be used in chemical programmes, or as a 'clean-up' before marketing. When using any of the pesticides listed in this report, label or off-label conditions relating to their use must be observed. The pesticides listed in this report are not necessarily proven to be safe to alstroemeria. If in doubt, a few plants should be treated first to check for potential crop damage. When using pesticides, resistance management precautions should be taken i.e. only use if necessary, use recommended rates and frequency of application, and if possible, rotate pesticides from different chemical groups within the programme.

Cultural control can often contribute to reducing pest infestations, e.g. controlling weeds both inside and around the glasshouses will reduce alternative hosts for many pests which can infest alstroemeria.

9.2.1 Whitefly

Glasshouse whitefly, *Trialeurodes vaporariorum* cause damage to alstroemeria by excreting honeydew on to the leaves, which leads to the growth of black sooty moulds. The adults and nymphal stages ('scales') are also contaminants at marketing. Both red and yellow-flowered varieties and also dark-leaved varieties have been reported to be particularly susceptible to the pest.

Plate 9.4. 'Glasshouse whitefly adult'

9.2.1.1 Biological control

As glasshouse whitefly is resistant to many pesticides, biological control is the preferred option. Use of the parasitoid wasp, *Encarsia formosa*, can give effective control as long as temperatures are adequate and release strategies are managed carefully. *E. formosa* can walk or fly at 15ºC but are more active at 18ºC. Weekly releases should be made as soon as temperatures are high enough for a few hours each day, and before any whiteflies are seen on the crop or on yellow sticky traps used for monitoring. If whiteflies are already present, a compatible pesticide should be used to reduce pest numbers before *E. formosa* releases begin. Release rates will depend on whether whiteflies are present and rates may be adjusted according to parasitism levels, determined by regular crop monitoring. Parasitised scales turn from white to black before the adult wasp emerges, whereas 'host-fed' scales i.e. those killed rather than parasitised by the wasps shrivel and turn pale brown.

9.2.1.2 Compatible pesticides within IPM

If necessary, the following pesticides may be used within IPM programmes for control of glasshouse whitefly without serious adverse effects on most biological control agents (consult your IPM adviser for full details of side effects):

- Savona (fatty acids).
- Eradicoat or Majestik (plant and vegetable extracts). Test for oil-tolerance with Eradicoat and avoid treating with Majestik close to sale as it may leave a sticky deposit;

- Applaud (buprofezin). Resistance in UK glasshouse whitefly populations to this insect growth regulator is now widespread (Gorman *et al.*, 2000);
- Nemolt (teflubenzuron). There may be a risk of whitefly resistance to this insect growth regulator, particularly if used repeatedly;
- Nicosoap, No-Fid, XL-All Insecticide, XL Nicotine 95% (nicotine). These products are likely to give only partial control of whitefly;
- Chess (pymetrozine). This antifeedant is recommended for aphid control, but if used at double the label-recommended rate, under SOLA 1428/02 for use on protected peppers and aubergine, the product should give control of whiteflies;
- Calypso (thiacloprid). See SOLA 1818/02 for use on protected crops including ornamentals, for control of various pests including the notifiable pest, tobacco whitefly, *Bemisia tabaci*. The product should also give control of glasshouse whitefly;
- Intercept (imidacloprid). This product, which is in the same pesticide group as thiacloprid, may only be used on potted alstroemeria, applied either as a drench (Intercept 70WG) or incorporated into compost (Intercept 5GR).

9.2.1.3 Additional pesticides - incompatible with IPM

In addition to the compatible pesticides listed above, pyrethroid insecticides e.g. Talstar (bifenthrin) and Decis (deltamethrin) have label recommendations for whitefly control. However, severe whitefly resistance to pyrethroids is widespread and spray residues on the crop are harmful to biological control agents for up to three months.

Further information on glasshouse whitefly, biological and chemical control methods can be found in the report and Factsheet for HDC project PC 178 (Bennison, 2001b).

9.2.2 Aphids

Aphids of various species can infest alstroemeria. The most commonly occurring species on UK crops is the peach-potato aphid, *Myzus persicae*, although the glasshouse and potato aphid, *Aulacorthum solani*; the potato aphid, *Macrosiphum euphorbiae*; the melon and cotton aphid, *Aphis gossypii* and the black bean aphid, *Aphis fabae* can also occur. Correct identification is essential for effective biological or chemical control. Photographs and identification guidelines of most of the aphid species above are given in HDC Identification cards ‘Diseases and pests of bedding plants’, but if in doubt, seek confirmation from a consultant. Aphids can cause leaf and shoot yellowing and distortion, and as with whitefly infestation, excretion of honeydew leads to the growth of black sooty moulds. In addition to causing direct damage, aphids can also transmit some viruses that can occur on alstroemeria.

Plate 9.5. The peach-potato aphid, *Myzus persicae*(pink/red forms of this aphid can also occur).

9.2.2.1 Biological control

Most aphid species infesting alstroemeria can be controlled effectively with parasitic wasps and predatory midge larvae, providing that releases of the appropriate species are managed carefully. Correct aphid identification will enable the appropriate parasitoid species to be selected; otherwise a mixture of parasitoid species should be released. Aphid parasitoids are most effective when released preventively at a low rate every week before aphids are seen. When the first aphids are detected, release rates should be increased. Aphid predators should be released as a supplement to parasitoids if necessary. Commercially available biological control agents against aphids include:

- *Aphidius colemani*, effective against the peach-potato aphid and the melon and cotton aphid.
- *Aphidius ervi*, effective against the glasshouse and potato aphid and the potato aphid.

- *Aphelinus abdominalis* will parasitise all four aphid species controlled by the *Aphidius* species above, but is best used in a mixture with the *Aphidius* species (mixtures are commercially available).
- None of the commercially-available parasitoid species seems to attack the black bean aphid. A compatible aphicide should be used to control this species.
- The predatory midge larvae, *Aphidoletes aphidimyza* will feed on most aphid species and is best used to supplement *Aphidius* species if necessary.
- Lacewing larvae, *Chrysoperla carnea* will feed on most aphid species but in practice are usually less successful predators than *Aphidoletes*.
-

9.2.2.2 Compatible pesticides within IPM

If necessary, the following aphicides may be used within IPM programmes without serious adverse effects on most biological control agents (consult your IPM adviser for full details of side effects):

- Chess (pymetrozine) can be safely integrated with biological control agents. N.B. this product is an antifeedant, so aphids may take up to four days to die after application;
- Aphox, Greencrop Glenroe, Phantom (pirimicarb) are safe to biological control agents. However, the melon and cotton aphid and resistant strains of the peach-potato aphid will not be controlled by pirimicarb;
- Nicotine (see whitefly section above);
- Eradicoat or Majestic (see whitefly section above);
- Savona (see whitefly section above);
- Intercept (potted alstroemeria only: see whitefly section above);
- Calypso (SOLA 1818/02: see whitefly section above) .

9.2.2.3 Additional pesticides - incompatible with IPM

In addition to the compatible pesticides listed above, pyrethroid insecticides e.g. Talstar and Decis have label recommendations for aphid control. Certain resistant strains of the peach-potato aphid and the melon and cotton aphid will not be controlled by pyrethroids. Spray residues on the crop are harmful to biological control agents for up to three months.

9.2.3 Thrips

The main species of thrips infesting alstroemeria is the western flower thrips (WFT), *Frankliniella occidentalis,* although other species such as the onion thrips, *Thrips tabaci* may also occur. Although on most ornamental crops, common WFT damage symptoms are white flecking of leaves and petals and distortion of leaves and growing points, a common symptom of WFT damage on alstroemeria is slight necrosis of the flower bud tips, similar to scorch. WFT seem to be more of a problem on dark-flowered varieties with a hint of blue. Early thrips damage symptoms can be difficult to detect, so regular monitoring for WFT adults using blue sticky traps is a useful management tool. In addition to causing direct damage, WFT can be a vector of the tospoviruses Tomato spotted wilt virus (TSWV) and Impatiens necrotic spot virus (INSV) – see section 9.1.9.

Plate 9.6. Western flower thrips (WFT) adult.

Full details for practical use of biological control agents and IPM are available from biological control suppliers, distributors and from private IPM consultants including ADAS.

9.2.3.1 Cultural control

In addition to weed control, removing unmarketable alstroemeria flowers will reduce thrips multiplication in older flowers with plentiful pollen which provides a rich food source for WFT.

9.2.3.2 Biological control

As WFT is resistant to many pesticides, biological control methods are the preferred option. Use of the predatory mites *Amblyseius cucumeris* against WFT larvae is usually effective on alstroemeria, supplemented if necessary by control of thrips pupae by the soil-dwelling predatory mites, *Hypoaspis* spp. Defra-funded research on improving biological control of WFT on chrysanthemums (project HH1838SPC) has shown that both *Hypoaspis miles* and *H. aculeifer* can contribute to WFT control (Bennison *et al*,. 2002).

At present, biological control programmes for thrips on alstroemeria give adequate control, but research is being done on additional biological control agents against WFT on other ornamental crops, which may be useful to alstroemeria growers in the future, should thrips or tospoviruses become more of a problem. Research in Defra-funded project HH1838SPC has shown that the predatory bugs *Orius laevigatus* have potential for thrips control on chrysanthemum crops. There is recent interest and commercial uptake of the use of foliar applications of insect-pathogenic nematodes against WFT on chrysanthemums and other ornamental crops (Wardlow, 2002; Piggot & Wardlow, 2002) Defra-funded research by ADAS and collaborators in projects HH1838SPC and HH3109TPC 'Exploiting knowledge of WFT behaviour to improve the efficacy of biological control measures' is further investigating the efficacy of nematodes.

Anecdotal evidence suggests that incidence of TSWV is lower in ornamental crops using biological control methods than in crops where thrips are controlled using pesticides. In Defra-funded project HH1758SPC, 'Epidemiology of viruses of protected crops' it was shown that use of *A. cucumeris* can reduce the spread and severity of TSWV on Impatiens (Bennison *et al*,. 2001). In a new Defra-funded project (HH3212SPC) continuing on from this work, the efficacy of insect-pathogenic nematodes in reducing the spread of TSWV and INSV on chrysanthemums will be evaluated.

9.2.3.3 Compatible pesticides within IPM

If necessary, the following pesticides may be used against thrips within IPM programmes without serious adverse effects on most biological control agents (consult your IPM adviser for full details of side effects):

- Conserve (spinosad) is safe to most biological control agents but has some short-term effects on parasitic wasps;
- Dynamec (abamectin) has some harmful effects on biological control agents but can be integrated with care;
- Calypso (thiacloprid) has some harmful effects on biological control agents but can be integrated with care. See SOLA 1818/2002 for details of off-label approval for use on protected crops including ornamentals, for control of various pests including WFT;
- Eradicoat / Majestik (see whitefly section above);
- Luxan Dichlorvos 600 (dichlorvos). The continued approval of this organophosphorus (OP) pesticide is currently under review. Existing stocks may continue to be used and stored by growers but further sale/supply has been suspended. The SOLA's 0625/99 (use as a high volume spray) and 0626/99 (use as a thermal fog) remain in place and off-label use of existing stocks may currently continue at grower's own risk. Existing stocks of Luxan Dichlorvos Aerosol 15 may also currently continue (this product is approved for use on cucumber and therefore may be used on protected ornamentals under the Long-Term Arrangements for Extension of Use (2002). Dichlorvos is harmful to most biological control agents but is persistent for only a few days.

9.2.3.4 Additional pesticides - incompatible with IPM

- Malathion 60 (malathion);
- Decis (deltamethrin) is recommended for the control of thrips but WFT resistance to the pyrethroid insecticides is widespread and severe, and residues on the crop are harmful to biological control agents for up to three months.

9.2.4 Spider mites

Two-spotted spider mite (*Tetranychus urticae)* can cause serious damage on alstroemeria if the symptoms and infestations are not recognised early enough. The mites feed on the underside of the leaves and damage symptoms are leaf yellowing and fine speckling. In severe attacks, leaf or plant senescence can occur and webbing produced by the mites can be extensive. Two-spotted spider mites can be either green or brick-red in colour. The red forms develop in response to shortening day-length and plant senescence, and hibernate in the glasshouse structure or in plant debris. In the spring, the mites come out of hibernation as day-length and temperatures increase. The new spring and summer generations are green in colour.

Plate 9.7. Green and red forms of two-spotted spider mite.

9.2.4.1 Cultural control

In addition to weed control, removal of excess plant debris will reduce hiding places and breeding grounds for spider mites.

9.2.4.2 Biological control

The predatory mite *Phytoseiulus persimilis* should be released to infested and adjacent plants at the first sign of the pest, which can be detected in the spring by regular monitoring of known 'hotspots' e.g. near to heating pipes and stanchions. Release rates and frequency will depend on the pest infestation level. During hot summer periods, *P. persimilis* may lose control of the spider mites and the use of a compatible acaricide may be necessary. Alternatively, *P. persimilis* can be supplemented with releases of another predatory mite, *Amblyseius californicus* which is more tolerant of hot dry conditions and which has made a useful contribution to spider mite control on some alstroemeria crops. The predatory midge larvae, *Feltiella acarisuga* can sometimes occur naturally on spider mite-infested alstroemeria where IPM is used. This predator is also commercially available and releases should be considered if predatory mites are not giving adequate control. Spider mites should be controlled before the end of September to avoid them hibernating in the glasshouse, ready to infest the crop the following spring.

9.2.4.3 Compatible acaricides within IPM

If necessary, the following acaricides may be used against spider mites within IPM programmes without serious adverse effects on most biological control agents (consult your IPM adviser for full details of side effects):

- Torq (fenbutatin oxide) is safe to biological control agents;
- Dynamec (abamectin) has some harmful effects on biological control agents but can be integrated with care;
- Masai (tebufenpyrad) is approved for use on protected roses and may therefore be used on alstroemeria at the grower's own risk. This acaricide has some harmful effects on biological control agents but can be integrated with care;
- Matador (fenazaquin). This acaricide has some harmful effects on biological control agents but can be integrated with care.

9.2.4.4 Additional acaricides - incompatible with IPM

- Talstar (bifenthrin). This pesticide is harmful to biological control agents for up to three months after application.

9.2.5 Caterpillars

Carnation tortrix moth (*Cacoecimorpha pronubana*) caterpillars are the most common species damaging alstoemeria crops, although another tortrix species, light brown apple moth (*Epiphyas postvittana*) has also been recorded. Both of these tortrix caterpillars feed within rolled-up leaves and are thus difficult to control with pesticides. Use of pheromone traps to monitor for adult moths allows timely application of pesticides to control the young caterpillars before extensive leaf-rolling and damage occurs. Other caterpillar species that can occur on alstroemeria are the diamond back moth, *Plutella xylostella* and the cabbage moth, *Mamestra brassicae*. Both of these species cause leaf holes and leave black faecal pellets on the leaves.

Plate 9.8. Caterpillar on alstroemeria leaf.

9.2.5.1 Biological control

- Dipel DF (*Bacillus thuringiensis*) is a bacteria specific to caterpillars and safe to biological control agents. Sprays of this product are more effective against young caterpillars.

9.2.5.2 Compatible pesticides within IPM

- Nemolt (teflubenzuron) is safe to most biological control agents. This product is an insect growth regulator, so is more effective against young caterpillars.
- Dimilin (diflubenzuron) is a similar insect growth regulator to Nemolt.

9.2.5.3 Pesticides incompatible with IPM

- Pyrethroid insecticides such as Toppel 10 (cypermethrin) and Decis (deltamethrin) are effective against caterpillars but are harmful to biological control agents for up to three months after application.

9.2.6 Leafhoppers

Leafhoppers can be a problem on some alstroemeria crops, particularly when IPM is used and broad-spectrum pesticides are discontinued. Both the glasshouse leafhopper, *Hauptidia maroccana* and the green leafhopper, *Empoasca decipiens* can occur on alstroemeria. Feeding damage to the leaves appears as white, indistinct spotting and bleaching.

9.2.6.1 Biological control

The leafhopper egg parasitoid, *Anagrus atomus* is commercially available and has been used on some commercial ornamental crops including alstroemeria (Cooper, 1993) although no research has yet been done on using this beneficial on ornamentals. *Anagrus* was first developed for use against the glasshouse leafhopper on tomatoes (Wardlow, 1990) and can be effective if released at the very start of an infestation. In HDC project PC 76, *A. atomus* was also shown to parasitise the green leafhopper (Jervis & Kidd, 1995).

9.2.6.2 Compatible pesticides within IPM

If necessary, the following pesticides may be used against leafhoppers within IPM programmes without serious adverse effects on most biological control agents (consult your IPM adviser for full details of side effects);

- Applaud (buprofezin). This insect growth regulator, recommended for the control of whitefly, will also control leafhopper nymphs and can be safely integrated with biological control agents;
- Chess (pymetrozine). This antifeedant is recommended for aphid control, but if used at double the label-recommended rate, under SOLA 1428/2002 for use on protected peppers and aubergine, the product should give control of leafhoppers;
- Savona (fatty acids) should give partial control of leafhoppers;
- Eradicoat and Majestik (see whitefly section above) should give partial control of leafhoppers;
- Nicotine products (see whitefly section above) should give partial control of leafhoppers;
- Calypso (thiacloprid). See SOLA 1818/02 and whitefly section above. Although not included on the list of pests controlled, it is known that this product has some activity against leafhoppers. This product has some side effects on biological control agents but can be integrated with care.

9.2.6.3 Pesticides incompatible with IPM

- Pyethroid insecticides such as Decis (deltamethrin) are effective against leafhoppers but are harmful to biological control agents for up to three months after application.

Further information on leafhopper control is given in HDC report for project PC 178 (Bennison, 2001), although this project focussed on the 'sage' leafhopper that damages herbs and certain hardy nursery stock crops.

9.2.7 Slugs and snails

Slugs and snails can be a problem on alstroemeria, particularly on older crops as they thrive in the mulch and plant debris. Slugs and snails can climb up the crop to damage the leaves, where damage symptoms are leaf holes and shredding and chewing to leaf edges. Trails of slime or faeces are often evident. The species of slugs and snails occurring on alstroemeria have not been confirmed, but may include those commonly occurring on hardy ornamental nursery stock under protection, i.e. the slug *Deroceras panormitanum* and the small semi-aquatic snail *Oxyloma pfeifferi*. The biology and integrated control of these two species are being studied in HDC project HNS 105 and further details are given in the HDC annual report and Factsheet 07/02 (Bennison, 2001; Bennison & Schüder, 2002)

9.2.7.1 Biological control

Parasitic nematodes, *Phasmarhabditis hermaphrodita* ('Nemaslug') are commercially available but have been promoted mainly for the home/garden market, due to cost implications for large-scale commercial use. Research on efficacy and cost-effective rates of 'Nemaslug' against selected slug and snail species is being done in HDC project HNS 105 (Bennison, 2001 and Bennison and Schüder, 2002). 'Nemaslug' is being used successfully on some UK alstroemeria crops.

9.2.7.1 9.2.7.1.1 Molluscicides

- Methiocarb (Draza) has off-label approval for use against slugs and snails on all protected crops. See SOLA 3215/02, which replaces SOLA 1599/98; the latter SOLA will be revoked on 30 November 2002.

- Various metaldehyde products are approved for use on all ornamental crops.

9.2.8 Nematodes

Alstroemerias are recorded as being susceptible to root lesion nematodes, including both *Pratylenchus penetrans* and *P. bolivianus*. The latter species was found in the UK for the first time in 1989, in a crop of alstroemeria that was showing signs of reduced vigour. A survey of 35 alstroemeria crops in England and one crop in Wales was carried out by the Plant Health and Seeds Inspectorate (PHSI) of the Ministry of Agriculture, Fisheries and Food (MAFF, now Defra), to establish the extent to which the *P. bolivianus* had become established. The nematode was found on twelve widely distributed nurseries nurseries in England (Cotton & Bartlett, 1991). Roots and rhizomes infested with the nematodes showed the necrotic lesions typical of *Pratylenchus* sp. invasion. Some but not all of the infested crops showed patches of depressed growth. *Pratylenchus*-infested roots can also be more susceptible to soil-borne pathogens. It was concluded that as populations of *Pratylenchus* are slow to increase, the practice of soil sterilisation in between crops and using nematode-free planting material should prevent further potential problems. Since the survey, there have been no further confirmations of *P. bolivianus* in UK alstroemeria crops (Roger Hammon, CSL York, personal communication), although this does not guarantee that all UK crops are currently free from the pest.

The free-living nematodes *Trichodorus* and *Paratrichodorus* spp. can transmit tobacco rattle virus. These nematodes are more common on light, sandy soils.

9.2.8.1 Cultural and chemical control

Using nematode-free planting material will prevent introducing the pests to the nursery. Soil sterilisation and careful disposal of crop debris will prevent any carry-over of nematodes in infested soil or roots from the previous crop.

9.3 Summary

Fungal pathogens, viruses and pests affecting alstroemeria are reviewed with regard to:

- symptoms;
- cultural control;
- biological control ;
- chemical control;

The most common diseases found in UK crops are *Pythium, Phytophthora* and *Rhizoctonia* root trots, *Botrytis,* and, more especially, virus problems. The aphid transmitted alstroemeria mosiac virus was found to be widespread in a survey of crops in 2000.

The major pests infesting alstroemeria in the UK are whitefly, aphids, thrips, spider mites, caterpillars, leafhoppers, slugs and snails and nematodes. Several of these are important as virus vectors as well as being pests in their own right.

- Biological control methods, within IPM strategies, are available for most pest problems and are the preferred option.
- With the loss of pesticides and increasing use of IPM, controlling leafhoppers and caterpillars remains a challenge for effective IPM control.
- The damage caused by alstroemeria mosaic virus varies with variety and crop production, and in some cases, appears to cause little damage.

10. Harvesting and post-harvest handling

10.1 Thinning

Thinning consists of the pinching off or removing thin and/or blind and/or old shoots from the plant. Flowers that are not harvested should also be removed. Flowers that are left blooming on the plant lead to dormancy of an alstroemeria plant. Thinning increases light perceived by upcoming shoots, and improves the air circulation, thus reducing the risk of *Botrytis*. Thinning enhances shoot growth on seasonally flowering varieties. The amount of thinning required is cultivar-dependent. During thinning, a distinction is made between thinning young and old plants.

10.1.1 Young plants

These first develop thin shoots that may or may not carry a flower bud. The top of these first shoots should be pinched or broken off. This helps a young plant to establish itself. When the development of the flowering shoots is well under way, the plant can become over-dense. In order to stimulate the development of the plant shoots, a number of thin shoots are pinched off or removed. In the spring, bud pinching has preference over plant thinning. The pinched shoots that remain provide an insulation in warm weather. They also reduce any potential increase in soil temperature due to their shading effect.

10.1.2 Older plants

Thinning older plants (those more than one year old) is variety-dependant. Producers may remove the harvested stem leaves after harvesting, or regularly thin out and/or remove blind stems from the plant during the entire year. It is advisable to regularly remove a few stems at one time. This promotes steady plant growth. Thinning primarily takes place in autumn/winter.

10.2 Harvesting and post-harvest handling

Stems should be harvested in the morning whilst stems and leaves are still firm and taut. In the UK, producers may use a mixture of cutting and pulling depending on the season: in winter 50% may be cut and 50% pulled, and in summer all stems may be pulled. To harvest, pull the stems when the first flowers are just showing colour, when at least a few buds are open on each stem. When a stem is pulled upon which a piece of rhizome is still attached it is advisable not to continue pulling the stems.

Growers who are producing alstroemeria for a local market will harvest flowers when the primary florets reach the 'Rolled Petal Stage'. By delaying harvest until this point, the primary and secondary flower colours intensify. Growers who will be shipping the flowers will harvest earlier when buds are starting to show colour. Earlier harvest decreases petal damage in shipment, but may reduce flower quality by decreasing flower colour.

Plate 10.1. Transporting harvested stems in Holland. Note trolley moving along heating pipes.

Plate 10.2. Cut stems nestled in fabric 'stretcher' for ease of trimming and to reduce damage to stems.

Handling systems are of increasing importance to save labour for picking. In the UK, most growers use mobile plastic coffins that allow growers to pick and place bunches in the coffin which can then be transferred to other transport systems or returned individually or in bunches to the packing shed. In Holland, most growers use mobile metal transporters that run along the heating pipes between rows (Plate 10.1). These units are used to collect stems (Plate 10.2) which are then trimmed and placed into larger mobile units that transport the large bunches to the packing shed (Plates 10.3 & 10.4).

Plate 10.3. Harvester closing fabric ‘stretcher’, enclosing a large bunch of stems.

Plate 10.4. Water-filled trolley to transport harvest to sorting/packing shed.

In the Netherlands, the stems are harvested twice a week during the winter, and three to four times a week during the summer. When the crop is sold at auction the stems should be harvested at the moment the buds begin to open. When sold directly, the stems should be harvested when the first flowers have just opened. One harvester can harvest l ha per day, especially with trolleys to assist removal of harvested stems to the grading shed.

Breeders in Holland are developing a number of labour–saving devices to move harvested stems around the glasshouse. These include moving frames that transport stems to a central collection point (Plates 10.5 & 10.6). Savings of 20% in labour costs are probably required to make installation of these systems economic.

Plate 10.5. Moving frame being developed by Royal Van Zanten, Holland.

Plate 10.6. Moving frame being developed by Könst Alstroemeria Holland. Note pulley.

Once harvested and moved to a central grading/packing area, alstroemeria are graded. During grading, stems are bunched according to similar maturity, stem thickness, stem strength, stem length and the number of flowers on a crown. The lower 10 cm is defoliated, and any damaged leaves are removed. In the UK, five stems per bunch are packed. In Holland, 10 stems per bunch are packed into plastic jackets.

There is no single accepted grading scheme. However, the criteria given in Table 10.1 are widely followed.

Table 10.1. Suggested grading system for alstroemeria

Number of stems	**Overall length/cm**	**Flowers per stem**
5/wrap	75-90 cm	5
5/8 smaller wrap	68-85 cm	4
5-10 stems	50-60	3 or less including bent and short stems

J. Sainsbury sell alstroemeria as a straight line and as a component in mixed bouquets. They require 62 cm stem length and a medium grade of product, which would usually have a minimum of four flowering pedicels. Stage of development is critical; sales are better if customers can see the colour of the flowers. This is possible with aqua pack, but flowers are likely to be damaged if packed flat in boxes at this stage. Resistance to mechanical damage is important, as is long vase-life. Also, they require a colour range. Yellowing foliage can be a problem, but correct application of post harvest treatments containing gibberellins helps this.

The majority of alstroemeria are packed in tapering unperforated polypropylene wraps (sleeves) for sale through the wholesale market with a single elastic band at base of the stems. A common sleeve size is 70 cm long by 30 cm wide at the top narrowing to 10 cm wide at the bottom. Narrower sleeves are cheaper but slower to fill.

Where flowers are sold direct to florists or secondary wholesalers the grading system is often amended to maximise the sale of flowers to the outlet. Traditional grading is done by eye (Plate 10.7) and the bunches sleeved manually (Plate 10.8).

Plate 10.7. Manual grading of alstroemerias in Holland

Plate 10.8. Manual sleeving of alstroemerias

10.3 Labour–saving mechanisation

10.3.1 Filling the buckets with solution

After the grading machine, bunches with shoots are placed in a container with water and pre-treatment solution. Traditionally, these were filled manually, but in Holland this is now done with an automatic container filler. This machine saves 160 man hours per year. The machine is produced by Schijf Tuinbouwtechniek and costs about £1,720.

10.3.2 Grading

Grading of the shoots is a matter of 'eye' and 'hand'. There are several manufacturers of grading machines, Olimex BTM Aweta, and van de Berg , who have constructed a special alstroemeria grading machine based on a rose grading machine. It is possible to measure not only the thickness of the stems, but also the firmness of the stems. The Applied Research Station (PPO) in Naaldwijk developed a test to measure the firmness of the stem of alstroemeria carefully and objectively. This test is able to characterise the shoot firmness and to measure the differences between varieties and nurseries. The producer sets the values for firmness to distinguish between first and second class of the different varieties.

10.3.3 Harvesting, grading, bunching and sleeving

Fully automated harvesting, transporting, grading, bunching and sleeving machines are being developed for many crops, whilst grading, bunching and sleeving machines for alstroemeria are already available. The following information is from the Könst web site (www.alstroemeria.com).

The company Jamafa is testing a bunching machine that already works quite well. Even with the uneven lengths of the flower breaks a moderately uniform bunch can be made. Automated grading of the stems cannot be achieved with this particular machine, but it is possible to re-direct stems to other "bunching stations" by pressing a button.

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Plate 10.9. Jamafa Bunching machine.

Plate 10.10. BTM bunching machine

The BTM company is testing a machine that can grade and bunch; and the bunches can be put into individual plastic sleeves. The main difference between the BTM and the Jamafa machines is that the whole process and even the sleeving is done with the plants laid flat, in contrast to the vertical hanging system used by Jamafa. Processing the flowers horizontally results in less damage to the stems. Another important part of the BTM machine is the Vision Camera, which can handle two to eight to different grades. This camera is able to ‘see’ the difference in quantity of flower buds; maturity length, thickness and straightness of the stem.

After the stems have been graded, they are then transported to the bunching unit. This part of the machine counts the stems (adjustable); the machine can be programmed to remove leaves and to shorten the stems before it makes the bunch. Thereafter, the bunch is ready to be put into the sleeves. Currently, the machine can only process rectangular sleeves rather than conic shaped ones. The rectangular sleeves can easily be pulled off while the bunches are still in the bucket without damaging the stems and leaves. This cannot be done with the cone shaped sleeves because of its narrow shape.

The grading machines have a capacity of handling 5,000 to 6,000 stems/hour with approximately three workers; manually, three workers can only handle approximately 2,200 stems/hour (grading, bunching and sleeving).

Machine packing also offers the prospect of a more uniform, higher quality product due to less damage. Mistakes in counting and grading will also be reduced. Statistical information on production quantities can also be collated.

The development of these machines will continue and they will be an important part of the production process in the future. However, only large nurseries (more than 30,000m²) that will be able to justify the costs of an automated bunching line.

10.4 Post–harvest handling

Cut alstroemeria stems in a vase are expected to have a vaselife of at least 14 days (Plate 10.11) during which the leaves should remain green and firm and the flowers should retain their ornamental value (without dropping or showing visible signs of ageing). Although the flowers and the inflorescence as a whole have very good durability characteristics, the leaves on flower stems are definitely a problem. The leaves start ageing and falling off considerably earlier than the flowers.

Problems associated with post-harvest handling of cut alstroemeria include leaf chlorosis, loss of leaf turgidity, floret desiccation, and petal shedding. Flowering shoots may fail to absorb water when the stem base is either not cut or cut through the blanched portion of the stem below the soil line. Leaves can be stripped from the stem without affecting vase life.

In Holland, vase life is perceived to be unaffected by maturity at harvest. Picking at a later date leads to damage of the flowers throughout the handling chain, however, and thus an earlier picking is used. This also minimises damage to blooms whilst in transit through the Dutch Auction system. In the UK alstroemeria producers recommend harvest at a more mature stage than this.

Cutting the stems prevents continued water supply from the plant. However, the stems continue to lose moisture through transpiration. This creates a suction effect in the stem, enabling air to penetrate into the vascular ducts and impeding further water uptake. Separation from the roots also impedes the supply of hormones formed in the roots. Poor lighting after harvest prevents adequate assimilation by the flowers and causes a sugar deficiency. The cut stems continue to respire and thus they use up their sugar reserves. This causes production of ammonia, polyphenols, and ethylene , which cause further damage to the flowers.

Plate 10.11. Vase life trials at Royal Van Zanten, Holland.

For optimum vase life, the water temperature in containers should be 20-25°C to reduce the oxygen in the water; the temperature of the storage room should not be below 10°C. Alstroemeria should always be stored in vase life solutions at 4-5°C (stored for 2 weeks).

10.5 Preservatives

Use of preservatives by the producer for 1-2 days obviates the need for later use by the wholesaler, florist or consumer. Suitable preservation agents contain the plant hormone gibberellin. This primarily prevents leaf yellowing (see below) and is used in solutions for supermarkets in the UK. Vase life solutions improve the durability of the marketed flower stems by 50-75%. Vegetative growth pollutes water, so the water needs changing frequently. It is important not to place flowers, even temporarily, in pure water as this reduces uptake of subsequent vase solutions.

As well as preventing leaf yellowing, preservatives are also used to:

- Reduce bacterial growth.
- Protect the flowers against ethylene.
- Administer nutrients.

- Improve absorption of treatments.

10.6 Leaf yellowing

One of the major factors reducing quality and longevity of cut alstroemeria flowers is the rapid loss of chlorophyll in leaves, which produces significant unattractive leaf yellowing.

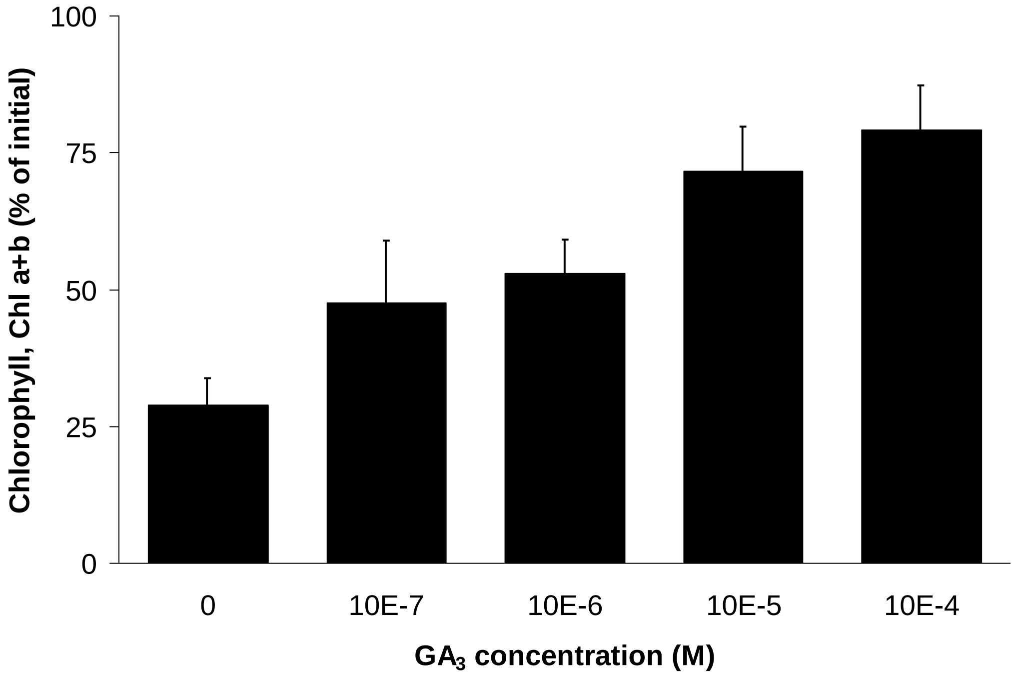

Figure 10.1. Effect of GA_3 concentration of chlorophyll concentration. M = Molarity. Reproduced from Jordi *et al.* (1993).

Leaf yellowing is brought about by a depletion of nitrogen in leaf tissues under dark conditions. This loss is mitigated by treatment with gibberellin; for example Jordi *et al.* (1993) showed that loss of chlorophyll could be reduced as a result of treatment with GA_3, especially at concentrations above 10^{-5}M (Fig. 10.1). The cause of chlorophyll degradation and leaf yellowing is unknown, but is related to endogenous gibberellin levels. Leaf yellowing may also be reduced by exposure of cut stems in the dark to irradiation with red light that stimulates gibberellin production (Van Doorn & Van Lieburg, l993). Maintaining cut flowers in natural daylight may reduce leaf yellowing. Some gibberellins (GA4 and GA7) are far more effective (in some cases, twice as active) than others (GA1 and GA3) at delaying leaf yellowing (Kappers *et al.*, l998).

Gibberellin is commercially available as a preservative treatment (0.0035mg/p) in CIRO Alstroemeria VB or Chrysal SVB2. Use of such solutions for cut alstroemeria are a requirement of Dutch auctions, and a test can be used to show that the correct concentration was used.

10.7 Ethylene

Ethylene is a naturally occurring plant hormone, which shortens the longevity of many flowers and plants. It also increases premature drop of buds and flowers. Alstroemerias produce small quantities of ethylene gas. Exposure to further ethylene causes discolouration and dropping of the flowers and leaves, especially the latter. Flowers may display a life of 18 days, whereas leaves may only have 10 days. To minimise effects of ethylene it is necessary to avoid sources of ethylene (fruits, vegetables and combustion engines). Ventilate storage or display areas with ethylene-free air (one or two air exchanges/hour). Ethylene scrubbers (containing potassium permanganate) can be used to absorb ethylene from the air.

New methods to control ethylene sensitivity are being introduced into the cut flower industry in the form of 1-methylcyclopropene (1-MCP, or Ethylbloc), which is used as a gas.

Other solutions or treatments can be used that either act as ethylene actions inhibitors (which protect the flowers from external sources of ethylene), or ethylene synthesis inhibitors which are useful where external ethylene levels are low (<100 ppm), such as in supermarkets. Two companies, Pokon & Chrysal B.V. of Naarden, Netherlands and Abbott Laboratories, North Chicago, Illinois, United States, have introduced materials for cut flowers that inhibit ethylene synthesis.

10.8 Summary

- Harvesting and packing alstroemeria is very labour intensive. Various novel systems for transporting cut flowers from the glasshouse to packhouse have been developed and are widely used in Holland.
- Machines to grade, bunch and pack are currently being developed and offer promise of further labour saving, especially for large scale nurseries, though there may be some spin-off benefits for smaller nurseries.
- Leaf yellowing is the major factor affecting vase life, rather than flower senescence. Gibberellins may be used in vase solutions to reduce leaf yellowing and prolong vase life.

11. Environmental legislation

11.1 Introduction

This section summarises and highlights some of the environmental legislation likely to affect alstroemeria production.

The enforcement of most environment-related legislation is the responsibility of the Environment Agency (England and Wales) and the Scottish Environmental Protection Agency (Scotland). Most concerns over legal compliance should be routed through these agencies in the first instance. The agencies have powers (under the Environment Act 1995) to prosecute offenders.

Much of the environmental legislation presently imposed, or to be imposed, on growers stems from Directives from the European Union. The requirements from these Directives are then absorbed into UK legislation and relevant Regulations are introduced.

11.2 Legislation relating to pesticides, fertilisers and water

Under part III of the **Food and Environmental Protection Act (FEPA) 1985** the **Control of Pesticides Regulations (COPR) 1986** are implemented. These regulations require the users of pesticides take all reasonable precautions to protect the environment and "in particular avoid the pollution of water". People using pesticides must be "competent" and have received proper instruction. This is typically obtained by a certification from the NPTC (National Proficiency Tests Council)

The Code of Practice for the Safe Use of Pesticides on Farms and Holdings (1998) provides guidance on pesticide use and precautions to be taken to prevent pollution. Growers applying pesticides near water with a ground crop sprayer should also be aware of the need to carry out a Local Environmental Risk Assessment for Pesticides (LERAPs). LERAPs relate to buffer zones near water and should be carried out for each listed substance used. Further information is available in a Technical Note available from ADAS as well as a Guide produced by Defra.

The **Control of Substances Hazardous to Health (COSHH) Regulations 1999** require risk assessments to be carried out for hazardous substances and a record of these assessments should be retained and regularly reviewed.

The **Water Resources Act (WRA) 1991** allows for individuals to be prosecuted if pollution occurs and contains measures to encourage pollution prevention. Under the WRA, it is an offence to cause or knowingly permit a discharge of poisonous, noxious or polluting matter or any solid waste to enter ground or surface waters without proper authorisation. Within the WRA, the **Groundwater Regulations 1998** have been implemented. These regulations make it an offence to dispose of listed substances (including pesticides and some elements in fertilisers) to land where this may lead to a direct or indirect discharge of the pollutant via groundwater. Growers need to apply to the Environment Agency for authorisation to dispose of listed substances, including pesticide tank washings. A Technical Note on compliance with these Regulations is available from ADAS.

Water pollution offences can carry a penalty of up to £20,000 in a Magistrates Court and an unlimited fine in the crown court. It may also be necessary to pay for any damage caused by pollution and clean up costs.

The **Code of Good Agricultural Practice for the Protection of Water ('Water Code') 1998** contains a section on 'Specialised Horticulture'. The Code suggests that overhead irrigation systems should be designed to match crop requirements and that fertiliser is applied in a way that minimises nutrient run-off. It also suggests that new container areas are planned with the possibility of recirculation in mind. Pressures to improve the efficiency of water use will also come about following the review of the water abstraction licensing system. It is likely that abstraction licence holders will be required to demonstrate that the abstracted water is being used in an efficient way.

The **Drinking Water Directive (80/778/EEC)** has been implemented under the **Water Industry Act 1991.** This act sets maximum admissible concentrations (MACs) for 57 listed parameters. The MAC for nitrate in drinking water is 50 mg/l. The MAC for total pesticide is 0.5 ppb and 0.1 ppb for a single pesticide. Research has shown that run-off water leaving container nurseries often exceeds these limits. Restrictions could be imposed on nurseries found to be causing MACs in drinking water to be exceeded.

The **Nitrate Detective (91/676/EEC)** is implemented under **The Protection of Water Against Agricultural Nitrate Pollution (England and Wales) Regulations 1996.** These Regulations have brought about the designation of Nitrate Vulnerable

Zones (NVZs) across England and Wales. The publication 'Guidelines for Farmers in NVZs' gives instructions on the activities permitted and forbidden within these zones. At the moment, container nurseries within NVZs do not come under the legislation. However, it is recommended that growers within these areas minimise nitrate run-off to avoid the nursery coming under future legislation.

11.3 Climate Change Levy (CCL)

As a party to the Kyoto Protocol, the UK agreed to cut emissions of the six greenhouse gases by 5.2% on l990 levels, between 2008 and 2012. The DETR has agreed to reductions that go beyond the Kyoto agreement and emissions of the six gases will be reduced by 12.5%, with cuts in carbon dioxide emissions by 2012 of 20%.

The UK glasshouse industry is a major user of energy and thus a significant source of greenhouse gases, predominantly CO_2 emissions as a result of oxidation of the fuel. As well as heat and electrical energy for glasshouse heating, lighting, cooling and mechanisation, road transport for plant and produce deliveries consumes considerable amounts of DERV, adding to the emissions of the industry as a whole, but particularly the ornamentals sector.

Different fuels produce differing amounts of CO_2 when burned to produce energy. Heavy fuel oil and DERV produce similar amounts of CO_2, with propane and mains gas a little less. Electricity, because it is still dependent on coal for some of its generation, has the highest CO_2 production.

Increasing use of gas for electricity generation in the future, as well as generation through CHP units is likely to reduce the high emission level.

The CCL was announced in the 2000 Budget, and is a levy based on the energy content of fuels. It was imposed from April 2001. The current rates of levy are as follows:

- 0.07 pence/kWh for Liquid Petroleum Gas (LPG);
- 0.15 pence/kWh for natural gas;
- 0.15 pence/kWh for coal;

- 0.43 pence/kWh for electricity.

Fuels already subject to duty (fuel oils) are not subject to the Climate Change Levy (CCL). The Government will monitor and evaluate the contribution that the levy makes to the UK's targets for emission reduction. The CCL is being added to utility bills by the suppliers, in a similar fashion to VAT.

The vast majority of CHP schemes are exempt from all Levy payments on the fuel input, and on the heat supplied. Qualifying electricity generation from CHP is also exempt where it is consumed on site or sold direct to another customer. Electricity sales via an electricity supplier are subject to the CCL. A temporary 50% discount on the levy for glasshouse businesses for up to five years is in the place, while the energy efficiency measures targeted at the sector take effect. A voluntary reduction of 15% in energy use per unit of production by 2010 has been agreed by the glasshouse sector.

11.4 Legislation guides and codes of practice

1. '**Code of Practice for the Safe Use of Pesticides an Farms and Holdings'** (The Green Code), 1998 MAFF Publications.

2. '**Code of Good Agricultural Practice for the Protection of Wales'** (The Water Code),1998 MAFF Publications.

3. '**Code of Good Agricultural Practice for the Protection of Air**' (The Air Code), 1998 MAFF Publications.

4. '**Code of Good Agricultural Practice for the Protection of Soil**' (The Soil Code), 19998 MAFF Publications.

5. '**Code of Practice for the Prevention of Water Pollution from the Storage and Handling of Solid Fertilisers'** (Separate Code for Liquid Fertilisers), 1998. Fertiliser Manufacturers Association.

6. '**Guidelines on Storing Pesticides for Farmers and Other Professional Users'**. HSF Agricultural Information Sheet No 16.

7. ‘**Local Environmental Risk Assessments for Pesticides: A Practical Guide**’, 1999 MAFF Publications.

8. ‘**LERAPs – ADAS Technical Note**’, 2000 ADAS.

9. ‘**Taking Water Responsibly. Government Decisions Following Consultation on Changes to the Water Abstraction Licensing System in England and Wales**’ 1999 DETR Free Literature.

10. ‘**Groundwater Regulations**’, 1999 Environment Agency.

11. ‘**Groundwater Regulations, 1998 ADAS Technical Note**’, 1999 ADAS.

12. ‘**Environmentally Sensitive Areas – complete information pack**’ MAFF Publications.

13. ‘**Code of Practice for the Management of Agricultural and Horticultural Waste**’, 1998 MAFF Publications.

14. ‘**The Packaging Waste Regulations User’s Guide (Code Pack 2)**’ DETR Free Literature.

15. ‘**Ready Reckoner (Code Pack 3)**’. DETR Free Literature.

16. ‘**Guidelines for Farmers in NVZs – Nitrate Vulnerable Zones**’, 1998 MAFF Publications.

11.5 Technical notes and guides

1. ‘**The UK Pesticide Guide**’. Published annually by BCPC and CARL.

2. ‘**Insulation of Boilers and Pipework**’, 1977 BS 5422. British Standards Institute.

3. ‘**Opportunities for Saving Money by Reducing Waste on Your Farm**’ PB4819. MAFF Publications.

4. ‘**ADAS Colour Atlas of Weed Seedlings**’ Wolfe Publishing Ltd.

5. '**Practical Weed Control for Nursery Stock**', 1999 HDC (members only).

6. '**Side Effects Guide**' (a guide to pesticide compatibility in IPM), Koppert Biological Systems.

7. '**Knowing and Recognising – The biology of Glasshouse Pests and Their Natural Enemies**', 1992, Koppert Biological Systems.

11.6 Relevant Organisations and Contact Details

1. Defra Publications, Admail 6000, London SW 1A 2XX; Tel: 08495 556000; Internet: http://www.defra.gov.uk .

2. DETR, Eland House, Bressenden Place, London SW1E 5DU. Tel: 0207890 3000

3. DETR Free Literature, PO Box 236, Wetherby, West Yorkshire, LS23 7NB. Tel: 0870 1226236; Internet: http://www.detr.gov.uk

4. Environment Agency, Head Office, Rivers House Waterside Drive, Aztec West, Almondsbury, Bristol, BS125 4UD. Tel: 01454 624400 or 0645 333 111. Emergency Hotline 0800 80 70 60; Internet: http://www.environment.agency.gov.uk; http://www.environment.agency.wales.gov.uk.

5. Health and Safety Executive, Infoline, HSE Information Centre, Broad Lane, Sheffield, S3 7HQ; Tel: 0541 545500. (HSE Books Tel: 01787 881165). Internet: http://www.open.gov.uk/hse/hsehome.htm.

6. ADAS Horticulture Ltd., Oast Building, East Malling, Kent, ME19 6BJ. Tel: 01732 876662. Internet: http://www.adas.co.uk.

7. Basis Ltd, 34, St John Street, Ashbourne, Derbyshire, DE6 1GH. Tel: 01353 343945

8. Horticultural Development Council (HDC), Bradbourne House, East Maling, Kent, ME19 6DZ. Tel: 01732 848888; Internet: http://www.hdc.org.uk.

9. Grow Electric/Farm Energy Centre, NAC, Stoneleigh Park, Kenilworth, Warwickshire CV8 2BS. Tel: 02476 696512; Internet: http://www.farmenergy.com

10. Fertiliser Manufacturers Association, Greenhill House, Thorpe Road, Peterborough, PE3 6GF. Tel: 01733 331303.

11. Climate Change, Levy Help Desk, H.M. Customs and Excise, 3rd Floor, Ralli Quays, 3 Stanley Street, Salford, M60 9LA. Tel: 0161 827 0882.

12. National Proficiency Test Council, Avenue J, National Agricultural Centre, Kenilworth, Warwickshire, CV8 2LG. Tel: 02476 696553

Appendix 1. Classification of soil analysis results from samples analysed by standard ADAS procedures

Soil and loam based composts (analysis on dried, ground sample)

Index	Phosphorus (mg/litre)	Potassium (mg/litre)	Magnesium (mg/litre)	Conductivity (micro-siemens)	Nitrate N (mg/litre)
0	0-9	0-60	0-25	1900-2200	0-25
1	10-15	61-120	26-50	2210-2400	26-50
2	16-25	121-240	51-100	2410-2600	51-100
3	26-45	241-400	101-175	2610-2700	101-150
4	46-70	401-600	176-250	2710-2800	151-250
5	71-100	601-900	251-350	2810-3000	251-350
6	101-140	901-1500	351-600	3010-3300	over 350
7	141-200	1501-2400	601-1000	3310-3700	
8	201-280	2401-3600	1001-1500	3710-4000	
9	over 280	over 3600	over 1500	over 4000	

Appendix 2. Molar Equivalents – Conversion between mg/l and mmol/l or µmol/l

Nitrate nitrogen	1 mmol/l NO_3	14 mg/litre N
Ammonium nitrogen	1 mmol/l NH_4	14 mg/litre N
Potassium	1 mmol/l K	39 mg/litre K
Phosphorus	1 mmol/l P	31 mg/litre P
Calcium	1 mmol/l Ca	40 mg/litre Ca
Magnesium	1mmol/l Mg	24 mg/litre Mg
Sulphate	1mmol/l SO_4	32mg/litre S
Chloride	1 mmol/lCl	35 mg/litre Cl
Iron	1 µmol/l Fe	0.056 mg/litre Fe
Manganese	1 µmol/l Mn	0.055 mg/litre Mn
Zinc	1 µmol/l Zn	0.065 mg/litre Zn
Boron	1 µmol/l B	0.011 mg/litre B
Copper	1 µmol/l Cu	0.064 mg/litre Cu
Molybdenum	1 µmol/l Mo	0.096 mg/litre Mo