THE INFLUENCE OF TEMPERATURE ON THE GROWTH AND FLOWERING OF ORIENTAL LILIES (*Lilium* cultivars)

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ABSTRACT

The potentiality of growing dwarf cultivars of Oriental lilies as flowering pot plants was investigated. Two cultivars, *L. auratum* 'Little Gem' and *L. x parkmanni* 'Little Robin' were grown to assess their suitability and determine a predictable schedule of production.

Initially it was established that these plants could be grown satisfactorily in containers and that after adequate vernalization adequate growth and flowering took place.

In bulbs selected after natural senescence, vernalization can be achieved by planting and storing the bulbs outdoors to experience natural winter chilling and also artificially by storage at controlled cool temperatures. Planting prior to artificial cool storage was not advantageous.

There is a minimum period of storage of 35 days and preferably 42 days for both cultivars, while temperatures may range from 1.7°C to 8°C for *L. auratum* 'Little Gem and to 12°C for *L. x parkmanni* 'Little Robin'.

The periods from planting to emergence and emergence to macroscopically visible flower buds are inversely related to the length of time the bulbs are stored, irrespective of the cool temperature. Subsequent growth to anthesis is directly related to the temperature at which the plants are grown and independant of previous storage times and temperatures. The time required to achieve anthesis is consistent in any one temperature regime.

Although the longer the time the bulbs experience cool temperatures, the sooner the plants achieve anthesis. the total time from commencement of storage to anthesis is similar for all storage periods up to 10 weeks.

When bulbs are inadequately vernalized, growth and flowering is irregular; growth being rosetted and anthesis delayed or occuring spasmodically.

The growth and development of lilies is considered and compared with that of other bulbous geophytes.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

Plants of the genus *Lilium* have for centuries had a particular significance for people, either as a source of food (Wilson 1929), the bulbs being gathered from the wild and eaten in Japan or with religious connotations in Christian communities (Woodcock and Stearn 1950). In addition they have been admired and cultivated as plants of beauty to decorate gardens. The alimentary aspect will not be considered further, while the religious significance must be referred to in greater detail.

Traditionally the pure white flowers of *Lilium candidum* have been associated with the Madonna, in fact both the specific and common English name indicate that the flowers were of exceptional purity. Similarly *L. longiflorum* has been known for years as Easter lily and many millions of bulbs are forced in the United States of America as a flowering pot plant specifically for sale at that time and at no other period of the year. In New Zealand, lilies with white flowers either *L. regale* or *L. longiflorum* 'Dutch Glory', are grown outdoors to be sold as cut flowers at Christmas only; should they flower too early or too late they have no commercial value.

Those species and cultivars with coloured flowers, particularly *L.* (Asiatic hybrid) 'Enchantment' and cultivars of *L. speciosum* are grown for cut flower sale in Europe and more recently, *L. X parkmanni* cultivars bred in New Zealand have been exported for the same purpose (Doreen pers. comm.).

Apart from Easter lily cultivars, few others are grown as pot plants for they do not possess the desirable characteristics of a pot plant as specified by Sachs *et al.* (1976), mostly being too tall or not attaining the desirable height/width ratio of 1.62/1. In fact growth retardants such as chlormequat, ethephon or ancymidol are applied to

Easter and Asiatic hybrid lilies (Dick 1974, Wade 1972, Roh and Wilkins 1977b) to obtain a more compact and suitably shaped plant. Woodley and Thomas (1973) similarly applied growth retardants to *L. regale* to produce a more acceptable pot plant.

The selection of a genetically dwarf cultivar of *L. auratum* by Dr J.S. Yeates (Yeates 1956) named 'Little Gem' and its subsequent crossing with *L. X parkmanni* cultivars produced a genetically stable strain of plants named 'Little Rascal' (McRae 1972). These plants approximated closer to the desirable height/width ratio of a pot plant and appear to have other suitable characteristics for this purpose.

The studies undertaken and reported here, were carried out to confirm these aspects, and also draw up a blue print of culture as proposed by Bredmose (1973) and Christensen (1976). Concurrently studies were undertaken on the culture of other geophytes especially *Narcissus*, *Iris* 'Wedgwood', tulips and freesias from corms particularly to advance their flowering. The results have been reported elsewhere (Salinger 1976, 1977). These studies enhanced an understanding of the morphology and growth of monocotyledonous geophytes while observations made during these investigations have been incorporated in this thesis.

CHAPTER ONE

THE LILY PLANT

1.1. Classification of lilies

1.1.1. Botanical classification

According to Woodcock and Stearn (1950) the Genus *Lilium*, excluding *Cardiocrinum* and *Notholirion* was divided into four sections on the basis of corolla and flower shape. These divisions were:

I. LEUCOLIRION, the flowers being trumpet or funnel-shaped ... with the perianth segments overlapping for the greater part of their length.

II. ARCHELIRION, comprising *L. auratum*, with bowl or open funnel-shaped flowers.

III. PSEUDOLIRION. Flowers erect and open widely.

IV. MARTAGON. Flowers pendulous with the segments strongly recurved.

A classification based on flower shape is inappropriate and ignores many more basic aspects of growth such as bulb habit and compatibility in breeding. Species such as *L. longiflorum*, *L. parryi* and *L. rubellum*, all Leucolirion, come from distinctly different parts of the world, have different forms of bulbs and are all cross incompatible. Comber (1949) proposed a more natural classification based on six major characters, namely:

1. Germination of seed, hypogeal or epigeal.
2. Germination, delayed or immediate.
3. Leaf arrangement, whorled or scattered.
4. Bulb scale, jointed or entire.
5. Seeds, heavy or light.
6. Bulb shape: (a) erect or (b) subrhizomatous
   (c) rhizomatous (d) stoloniferous.

On these premises, he classifies the genus *Lilium* into two subgenera, Cardiocrinum and Eulirion.

The subgenus Eulirion which includes all the plants now placed in the genus *Lilium* is subdivided into seven sections, notably: *Martagon, Pseudolirium, Liriotypus, Archelirion, Sinomartagon, Leucolirion* and *Daurolirion*. Comber developed this classification after cultivating and observing the living plants, including germinating the seed and it has been shown to be more natural in subsequent interspecific breeding. Woodcock and Stearn (1950) suggested that the genus should be divided into "about twenty groups of allied species". They divided lilies into two major sections, Old World Species and New World Species but apart from these divisions do not justify their classification. De Jong (1974) proposed a modification of Comber's classification based on phylogenetic grounds. He also divides the genus into seven sections but discards Comber's Liriotypus and Daurolirion. His classification then stands as: Sections, Lilium (Syn. Eulirion and Liriotypus), Martagon, Pseudolirium, Archelirion, Sinomartagon, Leucolirion and Oxypetala. The latter includes the section oxypetala of the genus *Nomocharis* on the basis of a paper by Sealy (1950).

1.1.2. Horticultural classification

As with many other horticultural plants, e.g. *Rosa* and *Chrysanthemum morifolium*, Ramat a botanical classification is not sufficiently exact to describe the many types of cultivars which are commonly grown, particularly when considerable interspecific and intercultivar breeding is undertaken.

The Royal Horticultural Society and North American Lily Society proposed a system of eight Divisions based on Comber's classification and often related geographically (Synge 1969). These Divisions are:

1. The Asiatic hybrids
2. The Martagon hybrids
3. The Candidum hybrids
4. The American hybrids
5. The Longiflorum hybrids

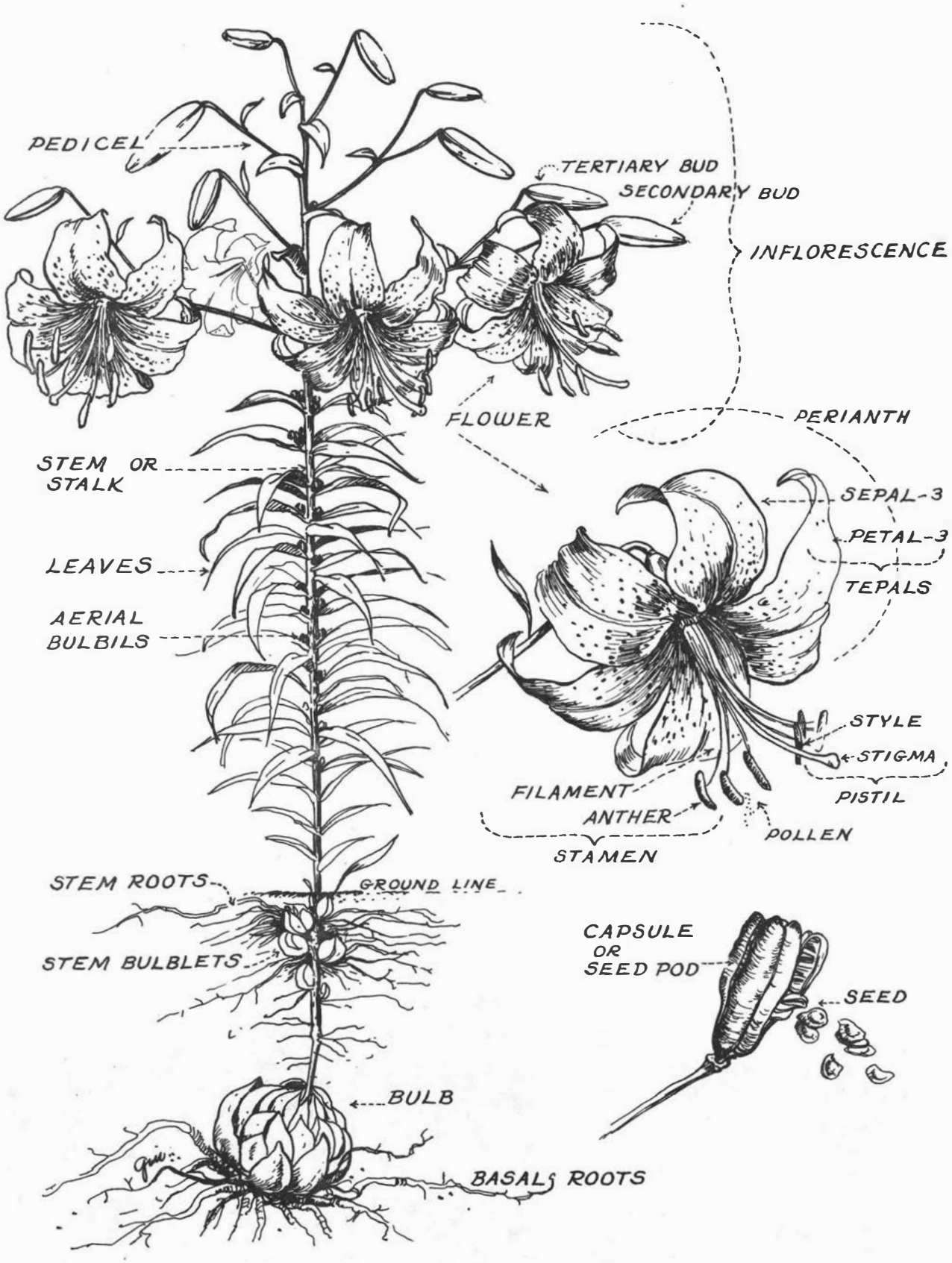
6. The Aurelian hybrids
7. The Oriental hybrids
8. All hybrids not provided for in any previous division
9. The Species.

The plants used in the experiments reported are classified as Division 7, the Oriental hybrids, being either a cultivar of *L. auratum*, specifically *L. auratum*, 'Little Gem' or a hybrid between this plant and *L. X parkmanni* 'Excelsior' named *L. X parkmanni* 'Little Robin'.

1.1.3. Comparison of Longiflorum hybrids and Oriental hybrids

One of the major features of *L. longiflorum* cultivars is the variation in numbers of flowers produced by bulbs of the same weight. Under appropriate conditions, primary (terminating), secondary and even tertiary flowers may be formed on a pedicel. In fact Roh and Wilkins (1975) indicated that replacing cool treatment of the bulbs with long days increased the number of flowers and indeed secondary and tertiary flower development. Alternatively Smith (1963) and De Hertogh and Wilkins (1971) showed that increasing periods of cool storage decreased the number of flowers.

Although secondary flowers may be subtended in *L. speciosum*, this is not a feature of dwarf cultivars of *L. X parkmanni*. Flower numbers per plant are stable and not affected by increasing periods of cool storage. However with inadequate cool storage secondary flowering can take place (Experiments 1, 2 and 5) but in these instances there was an extension of the growing axis after the initial flowering. In fact normal foliage leaves were produced on the stem between the initial and later flowers.



PRINCIPAL PARTS OF A LILY

(HOWIE 1964)

CHAPTER TWO

GROWTH AND DEVELOPMENT OF THE LILY PLANT

2.1. Studies on development

Despite the considerable emphasis on factors influencing flowering in lilies and particularly *L. longiflorum*, few studies have been carried out on growth and development of the whole plant, from the initial propagule to the mature plant and anthesis. Blaney and Roberts (1966) describe the development of *L. longiflorum* 'Croft' over a period of three seasons from initial bulblet to the commercial size bulb, but the majority of studies, e.g. Krythe (1938) with *Lilium regale*, Riviere (1969) with *L. candidum* discuss growth and development within the mature bulb, with emphasis on floral initiation.

It is understandable that concommitant with studies of factors affecting the flowering of lilies the development of the plants and floral initiation has also been investigated. Since the plants have been intended to be sold in flower, many of the studies have accentuated floral development and ignored other aspects, namely McArthur (1939), Kosugi (1952), Pfeiffer (1935), Emsweller and Pryor (1943), Smith (1963) all of whom described floral development in various cultivars of *L. longiflorum*. However such a limited study ignores the fact that several activities and morphological changes are taking place at the same time, some complimentary, others competitive.

Deeper studies of growth and development have been reported by Duchartre (1875) mainly with *Lilium giganteum*, (now considered to be *Cardiocrinum giganteum*), with less detailed descriptions of *L. cordifolium* (*Cardiocrinum cordifolium*). Krythe (1938) describes the growth of *L. regale*, but emphasises the aerial apices and ignores the growth of the roots. She points out that the daughter axis in *L. regale* is not evident until floral initiation in contrast with *L. longiflorum* 'Croft' where it is evident under natural conditions in December prior to this stage according to Blaney and Roberts (1966). Ohkawa (1977) similarly states that in *L. speciosum rubrum* the daughter

axis is not determinable until inflorescence differentiation takes place in the mother stem.

Similar dissection of plants of *L. X parkmanni* 'Little Robin' showed that the daughter axis was not discernable until stage P2 of the flowers had been reached.

Blaney and Roberts (1966) describe the growth of *L. longiflorum* from the initial bulblet to the saleable commercial bulb over a period of three growing seasons. Of particular significance is the development of the daughter bud. This is initiated adjacent to the flower stem in the axil of the innermost scale leaf and itself forms scales until anthesis of the mother bulb when foliar development continues until flower initiation.

2.2. Lily morphology

A longitudinal section through a mature bulb at anthesis shows three generations of growth:

a. The desiccated scales of the parent bulb.

b. The storage scales of the mother bulb, contractile roots, flower stem subtending stem roots, foliage leaves and flowers.

c. The daughter bulb and stem bulblets with their contractile roots.

There is in fact competition between mother bulb and daughter bulb as removal of inner bulb scales formed after sprouting accelerated anthesis while removal of the outer scales formed the previous year delayed flowering (Wang and Roberts 1970).

This can be explained partially by levels of growth regulators, specifically gibberellic acid and abscissic acid as Lin *et al.* (1975b) showed that GA activity was greater in the inner scales and ABA activity in the outer scales, although Lin *et al.* (1975a) showed that exogenous GA applications stimulated bolting, e.g. flower stem emergence. With bulbs cooled for 40 days at 4.5°C and then placed in a glasshouse at 15.5/21°C night and day temperatures, both GA and

ABA increased markedly with the highest ABA level occuring in the inner scales of the bulb.

An interesting unexplained feature was the fact that in bulbs stored for 80 days at 4.5°C both growth regulators were at a low level after this storage period.

2.2.1. Basal or contractile roots

As in other monocotyledons the basal roots are secondary. They develop from the basal axis penetrating this tissue and the vascular connections apparently directly associated with the bulb scales subtended on this axis. Duchartre (1875) and Stoker (1936) point out that the development of these roots occurs even in the seedling lily, the primary root produced by the embryo being ephemeral. They draw the young plant down into the soil, Stoker (loc. cit.) suggests to regions of greater moisture level; and this continues as the bulb increases in size. Stem bulblets also produce such roots early in their development and continue their production as apices are formed, and scales are differentiated. In a mature bulb the daughter bud produces contractile roots penetrating between the scales or even through the axis itself. The persistence of the roots is similar to that of the scales on the mother bulb.

The roots themselves contract in the adaxial area being rugose or corrugated beneath the bulb but smooth and branching towards the distal portion. They are similar in structure to those described by Chan (1952) and Chen (1969) in *Narcissus*. Chen states that these roots are shortened by longitudinal retraction and radial enlargement of the inner cortical parenchyma cells in the contractile region, while the outer tissues, including the outer cortical cells, exodermis and endodermis are lifted over the contracticle region.

The perennial nature of the basal roots of lilies contrasts with the annual roots of many perennial bulbs such as *Hyacinthsus* and reinforces their pachycaul structure. The latter is exemplified by *Agave* in which, according to Arber (1925), the roots are long lived and are increased by the annual development of fresh roots outside the older ones, as also occurs in the lily.

These roots originate in the basal axillary region the vascular strands being traced into that structure and then becoming indeterminable as described by Mann (1952) in garlic. It is unlikely that any root is associated with any specific scale or vascular bundle within a scale particularly as the roots die centrifugally while scales are absorbed centripetally.

Linderman *et al.* (1975) have stated that roots of lilies growing in soil in Oregon are associated with vesicular arbuscular mycorrhizae of two genera, namely *Glomus* and *Acaulospora*.

Examination of the lily roots grown in peat - sand medium showed no mycorrhiza when stained with lactophenol cotton blue, while Tincker (1947) also could not recognize any associated mycorrhizae.

Tincker (1947) summarizing the results of six previous reports particularly emphasized the need for adequate aeration of the growing medium and discussed the persistence of basal roots. He observed these roots on *L. superbum*, a plant which produces a bulb annually at the end of stout stolons. It was therefore possible to separate the roots of an older generation from those produced on a daughter axis.

The basal roots grew in summer as the bulb developed and by mid winter were approximately 25-35 cm long; these roots supported the growth of the flower stem and persisted 15-18 months. In *L. candidum* roots were formed by the daughter bulb both in spring and early summer and again when the radical leaves are formed in late summer and autumn. In *L. henryi*, new basal roots appeared to be produced continuously except for a short period in mid winter.

Grove (1942) ostensibly considering the resting period of the lily bulbs in fact dismisses their basal roots and time of production; he suggests that Asiatic lilies, e.g. *L. sargentii*, but not *L. henryi*, have a longer resting period when basal roots are not produced, than European and American species.

Generally therefore if basal root production is related to the growth of daughter bulbs their rhythm and persistence are similar.

The daughter bud is differentiated at floral initiation of the mother stem in early spring when roots emerge, these increase and extend during the summer with bud expansion, the flowering stem being supported mainly by stem roots. After anthesis the daughter bulb, now the major axis gradually decreases in activity and root production slows, finally ceasing during winter quiescence; the cycle continues as the next daughter bulb is formed.

An understanding of this rhythm of growth explains why basal roots persist for more than one season and also how bulbs grew, flowered and produced larger daughter bulbs even when basal roots were few, inactive or absent at planting as in the experiments 2 and 3.

2.2.2. Stem roots

In many species of *Lilium* particularly *L. henryi* and *L. regale* the basal roots are large and numerous. In contrast in both the cultivars grown by the author although present, they were not numerous and, as recorded in some instances, few were apparently healthy and active.

In contrast, the plants produced a profuse growth of stem roots on the underground portion of the stem, being apparent as soon as this region had completed growth after emergence. They appear internodally as well as nodally, their growth sometimes being fused after emergence.

Their abundant production suggests that the whole of this etiolated region is an intercalary meristem as the roots can be produced as a whorl around the stem. Esau (1965) states that the stem roots arise in the parenchyma in perivascular position.

The stem roots of lilies are more profusely produced than in graminaceous monocots, such as *Zea mays* where roots are produced mainly at the nodes and are not fused. Similarly in comparison, members of the Iridaceae such as *Gladiolus* develop a massive stem but produce only contractile roots from the basal axis both of the parent and the filial corms.

These roots are more efficient absorbers of moisture and nutrients than basal roots as they not only maintain the flower stem, but also enable the bulb to increase in weight as shown in experiments 1 and 2.

Some lilies, notably those of North American origin, do not produce stem roots and one can assume that the radical leaves act as the source of nutrients to the daughter bulb.

2.2.3. The stem

The main stem, or flowering axis, is initiated in the centre of the daughter bulb or bulblet. It is normally quiescent until after senescence of the mother axis and a period of winter chilling or its equivalent. Exceptionally in *L. longiflorum*, it may emerge coincidentally with the growth of the mother stem producing a condition known as "summer sprouting", this is more prevalent in cultivars such as 'Georgia' which are adapted to warmer climates (Roberts and Blaney (1967).

When a bulb is adequately mature, which may be in the first season with a large bulblet, or at least two years from seed in some species, the stem terminates in one or more flowers. Extension growth is therefore determinate and ceases when the pedicels of the flower buds are fully extended.

Leaf arrangement varies from whorls of leaves in *L. martagon* to a distichous arrangement in young stems of *L. speciosum* and *L. X parkmanni* In *L. auratum* 'Little Gem' study of mature stems showed a parastichy of two helices namely 8 : 13 and 5 : 13.

Snow (1958) proposed that in monocotyledons foliar helices are in threes. Plantefol (1945) had suggested that in *Lilium*, based on study of *L. candidum*, there was a law of juxtaposition as compared with a law of divergence. He considered that an ideal line joining the leaves showed that each leaf primordium was exactly contiguous with its predecessor. He also recognized three helices. The same author discussing *L. speciosum* (Plantefol 1946) considers that this is an exception as he could trace only two helices and the leaf bases did not

coincide. He also noted that beneath the flower a distichous arrangement occurred. This was also seen in the extension growth of bulbs which had been inadequately chilled in experiments. These had a fraction of ½. Similar phyllotaxy is shown by Ohkawa (1977) when plants made extended growth.

2.2.3.1. Fasciation

Although the stem after emergence is normally circular in section occasionally fasciated stems are produced in *Lilium* species and particularly *L. auratum*. Although not observed in *L. auratum* 'Little Gem', at least two plants of *L. X parkmanni* 'Little Robin' developed fasciated stems in experiment 5, although unlike other instances these stems branched soon after emergence, thus producing up to 54 flowers.

The cause of fasciation or predisposing factors have not been identified but Withers (1967) states that the tendency to fasciation can be transmitted genetically in lilies.

Ducker (1977) describes fasciation in *Lilium* stems as the development of a strap shaped structure often several inches broad. These fasciated stems have a "growing line" instead of a growing point, indicating many apical meristems side by side. She states that there is no complete explanation of the structural development of these stems, but observes that there are two theories, either that there has been an enlargement of a single apical meristem or that during development there has been fusion of many shoots. Since lilies at the vegetative stage normally have a single dominant apical meristem the former theory appears more acceptable.

As with other authors, she can offer no definite explanation for the cause of this phenomenon in lilies, though she suggests it occurs more frequently when the plants are grown under "exceptionally good growing conditions". She endorses the statement that certain strains of Oriental lilies are more prone to produce such stems.

2.2.3.2. Types of leaves

An aspect which has received little attention is the difference

between the leaves produced at the apex of storage scales of the immature bulb or bulblets, radical leaves, as compared with the foliar leaves of the main axis or flower stem of the lily, foliage or axillary leaves, typical of each species. The radical leaves differ in being more like a prophyll and possessing a definite petiole gradually merging into a lamina. They differ in shape from the axillary leaves.

Table 2.1: Dimensions in mm of leaves produced by (a) bulblet (b) base of flowering axis (c) centre of flowering axis, *L.* 'Little Robin'. 2.9.76 (Illustration)

	a	b	c
Width of lamina	27	26	47
Length of lamina	42	71	85
Width of petiole	1	3	8
Length of petiole	32	9	6

Radical or scale leaves are developed to the greatest extent in *L. candidum* where the scales of the daughter bulbs produce these leaves for a full season prior to the growth of the main axis. As the latter extends, the radical leaves senesce while the scales which subtended them are gradually absorbed.

Blaney and Roberts (1966) describing the growth of *L. longiflorum* from bulblets did not refer to the radical leaves or that some bulblets produce these leaves while others immediately develop a main axis. Matsuo (1972) discussing the growth of bulblets of those cultivars of *L. longiflorum* from the Riyuku Islands pointed out that these plants could show three different types of growth. There were bulblets with radical or scale leaves only, bulblets which bolted producing solely a main axis and an intermediate type exhibiting both radical leaves and a main axis. Matsuo and Arisumi (1975) identified the subsequent plants as hypogeous type plant (HTP), epigeous type plant (ETP) and hypo-epigeous type plant (HETP) respectively. Matsuo *et al.* (1977) relating the growth to propagation and bulblet size showed that larger parent scales produced larger bulblets with a higher ratio of ETP's and the greater the number of bulblets per scale the higher the ratio of

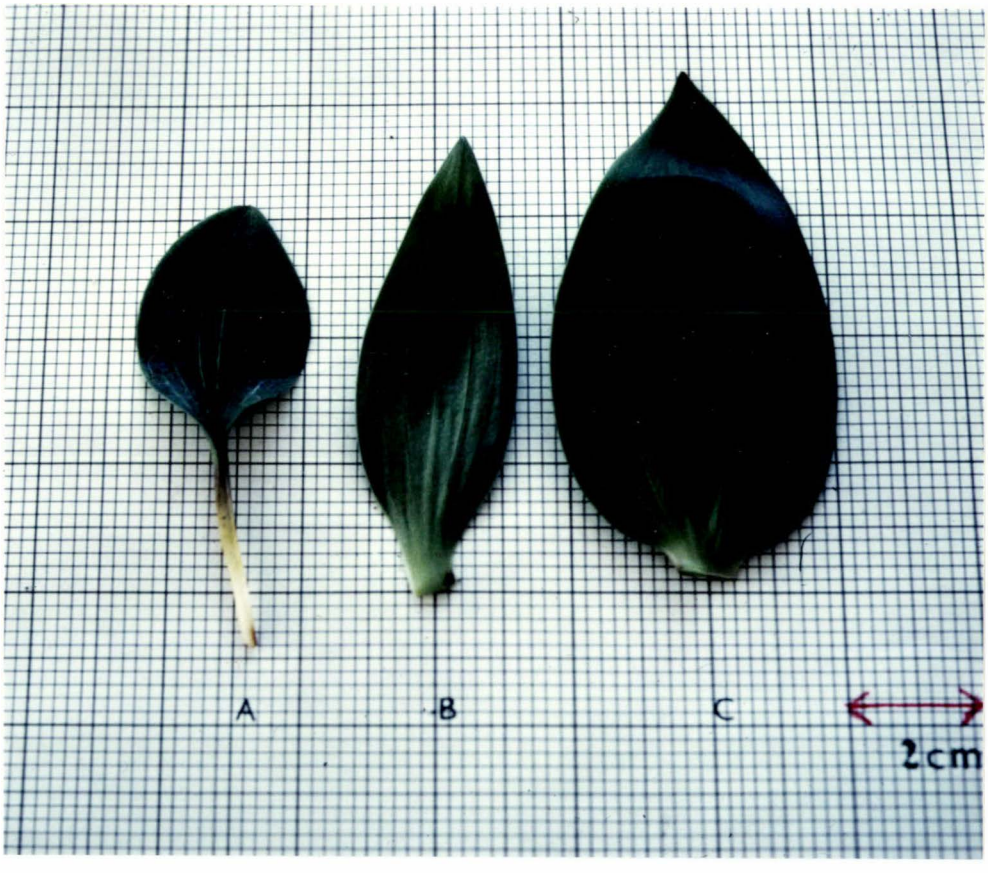
Photograph 1

Longtitudinal sections of *Narcissus*, Lily and tulip bulbs at dormant stage. Flower undifferentiated in Lily.

Photograph 2

Foliage of *L. x parkmanni* 'Little Robin'
A = Radical leaf from bulblet
B = Leaf from base of stem
C = Leaf from middle of stem


cm
0 1 2 3 4


A
B
C
2cm

HTP's. More HETP were produced on the middle or inner parent scales than on the outer scales.

Matsuo (1974, 1975) discussed the influence of light and temperature on growth of bulblets produced by scaling. He showed that scales placed in the dark at 25°C produced bulblets which tended to bolt as compared with those on scales exposed to the light or stored at 15°C. Bolting was induced more in bulblets grown subsequently at 15°C than at 25°C. Further stem growth was enhanced by high temperatures. This coincides both with recommendations given by Doreen (pers. comm.) and with natural conditions where bulblets are produced in the warm temperatures of summer on the portion of the stem below ground, undergo winter chilling and produce shoots during the rising temperatures of spring and summer. Since the parent stem has senesced the previous autumn the bulblets are independent plantlets and therefore subject to natural conditions uninhibited by their subtending parent.

Ontogenetically, one could consider the radical leaves as a primitive form and *L. candidum* either as a primitive species or an anomalous type; since it produces large radical leaves, is not stem rooting and does not develop stem bulblets.

2.2.3.3. Axillary leaves

When a bulb is adequately mature to produce a main stem, no further radical leaves are produced by the scales. At the base of the stem however transitional leaves are produced; these are swollen with storage material similar to the scales, gradually becoming membraneous and then photosynthetic when the axis emerges from the bulb and is exposed to the light.

In all experiments some of the lower photosynthetic leaves abscissed, the proportion of those that abscissed were recorded in 1975. On twenty plants the number of leaves retained to number of nodes was 1 : 1.9.

Schenk (1974) states that with *L. speciosum* forms and Oriental hybrids, temperatures below 18.3°C at night in the autumn will induce yellowing and dropping of the leaves. The glasshouse conditions imposed during this experiment were below this temperature for up to 12 hours continuously through the night.

The majority of the axillary leaves on lilies are without a petiole, but the leaves of both *L. auratum* 'Little Gem' and *L. X parkmanni* 'Little Robin' possess a short petiole and their obovate shape is exceptional in lilies.

2.2.4. The flower

Unlike tunicate bulbous plants, flower formation in lilies does not take place until the stem has emerged from the bulb; this stage of growth is completed while the buds are still enclosed by the apical leaves and has been described by Creamer *et al.* (1974). They maintain that the flower is subtended by a bracteole although this is not present as the flowering axis extends, although each flower is subtended by a bract. Flowers are normally produced individually on each pedicel exceptionally in *L. speciosum* and *L. longiflorum* secondary and tertiary flowers develop on some of the pedicels.

The flower comprises two whorls of three tepals each segment being separate but attached to the receptacle and alternate with those of the adjacent whorl.

Measurements of individual flowers of *L. X parkmanni* 'Little Robin' are stated in Appendix 5.

Wilson (1925) describes the flowers of the species *L. auratum* as "powerfully scented bowl-shaped 25-30 cm across, white spotted with carmine, crimson or purple, rarely with yellow, each segment with central stripe of yellow (sometimes crimson), racemose 1-10 (under cultivation sometimes 30 and more, on wild plants usually 2-6): pedicels rigid, spreading or ascending spreading 4-10 cm long ..... Perianth segments spreading, forming a short, wide funnel recurved at the apex lanceolate to lanceolate-ovate, 11-18 cm long, 2.5-5 cm wide, inner the broadest,

apiculate and slightly pappilose at the apex, narrowed to base, lowerface with scattered, raised, fleshy, coloured papillae, keeled without, nectariferous furrow 3-4.5 cm long, glabrous; stamens shorter than perianth, 7-13 cm long, filaments glabrous, anthers 2-2.6 cm long, pollen chocolate red; pistil overtopping stamens, shorter than perianth, ovary 2-3.5 c, long, style thickened upward, stigma capitate. Fruit oblong, 5-8 cm long, obtusely 6 angled, summit slightly depressed".

The flowers tend to be protandrous, pollen grains being adhesive. The stigma exudes copious sugars in solution (illust4).

2.2.5. The nectaries or osmophores

Fahn (1974) has classified floral nectaries or osmophores into five types:

(i) Perigonial nectaries where they develop close to the base of the perianth parts or in spurs formed by these parts.

(ii) Toral which develop on the receptacle either marginally between the base of the sepals and petals, or annually in a ring on the surface of the receptacle or tubularly, in a tube-like receptacle.

(iii) Staminal nectaries related to stamens.

(iv) Ovarial nectaries which develop on the ovary wall.

(v) Stylar nectaries at the base of the style.

Ovarial nectaries may develop on all the free surface of the carpels, on the ovary base or septally on the partitions of monocotyledonous syncarpous ovaries. This final position occurs in the monocotyledonous families of Liliaceae, Musaceae, Amaryllidaceae and Iridaceae.

In *L. X parkmanni* 'Little Robin' it appears that the nectaries are perigonial and close to the base of the perianth parts. This was determined by sectioning longitudinally young mature flowers and standing them in a solution of neutral red 0.125% in 50% ETOH as referred to by Esau (1965) quoting Vogel (1962).

2.2.6. Fruit and seed

The fruit is a trilocular capsule with two rows of ovules in each locule, placentation is axile and dehisience locucidal.

Fertile seeds are flat, circular with a central fleshy endosperm in which the embryo is embedded, the whole being surrounded by membraneous tissue.

There is some variation of seed size between species and in interspecific hybrids. Under normal conditions the seed is distributed close to the parent plant, being too heavy for wind dispersal and unattractive to grain eating birds.

CHAPTER THREE

FACTORS INFLUENCING THE FLOWERING OF LILIES

3.1. Inductive factors

Lang (1965) maintains that flowering of higher plants can be divided into three major stages, namely:

1. Flower initiation marking the change from vegetative to reproductive growth.
2. Flower organization, although he questions whether this should be separated from stage 1.
3. Flower maturation or flower development where the flower develops to maturity, terminates in anthesis and is followed by fruit and seed development.

The plant must have achieved ripeness to flower, in which it produces a certain number of leaves or nodes before the first flowers can be formed. If this principle is applied to a bulb, flowering will take place, provided conditions are suitable, when it has achieved a certain size depending on the species. As the bulb scales are ontogenetically leaf structures, the same criterion can apply to these plants.

Lang (1965) points out that in many plants flower initiation is dependent on the interaction of the genotype and very specific environmental conditions especially the inductive factors of low temperature and photoperiod.

In bulbous geophytes photoperiod is not normally an inductive feature, but temperature is certainly the major inductive factor.

Rees (1972) in fact states that temperature is the most important factor affecting initiation and subsequent floral development in bulbs. This can be readily appreciated when the provenance (origin) of these plants and the fact that they are geophytes are considered. Hartsema

(1961) states that flower formation is not affected by light or day length. Although this may apply to her groups 1, 2, 3 and 6 where spathe is formed the previous season, in plants of groups 4 and 5 flower formation occurs in the current season when leaves have already emerged.

In certain genera of group 5, e.g. *Gladiolus*, adequate light is required for flower formation (Shillo and Hartsuiker 1976). Recent studies by Roh and Wilkins (1977a) show that extension of the day length can substitute for chilling by stimulating flower formation in certain cultivars of *L. longiflorum*. However temperature is still the major factor in flower formation and anthesis in *Lilium* species.

3.2. Vernalization

Vernalization is a phenomenon or treatment to which many plants respond; especially those which are in a vegetative condition at the onset of natural cold temperatures and then change to the reproductive phase under subsequent warmer conditions. Artificially it can be applied at any time appropriate to the responsive plant.

Chouard (1960) defines vernalization as the substitution of chilling a plant for the natural exposure to winter in order to make possible the initiation of flower primordia later. He points out that vernalization induces or hastens the development of the capacity for flowering and that although its action is not visible at first, the plant responds later. He rejects the derived meanings of either any physiological effect of chilling corresponding to the awakening of nature in spring or any physiological action stimulating the capacity for flowering, whatever the agency. He summarises his definition as "The acquisition or acceleration of the ability to flower by a chilling process" and stresses that it is essentially a preparatory process which is revealed by an after effect.

Lang (1961) referring to photo- and thermo-induction points out that vernalization is most typically expressed in the winter annual and biennial plants both of which begin their life cycle in one year and complete it in the next. In the former, thermo-induction is

quantitative in that they will form flowers without chilling although only with a greater or lesser delay. In biennials, thermo-induction is qualitative or obligatory.

If one considers a single growth bud, e.g. daughter bud within a lily bulb, this is formed in one season and flowers the next, although the bulb as a unit is perennial. The daughter bud can be compared with a winter annual and vernalization is quantitative or facultative.

Discussing temperature effects on *L. longiflorum* 'Ace', Langhans and Weiler (1971) indicated three responses depending on the level of the temperature:

(a) Vernalization at a level of $4^{o}C$ for six weeks for *L. longiflorum* 'Ace".

(b) Devernalization, which they set at temperatures above $21^{o}C$ before flower induction.

(c) Non-vernalizing temperatures which are above $21^{o}C$.

They realized that photoperiod can modify the vernalization period, but the response to day length occurs when the bulbs are mature and shoots have emerged.

The difference between devernalization and non-vernalization depends on the stage of development of the shoot; if flower induction is not complete, application of temperatures above $21^{o}C$ can be devernalizing, and subsequently plants will flower, but at a later period.

Non-vernalizing temperatures are those continuously maintained above $21^{o}C$, at least with *L. longiflorum*, before any flower induction takes place.

They state that high temperatures applied before leaf induction will delay flowering but induce an increase in flower number.

3.3. Dormancy in lilies

The majority of higher plants from temperate or cooler regions, e.g. those that experience a seasonal variation in temperature, show a similar seasonal pattern of growth and frequently exhibit a temporary cessation of growth above the ground although internal changes may be taking place. Kamerbeek *et al.* (1972) discuss dormancy in bulbs and corms, in which there is a rest period in which phenotypic development is arrested, although the definition of dormancy by Amen (1968) is quoted they comment that he uses qualitative terms such as "temporary" and "relatively".

They divide bulbs and corms into three groups in relation to their types of dormancy, namely:

Group I "Lily-type" dormancy. Bulbs and corms with true physiological dormancy. *Lilium*, *Allium*, *Gladiolus*, etc.

Group II "Tulip-type' dormancy. Bulbs in which hardly any true physiological dormancy can be observed. *Hyacinthus*, *Narcissus*, *Tulipa*, etc.

Group III bulbs in which apparently no true or physiological dormancy can be observed; bulbous *Iris*.

Considering in the present context Group I types only, they consider that the dormant condition which occurs before flower formation is an overall dormancy and rather deep. In the growth of these plants three morphogenetic successive developmental stages can be distinguished:

1. Formation of bulb scales or corms.
2. Formation of leaf and stem primordia.
3. Formation of one or more flowers.

Dormancy occurs chiefly at the end of stage one, although some leaf primordia are formed during apparent dormancy, no emergence of stems normally occurs. Considering the daughter bulb of a lily, scale formation ceases and dormancy commences at anthesis of the mother stem.

Low temperatures cause dormancy release in all cases of lily type dormancy, particularly in that genus, although there may be cultural differences within the genus. This release can be compared with the release from physiological dormancy of the buds of some woody plants following chilling. Dormancy is also exhibited in seeds of certain species, most frequently in those with hypogeal germination, e.g. *L. japonicum*. In such cases dormancy occurs after emergency of the radicle and the formation of the initial bulb. It could in fact be considered delayed emergence. This condition of quiescence of growth is satisfied by the application of cool temperatures (Section 3.2).

3.4. Forcing of lilies

Bailey (1933) defines forcing inter alia as the production of flowers from bulbs and tubers in a very short time under the influence of very high temperatures. This coincides with the Dutch view of forcing where treatment of bulbs prior to their growth at high temperatures is not considered part of the forcing process. Rees (1972) referring to general aspects of forcing *Narcissus* and tulips discusses forcing systems which are aimed at giving the bulbs the necessary cool period at a time when the outside temperatures are ineffective and transferring the bulbs into warm conditions when the cool period is satisfied.

The use of the phrase "forcing system" is significant indicating a continuing process rather than one stage of production. De Hertogh (1974) has amplified the idea of a system where he divides this into three phases:

1. The production phase in which the bulbs are grown to a size and condition suitable for the stage 2.
2. The programming phase which covers the period from post harvest to placing in the greenhouse.
3. The greenhouse period which accelerates the development of the plant until anthesis or the marketing of the plant.

3.4.1. The Production stage

Applying this to the lilies grown in this study, the production phase requires the growth of the bulbs through a whole season until senescence and their subsequent harvesting and storage under cool, moist conditions. This is in contrast to other bulbs particularly tunicate bulbs which are maintained in dry conditions at temperatures of 15-18°C.

3.4.2. The Programming stage

Programming involves, with lilies, a period of at least six weeks at temperatures between 3 and 12°C, there being little difference between the effect of these two temperatures, as compared again with bulbs such as *Narcissus*, other than *N. tazetta* cultivars, which responds to 8-9°C, tulip cultivars as Darwin hybrids 5°C or Triumph or Darwin cultivars 9°C or Dutch iris 9-15°C. The difference in response is due, partially at least to the various development stages of the bulbs at time of treatment, indicated by Hartsema (1961). Cool temperatures in the case of *Narcissus* and tulip influencing scape elongation only, in Dutch iris initiating leaf and flower formation, while in lilies such temperatures are initiatory only.

3.4.3. Stage 3. The Greenhouse stage

The greenhouse phase, applying above ambient temperatures, at least in areas of higher latitudes than 40°C, naturally hastens anthesis. At this stage also the influence of level of temperature varies. In the case of *Narcissus*, temperatures above 18°C can negate prior cool temperatures. With tulips stored at 9°C for six weeks flower abortion occurs or decreased stem length is observed. The flowers fail to emerge from the stem leaves while those bulbs stored for 10 weeks or longer at 5°C will flower satisfactorily with adequate stem length (Dickey 1957, Salinger 1976).

With Dutch iris such a temperature is satisfactory provided light levels are adequate. However lilies respond exponentially to increasing temperatures though light levels must not be inhibiting. The response of plants to these temperatures can be correlated with

their origin, e.g. provenance and flowering period under natural conditions.

3.5. The influence of temperature on reproduction of lilies

3.5.1. Germination of seed

Temperature is the determining factor in germination of normal seeds provided there is adequate moisture and air present, that the seeds are not infected by pathogens, nor that germination is restricted by internal or external inhibitors.

Temperatures for germination are normally considered as minimum, optimum and maximum although Thompson and Fox (1976) have shown that these are not absolute and Heydecker (1977) has obtained more rapid germination by "priming" seeds such as onion and cyclamen with an osmoticum prior to germination.

In his classification of lilies Comber (1949) lays emphasis on the different forms of germination in this genus. Germination can be epigeal or hypogeal, immediate or delayed.

The response of different species of lily has been recorded by Rockwell *et al.* (1961). Of the plants grown in this experiment *L. auratum* 'Little Gem' has delayed hypogeal germination while *L. X parkmanni* 'Little Robin' and hybrids between the two exhibited immediate hypogeal germination. This difference is understandable as strains of *L. speciosum* can exhibit both immediate and delayed hypogeal germination (Withers 1967).

In delayed hypogeal germination the seed is germinated at 20°C for three months during which time the primary root and bulblet is formed. After storage for 4-6 weeks at 2-6°C the bulblet is then sown in growing media at a temperature of 12-15°C. The first true leaves being produced. These leaves are often of a different shape from stem leaves and could be considered prophyll or radical leaves (Section 2.2.3.2.).

In immediate hypogeal germination, seed germinates and the prophylls are produced at the same temperature as that applied for germination. In the experiment with the hybrids produced in 1975 between *L. auratum* 'Little Gem' and *L. X parkmanni* 'Little Robin' seed was dusted with Captan dust 10% a.i. and placed in plastic bags mixed with moist pumice. These were stored at 20-22°C and germination took place in two months, subsequently as the prophyll and basal leaves were formed the plantlets were transplanted to individual containers and placed in a glasshouse at 16°C night 20°C day temperature for four months. Two further leaves were formed but no stem. Finally they were planted outdoors in early October and stems developed, presumably due to lower temperatures overcoming the inhibition of the prior higher temperatures. The requirement for chilling to induce subsequent growth is similar to that required by bulblets of some species produced from scales.

In some species exhibiting immediate hypogeal germination, such as *L. concolor* and *L. pumilum*, the plants can achieve anthesis at temperatures exceeding 15°C, without any prior chilling, within nine months of sowing the seed (Rockwell *et al.* 1961).

In slower growing species and hybrids the plant produces basal leaves the first season and after winter quiescence, a stem with foliage leaves and occasionally flowers in the second season of growth.

3.5.2. Epigeal germination

Similar temperature regimes are required by delayed and immediate epigeal seeds, though in these plants a cotyledon is produced followed by a prophyll and basal leaves.

3.5.3. Temperature and fertilization

Many lilies are self incompatible, and some may be cross incompatible. Even where species or hybrids are cross or self compatible temperature is an important factor in successful fertilization.

Ascher and Peloquin (1970) obtained complete penetration of the style of the pollen tube at temperatures of 31 and 39°C in *L. longiflorum*, while Myodo (1962) considers that the optimum temperatures for pollen tube development in *L. longiflorum*, *L. speciosum*, and *L. formosanum* were between 25 and 30°C the lower temperature is suitable for early flowering species and later flowering species require higher temperatures. Pollen tubes should reach the top of the ovary in 48 hours. *L. auratum* 'Little Gem' is self compatible and although no records were kept, it was noted that capsules on plants in glasshouses matured more fertile seeds than on those plants grown outdoors.

In 1976 an observation experiment was carried out backcrossing *L. X parkmanni* 'Little Robin' with *L. auratum* 'Little Gem' and selfing the latter.

On 30 January, six flowers of *L.* 'Little Robin' were pollinated with pollen from *L.* 'Little Gem' and after emasculation of six mature buds of *L.* 'Little Gem', which is self compatible, this cultivar was pollinated with pollen of *L.* 'Little Robin'. Six buds of *L.* 'Little Gem' were selfed. All plants were maintained in the glasshouse.

It was noticeable that following crosspollination the styles of the female plant remained green, while in self pollinated or non pollinated plants of *L.* 'Little Robin', the styles senesced approximately one day after the petals had senesced. Pollinated capsules developed and produced copious fertile seed changing in colour at maturity from green through yellow to pale brown, straw colour.

Maturity of the capsules varied in date.

L. 'Little Gem' selfed 18 May
L. 'Little Robin' x *L.* 'Little Gem' 25 May to 2 June
L. 'Little Gem' x *L.* 'Little Robin' 2 to 4 June.

Seeds of these crosses were subsequently sown and these germinated satisfactorily.

3.6. Reproduction asexually

Bulbous geophytes have achieved a high level of efficiency in vegetative reproduction; particularly when the basal axis is damaged. In fact, wounding of this region is carried out intentionally to stimulate the production of bulblets in hyacinths, while in amaryllidaceous plants as *Hippeastrum*, *Narcissus* and *Nerine* the basal axis and a small portion of two bulb scales can be cut into sections and treated as cuttings; bulbs are then formed on the axis at the base of the two scales. This process, called twin scaling, has been described by Tompsett (1972).

In lilies, bulblets develop in the lower nodes of the stem, on detached scales and even within a bulb if scales are rotting from pathogenic or other causes; the basal axis is not involved in this bulblet production, one can in fact consider scale bulblet production as a form of leaf cutting. Similar bulblet production from detached foliage leaves occurs in *Lachenalia* and plantlets from leaves or leaf sections of *Sanseveria laurentii* (Agavaceae).

Bulbs will continue growth without the requirement of cool temperature although Doreen (pers. comm.) states that shoot growth is enhanced if chilled at $5^{o}C$ for one month prior to planting.

Bulblets produce radical leaves and in rapid growing clones, stems in the one season (see Section 2.2.4.1).

3.7. The influence of light on flowering in lilies

Light is of course essential for the satisfactory growth and flowering of green plants, the three components of light being intensity, photoperiod and wavelength.

3.7.1. Light intensity

Under natural conditions light is not a limiting factor in the growth, flowering and vegetative reproduction of temperate bulbs and corms. When, however, bulbs are forced, e.g. grown for flowering prior to their normal time, light as a portion of total irradiation can

be a limiting factor especially in higher latitudes. In *Iris* for instance, lack of light can cause "blasting", a drying out of flowers after initiation (Rees 1972), as these plants unlike *Narcissus* and tulips depend on current photosynthesis to complete development of the inflorescence. That the two latter and hyacinths do not require a high light intensity, is indicated by the fact that they may be flowered in artificially illuminated "growing rooms" (de Pagter 1972, Anon 1972) where light intensity may be lower than under normal natural conditions.

Similarly when *Gladiolus* are grown in lower latitudes for flowering in winter, lack of light can cause blasting, particularly at the developmental stages of four to six leaves (Shillo and Halevy 1976).

In lilies, as with *Iris*, completion of flower formation and anthesis is associated with continuous photosynthesis and carbohydrate production.

Under low light intensity, lilies such as *L. longiflorum* and Asiatic hybrid 'Enchantment' may suffer from "bud blasting" in which the developing flowers turn yellow and shrivel, but do not abciss (Schenk and Boontjes 1970, Einert and Box 1967).

Kamerbeek and Durrieux (1971) state that the application of adequate light to lily 'Enchantment' when 70% of the pollen mother cells were in the meiotic stage was the critical time to inhibit abscission. They also found that the longer the bulbs were stored at low temperatures the less the abscission of buds even when the plants were grown in an 8 hour photoperiod,

3.7.2. Light as a substitute for vernalization

It has been known that in plants which require vernalization and which have photosynthesising organs, as compared with a seed such as rye, additional light can partially or almost wholly replace vernalization.

Recently Roh and Wilkins (1975) have shown that superior plants, as compared with cool stored bulbs, were obtained with *L. longiflorum* 'Ace' and 'Nellie White', if long days were applied to non-vernalized bulbs after emergence of the shoots. The highest bud numbers were obtained with 10 long days, 20 normal days and 20 long days; the treatment being 40 ft-c of incandescent light applied for 5 hours in the middle of the dark period. Subsequently the highest number of buds reaching anthesis was obtained by reducing the growing temperature 10°C for 7, 10 or 14 days, depending on the date the plants are required to flower (Wilkins and Roh 1977).

This reduction in temperature enhances further development of the secondary and tertiary buds. The interrupted day length is similar to the technique applied to chrysanthemums to increase disc floret numbers (Van Veen 1969).

3.7.3. Photoperiod

The response of lilies to extended day length and the substitution of long days for vernalization indicates that they are in fact quantitatively photoperiodic. Vince-Price (1975) does not refer to plants of the genus *Lilium* in her text; however those lilies that show a photoperiodic response could be classified under the heading 3a; "LDP, require or accelerated by low temperature vernalization".

C H A P T E R F O U R

THE GEOPHYTIC HABIT

4.1. Geophytes

The classification of higher plants proposed by Raunkiaer (1934) is extremely useful in categorizing plants of diverse origins and families with similar characteristics thereby constructing a biological spectrum (Kershaw 1964). The plants are classified by the amount and kind of protection to the perennating buds and shoot apices.

Within this classification his fourth class was cryptophytes in which "the surviving buds or shoot apices are buried in the ground at a distance from the surface that varies in the different species" (Raunkaier loc. cit.).

Division 12 comprises geocryptophytes or geophytes further subdivided into rhizome geophyte, bulb geophyte, stem tuber geophyte (including corms) and root tuber geophytes.

He therefore formalized morphological forms already accepted by horticulturists and botanists, but significantly he based his theory and classification on the premise of the evolution of the present flora in a climate more moist and uniformly warmer than at present, thus agreeing with Holttum (1954) and Corner (1968) in this idea.

He proposed the measurement of hydrotherms, e.g. seasonal temperatures and precipitation, and tabulates the types of plants both from regions of different lattitude and also different altitudes in the same latitude. He makes the statement "Of all the factors necessary for plant life, water is the one which over vast expanses of the earth's surface most nearly approaches the status of limiting factor".

Accepting his hypotheses it is possible to appreciate their significance in relation to geophytes in general and bulbs in particular.

The winter and spring foliage and flowering of *Narcissus*, and bulbous iris, of corms such as *Ixia* and *Freesia* is followed by summer dormancy, with the buds below ground during the period of summer heat and natural water deficit, typical of a Mediterranean climate. In contrast most lilies are quiescent in winter with no foliage above the ground (*Lilium candidum* is an exception) followed by summer foliage and flowering with gradual senescence in autumn. This indicates that they originated in regions of adequate summer rainfall or at least soil moisture, which is effectively absorbed by the mass of stem roots.

In contrast, autumn flowering bulbs such as *Amaryllis belladonna* and some *Nerine* species, e.g. *N. corusca* produce foliage immediately after flowering, which persists over winter and spring and gradually senesces in summer. These again are plants where water and heat are limiting factors in summer. It is of interest though that *Nerine bowdenii* and *N. flexuosa* in New Zealand do not produce foliage until the spring and under moist conditions this may persist until or after flowering in the autumn, followed by winter dormancy. We can assume that these species evolved in moister regions with a colder winter, in fact Norris (1975) has pointed out that one species, *N. gibsonii* is often totally submerged in water.

4.2. Comparison of geophytes

Raunkiaer wisely divided the geophytes into rhizome, bulb, stem tuber (corm) and root tuber geophytes. Apart from their obvious structural differences listed below, there is a significant difference in their growth and flowering habit, particularly when considered from the period of dormancy, this being the stage they are usually planted.

From this stage of development or growth deciduous bulbs are unique in that, provided they are at the stage of "ripeness to flower", flowering is the completion of the growth cycle commenced the previous season by a specific bud or daughter bulb.

In rhizomes, for example *Iris germanica*, leaves are formed one season, flowering takes place the next season, and the leaves may persist without flowering for at least one more year.

With stem tubers, e.g. potato and corms such as *Gladiolus* and *Freesia*, one or more buds are present on the tuber and these must complete a full life cycle in the season of growth; there is only limited differentiation of leaves at planting time and as Shillo and Halevy (1976) have shown in Gladiolus, foliage and flower formation takes place after these parts have emerged and are in active growth.

Similarly with root tuber geophytes as in *Dahlia* the buds at planting time are in an embryonic state and differentiation occurs during the growing season; it is an interesting phenomenon that tuberization is partially controlled by photoperiod, particularly in *Dahlia* and *Begonia tuberhybrida* by short days (Vince Prue 1975); this influence does not operate in rhizomes, bulbs and corms, whether spring, summer or autumn flowering.

Finally it should be mentioned that when raised from seed certain genera of the four forms of geophytes may complete all their growth cycle within the one season, even forming a large enough storage organ to grow and flower the following season.

Examples of each group being:

RHIZOME

Agrostis stolonifera

BULB

Lilium formosanum (exceptional in *Lilium*), *Chionodoxa lucilliae*, *Endymion non-scriptus*

STEM TUBER (Corm)

Freesia refracta

ROOT TUBER

Sinningia speciosa
Anemone coronaria

Table 4.2: Comparison of structure of Geophytes

	Type of geophyte			
	Rhizome	Bulb	Corm	Root Tuber
Structure of organ	Branching	Compressed	Compressed	Compressed
Structure of storage tissue	Solid	Separate Scales	Solid	Solid
Growth apices	External	Internal	External	External
Protection of apices	Naked	Scales	Scales (naked in stem tuber)	Naked
Roots	Contractile at nodes	Contractile occasionally stem	Contractile mother & filial	Non-Contractile
Leaves	Basal & stem	Basal & stem	Basal & stem	Stem
Filial buds	At nodes on rhizome	Subtended by scales and occasionally leaves	Basal & stem	Stem

4.3. Definition of bulbous geophytes

When considering the structure of a plant and its response to environment conditions, it is desirable to define the plant initially. The term bulb geophyte of Raunkaier or bulb of the horticulturist covers a wide range of genera, although the plant structures themselves have a common ground plan.

Various definitions have been offered, some more complex than others; for instance Bailey (1933) considers that a bulb is a thickened fleshy and commonly subterranean bud, usually emitting roots from its under side. Anon (1951) states that a bulb is a modified shoot consisting of a small more or less disk-like stem or "plate" bearing a more or less spherical mass of leaves above and developing adventitous roots below. Synge (1961) modifies this definition slightly in describing a bulb as a modified shoot with a disc-like basal plate and above it a number of fleshy scales ... each year from near the centre a new stem with or without flower buds arises.

Hartmann and Kester (1975) provide a useful definition in stating that a bulb is a specialized underground organ consisting of a short fleshy usually vertical stem axis (basal plate) bearing at its apex a growing point or a flower primordium enclosed by thick fleshy scales. Rees (1972) states that a bulb can be described as an organ consisting of a short stem bearing a number of swollen fleshy leaf bases or scale leaves with or without a tunic, the whole enclosing next year's bud.

One of the most exact definitions is that of Arber (1925) in which she says "whereas a corm is a thickened axis whose associated leaves contain little reserve material, a bulb is a reduced and abbreviated axis which itself stores little food, but is crowded with leaves or leaf bases whose cells are full of reserve substance. It is, as it were, a telescoped shoot, in which the internodes have almost no elongation".

Of particular significance is her use of the term "thickened axis" instead of the more inaccurate horticultural phase "basal plate" or "disc". De Hertogh *et al.* (1971) have defined the basal plate as

a perennial shortened modified stem which has a growing point and to which scales and roots are interjoined. De Hertogh (1973) also recognized a separate region, the root plate which he defined as the raised portion of the basal plate from which roots emerge. Chan (1952) referring to *Narcissus* calls this region the stem plate, apparently ignoring the origin of roots from this area. However when considering a tunicate bulb such as *Narcissus*, there is a distinct basal suberised region around which the roots are subtended. In imbricate bulbs such as lilies this area is not so distinctly developed and the basal roots grow through the basal region.

Both the words "plate" and "disk (c)" suggest a flattened structure, Garmonsway (1965) defining a plate as flat, shallow and round, a disk (c) as a round flat thin object, while he defines an axis as, inter alia, the central core of an organism or organ.

Rees' definition could be modified and completed by stating that a bulb is an organ consisting of a compressed stem or basal axis bearing a number of swollen fleshy leaf bases or scale leaves, with or without a tunic, subtending roots and enclosing the following season's bud.

Finally Stoker (1943) described a "lily unit" as a single bulb made up of scale leaves which are attached to a basal thick and flattish axis or disc. To this could be added "and subtending perennial roots".

4.4. Comparison of lilies with other types of bulbs

Monocotyledonous bulbs can be classified in various ways, periodic, structural or thermo-responsive.

4.4.1. Periodic classification

The periodic aspect relates to the normal time of anthesis, listed by Hartmann and Kester (1975) and is associated with provenance or origin (Table 4.3). Those bulbs flowering in winter or spring as *Galanthus* or *Leucojum vernum* are from cool temperate regions, while lilies as stated occur naturally in temperate or warm temperate areas and are summer flowering. Autumn flowering bulbs as *Amaryllis belladonna* occur naturally in the Mediterranean climate of South Africa.

Bulbs of the moist tropics such as *Hippeastrum vittatum* flower after the formation of an adequate number of foliage leaves; flowering is periodic.

4.4.2. Structural classification

Rees (1972) postulates three types of bulbs based on structure:

I. The *Hippeastrum* bulb type in which the bulb is composed entirely of leaf bases, the daughter bulbs being formed in the axils of the older scales.

II. The tulip bulb which is entirely composed of scales which enclose an axis bearing leaves and terminating in a flower; the lateral buds being borne in the axils of the scales.

III. The *Narcissus* bulb type where the bulb comprises both scales and leaf bases. He considers that the mature large *Narcissus* bulb is a branching system made up of annual increments. A lily bulb can be classified as a modified form of *Narcissus* type as this also comprises both scales and leaf bases, but there is a transition type of leaf at the base of the stem; these being partly swollen but not emerging from the bulb as true photosynthesising foliage leaves. In addition the presence of perennial basal roots and adventitious stem roots in most species differentiates lilies markedly from the tunicate bulb.

When describing a lily bulb, Rees bases his description, without stating it, on *L. candidum* which produces radical leaves in the autumn; this species is an exception to most lilies which do not produce radical leaves. It is possible that the swollen transitional leaves of *L.* 'Little Robin' are a relic of radical foliage leaves.

He considers that a *Narcissus* bulb is a four season branching system while in tulips, the buds are 2.5 year entities. In lilies, Blaney and Roberts (1966) and observations during this study indicate that 18-21 months covers the period from apex formation to anthesis although within that time there are three generations of bulb scales and two flowering apices (see Table 4.3).

Table 4.3: Comparison of five bulbous plants in relation to provenance

Species	*Narcissus tazetta*	*N. pseudo-Narcissus*	*Tulipa*	*Iris xiphium*	*Lilium*
Provenance	Spain - Japan	W. Europe	Iran	Morocco	Circum polar lats. 15-50°
Senescence	Mid summer	Mid summer	Mid summer	Mid summer	Late autumn
Quiescence	Late summer	Summer	Summer	Late summer	Winter
Leaf initiation	Mid summer	Mid summer	Mid summer	Autumn	Late winter Spring
Flower formation	Late summer	Mid summer	Mid summer	Late autumn	Spring
Anthesis	Autumn Winter	Spring	Late spring	Late spring	Summer

4.4.3. Thermo-responsive classification

On the basis of many studies carried out by Blaauw and his co-workers in Europe, Hartsema (1961) distinguishes seven different types of geophytes based on their flower formation in relation to temperature, although this cannot be separated from periodical development. She distinguishes these plants in the following fashion:

1. Flowers are formed during spring or early summer of the year preceding that in which they open, shortly after that year's flowering is completed and some time before the bulbs are harvested; *Narcissus*, *Galanthus*. Warm temperatures of 15-20°C are required for flower formation.

2. Flower formation occurs after the end of the previous assimilation period, i.e., after the bulbs are harvested, during the storage period; *Tulipa*, *Hyacinthus*. (In New Zealand this can occur before harvesting.) Like *Narcissus*, these bulbs are thermopositive requiring a warm temperature 20°C for flower formation in tulips.

3. Flowers are formed some time after replanting at low temperature of winter or early spring; bulbous iris excluding *I. reticulata*. These are thermonegative as flower initiation and formation in *I.* 'Imperator' requires a temperature of 9°C and *I.* 'Wedgwood' 9-13°C (Hartsema and Luyten 1940).

4. Flower formation starts during or towards the end of the storage period but has to be completed after planting (*Allium cepa*, *Lilium*, *Dahlia*, etc.). The first two are thermonegative for flower induction.

5. Flowers are formed after replanting in spring (*Gladiolus*, *Anemone*); they are thermopositive.

6. Flower formation begins more than a year before flowering; this type may be considered to be a variation of type 1. (*Amaryllis belladonna*, *Nerine sarniensis*); Probably therefore thermopositive as they are autumn flowering.

7. Flower formation occurs alternatingly with leaf formation during the whole assimilation period (*Hippeastrum*, *Zephyranthes*); thermoneutral.

Hartsema's classification is drawn up for the higher latitudes where the soil is frozen in winter and plants such as *Lilium* and *Dahlia* are lifted in the autumn, maintained in storage above 0°C and replanted in the spring.

In type 4, *Allium cepa* and *Lilium* are thermonegative for flower induction but not flower formation, while *Dahlia* is better classified as type 5, the plant being both thermo- and photopositive.

She adds that in types 4 and 5 flower formation "... is almost immediately followed by flowering, as flower formation occurs simultaneously with the emergence of the leaves and sprouts, it is hardly possible to analyse the influence of temperature on each of these processes".

She did not appreciate the influence of cool temperatures on flower induction. For *Lilium*, she based her conclusion on the studies of Pfeiffer (1935) with *L. longiflorum* and Krijthe (1938) with *L. regale*. In both cases the bulbs were stored before planting at cool temperatures, approx. 10°C and flower formation was observed only after emergence of the shoot apex.

Type 4 is a suitable classification for geophytes which after harvest require a cool period for flower initiation and a warm period for flower formation. In this type one can include *Allium cepa*, *Lilium*, *Beta vulgaris* and other biennial or perennial plants which "bolt", e.g., produce a flower stem after chilling, or a period of low temperature either before or after formation of the storage tissue. This can be considered vernalization as consistent high temperatures, e.g., above 20°C applied to *Allum cepa* 'Giant Zittau' will inhibit flower development and scape extension (Hartsema 1947) and temperatures above 21°C inhibit flower formation in *Lilium longiflorum* (Smith 1963)

4.4.4. Structural comparison between lilies and other monocots.

The definitions of "bulb" given above lay emphasis on the basal axis being a shortened or compressed stem, with little consideration of the roots which develop from this region. Rees (1972) in his

discussion of the bulbous habit, aptly makes the comment ... bulbs could be regarded as "trees without wood". Similarly Fahn (1974) includes a section on the thickening of the axis in monocotyledons. He points out that where secondary thickening is absent in plants with axial organs, e.g., Palms and *Musa* considerable and rapid thickening takes place below the apical meristem. The phrase used by Rees is particularly apposite, as bulbs can be considered herbaceous equivalents to many monocotyledonous woody plants.

Tomlinson and Esler (1973) stated that in the "establishment growth" process of larger monocotyledons the primary axis becomes converted into a massive structure capable of generating a large trunk, adventitious roots occur over the increasing stem surface and successive internodes become progressively wider producing an obconical axis. This development is described by these authors in *Rhopalostylis sapida*, *Freycinetia banksii*, *Ripogonum scandens* and *Cordyline spp*. In fact these plants and *Phormium spp*. produce a rhizome from which the aerial parts develop. Similarly when describing the germination of the seedling of *Rhopalostylis sapida*, they state that the seedling develops close to the seed because of limited elongation of the colyledon and that the seedling axis turns obliquely downward and then turns abruptly upwards. Parallel behaviour is evident in the delayed hypogeal germination of certain lilies.

One can therefore see many similarities between the growth of woody monocots and most lilies. Some species, e.g. *L. auratum* and the aurelian group produce massive annual stems often exceeding two metres in height, surmounted by racemes comprising 15 or more flowers, the stem supported and nourished by the numerous stem roots. Even the stem of a lily in transverse section shows some similarity to woody monocots, there being a marked zone of vascular tissue beneath the epidermis in addition to the scattered vascular bundles within the endodermis.

The basal axis of perennial bulbs is more than a "Meristematic cap" as proposed by Zimmerman and Tomlinson (1967), while Fahn (1974) describes the region as a massive thickening region; the adjective

"massive" is also appropriate to the basal axis of most bulbs as compared with many meristematic apicies.

Corner (1964) considers that monocotyledons are specialized leptocaul plants retaining remnants of pachycaul construction in their underground systems. He adds the comment "... the text books regard these parts as special storage organs adapted to the seasonal climate". In the light of Raunkaier's philosophy this statement appears justified.

CHAPTER FIVE

EXPERIMENTAL ASPECTS

The foregoing discusses the morphology and factors influencing the growth of lilies. The following experiments were carried out to examine the effect of modifying these factors to control the growth and flowering of dwarf Oriental lilies specifically to be grown as pot plants.

Experiment I

5.1 OBJECT

To evaluate the potentiality of *L. auratum* 'Little Gem' as a pot plant for glasshouse culture.

5.1.2 MATERIALS AND METHOD

5.1.2.1 Plant Material

35 bulbs of *L. auratum* 'Little Gem' were obtained on 20 May 1968. The bulbs were grown at Kimbolton, Manawatu, harvested on 10 May and washed free of soil. (Bulbs were supplied by courtesy of Dr J.S. Yeates, Palmerston North).

5.1.2.2 Bulb Treatment

On 21 May the bulbs were dipped for ½ hour in a therapeutant (Appendix 6) dip of:

Parathion	(20% e.c.)	3200 ppm a.i.
Captan	(80% w.p.)	4000 ppm a.i.

Parathion was used as *Pratylenchus* spp. had been reported as attacking bulbs grown in the area and could be transferred in the basal roots causing subsequent damage to the plants (Jensen and McWhorter 1956). Captan was selected as a precaution against fungous diseases. All bulbs showed 2 to 6 white basal roots but also some brown decayed roots; the cause of this condition not being determined.

Each bulb was separately labelled, weighed and potted into soil-less medium (Appendix 1) adapted from the University of California Mix IIc (Matkin and Chandler 1957).

The bulbs were planted 23 May in 2.2 l. black polythene planter bags with the apex 10 cm. below the surface. All containers were watered and placed outdoors on coarse grit.

5.1.2.3 The Glasshouse environment

The plants were introduced at intervals (Table 5.1.1) into a compartment of a heated glasshouse orientated North-South (Appendix 2). Neither temperature nor humidity were accurately controlled, ventilation being through ridge and later side ventilators at 30 cm above the ground. Plants were placed on the soil in the glasshouse and watered manually as required. No additional plant nutrients were applied and growth appeared adequate. On 10 October shading of oilbound water paint was applied to the glass and retained until the end of the experiment. Minimum night and maximum day temperatures as recorded on a mercury in glass maximum/minimum thermometer were 15.6^{o}C and 32.2^{o}C, during the growing period.

5.1.2.4 Pathogen Control

No pathogens or insect pests developed on the plants but at monthly intervals commencing one week after shoot emergence, the plants were sprayed with:

Maldison (25% w.p.)	1250 ppm a.i.
Captan (80% w.p.)	1000 ppm a.i.

5.1.2.5 Plant treatment

At intervals listed in Table 5.1.1 plants were brought into the glasshouse and grown to anthesis subsequently being allowed to senesce naturally.

Table 5.1.1

Number of days from planting to placing in glasshouse and number of bulbs per treatment.

Treatment	No. days	No. bulbs
1.	56	5
2.	91	5 (1 failed to grow)
3.	105	5
4.	118	5
5.	141	5
6.	162	5 (1 plant died)
7.	Control continuously outdoors	5

Plants of each treatment were maintained as one plot randomised within the growing area.

5.1.3 RECORDS AND RESULTS

5.1.3.1 Records

Records for each plant were maintained of number of days to emergence for treatments 1 to 4, number of days from emergence to anthesis, initial and lifted bulb weight and height from growing surface to first flower. Results were summed for number of days from housing to anthesis, emergence to anthesis and compared for change in weight between planted and lifted weights.

Although the treatments were replicated only in plants and not plots, the results were analysed by a computer programme devised by Dr I.L. Gordon of Massey University entitled Codon Listan. Results were subject to analysis of variance, chi square for individual variances, F - test for population differences and t - test for significance of differences between means.

5.1.3.2 Results

Results are considered on the basis of the T - test where they are placed in decreasing rank order. Treatments underlined are not significantly different at the level less than P=0.05

5.1.3.3 Housing to emergence

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Mean days to emergence	61.00	23.75	26.60	31.00
Ranked order		1 2 3 4		

The bulbs placed in the glasshouse after 56 days outdoors, emerged more slowly than the other recorded bulbs. It may be assumed that the bulbs outdoors for longer periods commenced growth of the stem prior to placing in the glasshouse; plants were not examined to confirm this aspect.

5.1.3.4 Emergence to anthesis

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Mean days to ~~emergence~~ anthesis	84.40	82.25	79.20	74.60
Ranked order		1 2 3 4		

Bulbs which had been held for 118 days outdoors achieved anthesis significantly sooner than those which were outdoors for 56 or 91 days, but they were not significantly different from those outdoors for 105 days.

5.1.3.5 Housing to anthesis

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118	(5) 141	(6) 162
Mean days to anthesis	145.40	116.00	105.80	105.60	81.80	67.50
Ranked order					7 5 4 3 2 1	

Except for bulbs which were outdoors for 105 and 118 days, all treatments were significantly different, the longer the bulbs were outdoors the sooner they achieved anthesis when placed in the glasshouse.

5.1.3.6 Planting to anthesis

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Mean days to anthesis	201.40	207.00	210.80	223.60

Days outdoors	(5) 141	(6) 162	(7) continuously
Mean days to anthesis	220.80	227.50	243.20

Ranked order 7 6 5 4 3 2 1

When the total period of growth from planting to anthesis is considered, time to anthesis was directly related to the length of time the bulbs were growing in the glasshouse. Differences were significant between treatments except for the bulbs held 91 and 105 days outdoors and those 56 and 91 days outdoors. As would be expected the bulbs grown continuously in the open took the longest period to flower.

5.1.3.7 Fresh weights of bulbs

The planting weight, lifted weight after senescence and change in weight were recorded in grams and analysed.

Planting weights

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Planting weight	37.66	29.10	37.44	25.20

Days outdoors	(5) 141	(6) 162	(7) continuously
Planting weight	37.46	46.97	36.02

Ranked order 6 1 5 3 7 2 4

5.1.3.8 Lifted weights

The analysis showed no significant difference between means, due to the wide variation in weights.

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Lifted weight	106.68	111.00	121.60	94.50

Days outdoors	(5) 141	(6) 162	(7) continuously
Lifted weight	143.60	141.70	158.26

Ranked order 7 5 6 3 2 1 4

5.1.3.9 Change in weight

There was no significant difference between ranked means after lifting in all cases bulbs had increased in weight.

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Change in weight	69.06	81.90	84.16	69.30

Days outdoors	(5) 141	(6) 162	(7) continuously
Change in weight	106.14	94.42	122.24
Ranked order		7 5 6 3 2 4 1	

Although the bulbs grown outdoors showed a greater change and increase in weight, the variations of changes in weight were so great that there is no significant differences between means. It is however noticeable that in all cases there was an increase in weight indicating that glasshouse culture is not detrimental to the daughter bulbs, which grew and flowered satisfactorily in subsequent experiments (2 and 4).

5.1.3.10 Length of stem

After anthesis the length of the stems was measured from the surface of the medium to the pedicel subtending the first flower. Measurements were taken in inches and converted to centimeters.

Days outdoors	(1) 56	(2) 91	(3) 105	(4) 118
Height cm.	27.18	27.46	29.59	27.30

Days outdoors	(5) 141	(6) 162	(7) continuously
Height cm.	30.61	30.00	22.86
Ranked order		5 6 3 2 4 1 7	

There was no significant difference between ranked means in the length of stem, though the bulbs grown continuously outdoors were shorter than all bulbs grown in the glasshouse.

5.1.4 DISCUSSION

The forcing of bulbs as pot plants is an accepted practice in temperate regions (De Hertogh 1974, de Pagter 1972). With spring flowering bulbs e.g. hyacinths, tulips etc; pretreatment of the

bulbs by artificial cooling is normally required to obtain adequate flowering or an acceptable height of plant. Provided the appropriate treatment has been given, bulbs flowered in glasshouses are normally taller than those grown outdoors and in fact the same effect is evident in those species of *Lilium* namely *L. longiflorum*, *L. auratum* and *L. speciosum* which are reported to respond to glasshouse culture (Woodcock & Stearn 1950).

Since this was a dwarf cultivar although the plants when forced were taller than those grown continuously outdoors, they were still of an acceptable height as a pot plant.

Since the plants were growing continously after planting, unlike cool storage of unplanted dry bulbs, the plants were undergoing vernalization during the earlier period of their growth. An initial period of 56 days was not sufficient to hasten their growth initially when planted in warm temperature but vernalization was satisfied after 91 days outdoors.

Although the most rapid flowering occured in those plants grown for the longer periods outdoors before forcing, from a commercial viewpoint periods of 105 and 118 days outdoors were the most economic periods to produce saleable plants prior to the normal flowering date, and in fact produced plants in flower just prior to Christmas, an important marketing season.

Should the plants not be disposed of, their culture in the glasshouse does not affect the bulbs, and they may be grown to senescence and harvested as normal bulbs. There was no significant difference in change of fresh bulb weight between plants grown for a long or a short time in the glasshouse. This again is in contrast with forced spring flowering bulbs, where the initial bulb has decreased in size and the daughter bulb not grown sufficiently to justify retention.

5.1.5 CONCLUSIONS

After planting and growing outdoors in ambient temperatures over the winter season, plants of *L. auratum* 'Little Gem' may be forced in the glasshouse and will flower satisfactorily; their height being genetically controlled, they produce a satisfactory pot plant without the use of growth retardents.

If they are required to flower at Christmas time, the normal period being early February, a period of 105 to 118 days outdoors followed by glasshouse culture is most economical in the time needed to grow them in the glasshouse.

Experiment II

5.2 OBJECT

To compare the growth and flowering of 2 sources of bulbs of *L. auratum* 'Little Gem' after cool storage or frame storage of the bulbs, followed by glasshouse culture or outdoor culture.

5.2.1. MATERIALS AND METHODS

5.2.1.1 Plant Material

In this experiment bulbs of *L. auratum* 'Little Gem' were obtained from two sources, namely bulbs which had been grown at Massey University in containers in the previous season (68 bulbs) and bulbs donated by Dr J.S. Yeates, grown at Kimbolton (69 bulbs).

The 68 bulbs after flowering had been placed in an uncovered frame outdoors and had senesced naturally; they were larger and heavier than the 69 bulbs. They had many white active basal roots. The 69 bulbs had been lifted, washed free of soil and packed in *Pinus radiata* sawdust moistened by applying 2 parts by volume of water to 1 part sawdust. The bulbs had 3 or 4 white active roots and several (4-12) brown basal roots.

The experiment commenced on 22 May 1969.

Details of results recorded in Appendix 9

Mean height in cm and number of days to various growth stages of two sources of bulbs, three treatments for three storage periods.

Tmt.	Ht.	Pl.em	Em-Vfb	Vfb-an	Pl-an
bulb source					
1968					
FF0	27.0	111.7	43.7	68.5	224.0
RG0	38.5	43.0	52.2	63.4	158.6
FF1	28.4	83.5	40.5	68.2	192.2
RG1	22.5	49.7	35.0	51.5	136.2
FG1	26.7	42.7	40.2	51.5	134.4
FF2	27.1	74.6	37.0	67.3	178.9
RG2	25.3	41.2	31.0	55.4	127.6
FG2	22.8	38.3	35.1	53.8	127.2
FF3	27.6	59.0	37.0	67.5	163.5
RG3	25.2	32.6	24.8	61.0	118.4
FG3	23.6	27.4	31.6	58.2	117.2
1969					
FF0	24.1	125.7	40.7	62.2	228.6
RG0	37.5	64.8	46.1	56.3	167.2
FF1	25.0	97.7	36.7	61.5	195.9
RG1	20.4	72.5	26.5	51.0	150.0
FG1	22.2	57.6	33.2	55.6	146.4
FF2	26.0	83.0	41.6	59.0	183.6
RG2	23.8	52.1	26.2	55.1	133.4
FG2	22.8	47.0	31.7	56.7	135.4
FF3	24.1	72.8	33.8	60.4	167.0
RG3	22.4	45.8	25.0	51.6	122.4
FG3	24.1	36.4	28.6	60.9	125.9

Treatments: Storage and cultural conditions: FF = cool + frame

RG: Cool + glasshouse, FG= Frame + glasshouse

Days of storage at 3.3°C: 0 = Nil, 1 = 32, 2 = 45, 3 = 60

5.2.1.2 Bulb Treatment

Three treatments were imposed on the bulbs, namely:

i. Cool storage in an HMV domestic refrigerator at 3.3°C followed by growth in the glasshouse (RG)

ii. Cool storage in the refrigerator at 3.3°C followed by growth outdoors in the frame (FF)

iii. Planted in containers of growing medium in the frame followed by glasshouse culture (FG). This treatment is equivalent of the Natural Temperature Storage (NTS) of Box and Payne (1967).

Storage periods were 0,35,42 and 60 days while three 68 bulbs and ten 69 bulbs comprised a plot. Both in the frame and in the glasshouse the plots were randomized but not grown in blocks.

While in cool storage, bulbs were individually placed in black planter bags and covered with damp sawdust, being subsequently potted in growing medium A listed in Appendix 1.

Similarly the bulbs in treatment iii. were planted in this medium. The apex of the bulbs were covered with 5 cm. of growing medium.

In the treatment of 0 days (RGO, FFO) the bulbs were potted in the medium and held continuously in a room at 13 ± 2°C until the 35 days cool storage or frame stored bulbs (RG1, FF1) were potted up and placed respectively in the glasshouse or frame.

5.2.1.3 Temperature and Treatment

Bulbs stored in the refrigerator were held at 3.3 ± 1°C, those stored or grown outside were subject to ambient temperatures extrapolated from records obtained at Grasslands Division Department of Scientific and Industrial Research adjacent to Massey University Campus. Temperatures experienced between periods are stated in Table 5.2.1

Table 5.2.1

Ambient temperatures during bulb growth outdoors.

Period of Storage or Months	Mean Temperature ^{o}C
35 days	10 decreasing to 7.2
42 days	7.5
60 days	6.3
August	9.8
September	11.2
October	11.4
November	14.8
December	17.2

Culture was in the same glasshouse as in Experiment I and temperatures recorded on a Casella thermohydrograph were consistently 6 - 10^{o}C higher than those outdoors.

5.2.3 RECORDS AND RESULTS

Records were maintained of the number of days to emergence of the Apex (Em.), emergence to visible flower buds (VFb) and visible flower bud to anthesis and the total growing period summed. These are listed in Appendix 9.

Results

As with experiment 1, results were analysed by computer programme Codon Listan, subjected to analysis of variance, chi square for individual variances, F- test for population differences and t - test for significance between means. Means were ranked in descending order and in all cases produced a series of overlapping significant differences. These are listed in appendix 10.

Treatments 68 RGO and 69 RGO showed such variation in individual results that they are omitted from consideration of significance of the means of treatments except planting to emergence. Comparison of days for RGO and RG1 are given in Table 5.2.2.

Table 5.2.2

Comparison of days to anthesis of bulbs subjected to nil or 32 days cool storage prior to glasshouse culture.

1968	RGO	RG_1	1969	RGO	RG_1
	139	133		145	143
	163	133		150	146
	167	139		167	147
	168	140		178	147
	182			178	151
				182	151
				183	151
				184	153
					156
					157

5.2.3.1 Planting to emergence

Source of bulbs

For any one treatment 1968 bulbs emerged significantly faster than equivalent 1969 bulbs.

Storage and cultural treatments

Cool storage frame bulbs emerged significantly later than bulbs of other treatments.

Cool storage glasshouse bulbs. R.G.1 bulbs of both sources emerged significantly later than R.G.O. bulbs. Frame storage glasshouse bulbs emerged significantly more rapidly than equivalent bulbs of the other treatments.

Period of Storage

For all treatments days to emergence were inversely related to numbers of days of storage.

5.2.3.2 Emergence to visible flower bud

Source of bulbs

There was no significant effect of the source of bulbs, whether 1968 or 1969 bulbs.

Storage and cultural treatments

1969 cool stored glasshouse grown achieved this stage significantly quicker than all other bulbs except 1968 R.G.3 and 1969 F.G.3.

Cool stored frame grown bulbs took significantly longer to reach visible flower bud than other treatments.

Period of storage

There was no distinct pattern in the effect of period of storage on the achievement of this stage.

5.2.3.3 Visible flower bud to anthesis

Source of bulbs

The source of bulbs was not significant during this stage of growth for any treatment.

Storage and cultural treatments

Cool stored glasshouse grown bulbs tended to achieve anthesis more rapidly than other treatments, while cool stored frame grown bulbs took significantly longer than glasshouse grown plants. Length of cool storage was not significant.

5.2.3.4 Planting to Anthesis

Source of bulbs

For any one treatment, 1968 bulbs flowered significantly faster than the equivalent 1969 bulbs.

Storage and cultural treatments

Total time to anthesis was inversely related significantly to cool storage period and as would be expected cool stored frame grown bulbs had a significantly longer growing period than glasshouse grown bulbs.

The most rapid flowering took place with glasshouse grown bulbs stored for 60 days.

It was noticeable that with glasshouse grown plants, the

difference between the number of days to anthesis for any two storage periods was not as great as the difference between two cool storage periods; however. with frame grown bulbs, the difference in total time to anthesis was almost equivalent to the difference between the cool storage periods.

5.2.3.5 Height at sensescence

When considering length of stem at senescence, only 1968 R.G.O. and 1969 R.G.1. were significantly taller than all other treatments. This could be due to there being plants in both treatments which exhibited extended growth or delayed flowering.

5.2.4 DISCUSSION

While experiment I indicated that *L. auratum* 'Little Gem' was suitable for glasshouse culture, this experiment initiated the evaluation both of storage treatment prior to planting the bulbs and subsequent cultural conditions.

The more rapid achievement of each growth stage by 1968 compared with 1969 bulbs could be due to their physiological condition as the former would have completed their growth earlier in the previous season and therefore be more mature. 1969 bulbs grown at a higher elevation were subject to cooler growing conditions.

The influence of length of storage is clearly indicated by the more rapid growth to emergence, the intermediate period of 45 days providing sufficient vernalization to ensure satisfactory development of all stages.

The ambient temperatures experienced by bulbs grown initially outdoors (F.G. group) were higher than the 3.3^{o}C temperature at which the other two groups of bulbs were held; possibly also the bulbs being in a growing medium were producing roots, though this aspect was not examined. These temperatures also appeared to be adequately vernalizing and are above those recommended for cultivars of *L. longiflorum*, being equivalent to the temperatures imposed by

Photograph 3

View of Experiment 2 *L. auratum* 'Little Gem'. Plants of treatment RGO with extended growth and delayed flowering at back.

Photograph 4

Detail of flower of *L. auratum* 'Little Gem'

Pertuit and Link (1971).

The abnormal growth either of delayed flowering or secondary flowering exhibited by bulbs which received no cool storage (1968 R.G.O. and 1969 R.G.O.) indicates that vernalization is a prerequisite for regular development in this cultivar.

As would be expected, bulbs grown in a heated glasshouse developed more rapidly through all stages than those grown continuously outdoors.

Finally, it can be noted that the influence of cool storage is no longer evident in the stage from visible flower bud to anthesis.

5.2.5 CONCLUSIONS

A period of 45 days storage at normal ambient winter temperatures in Manawatu or at 3.3°C is adequately vernalizing for bulbs of *L. auratum* 'Little Gem'.

The time taken to achieve emergence and development to the visible flower bud stage is inversely related to length of prior storage. Inadequate cool storage and subsequent glasshouse culture delays but does not inhibit anthesis.

Experiment III

5.3.1. OBJECT

To investigate the influence on bulb growth and flowering of prepotting, two cool storage temperatures and three periods of storage with *L. auratum* 'Little Gem'.

Introduction

In experiments I and II, bulbs of *L. auratum* 'Little Gem' had been subjected either to natural cooling outdoors or to imposed low temperatures in cool chambers. It had been ensured that the bulbs did not experience excessively high temperatures or desiccation

prior to cool temperature treatments but no specific observations had been made on the influence of the period or treatment prior to cooling. However naturally cooled bulbs flowered earlier in the glasshouse than those planted direct from cool store and this could be a consequence separately or in combination of warmer storage temperatures or rooting prior to placing in the glasshouse.

De Hertogh et al. (1969) proposed a bulb treatment which they named Controlled Temperature Forcing (CTF) of lily bulbs. In this process *L. longiflorum* 'Ace' and 'Nellie White' bulbs of specific sizes were potted in growing medium and then subjected to a temperature of 17.2°C for 3 weeks prior to cool storage for 5 weeks at 1.7°C.

The CTF treatment had no consistent effect on number of days to flower or plant height but increased the number of flowers and length of leaves in these lily cultivars.

It was decided to examine the influence of CTF on *L. auratum* 'Little Gem' at two cool storage temperatures and for three periods of storage.

5.3.2 MATERIALS AND METHODS

5.3.2.1 Plant Material

A total of 432 bulbs were used, comprising 144 bulbs grown in the previous experiment and 288 bulbs supplied by Dr Yeates from stock grown at Kimbolton.

5.3.2.2 Bulb Treatment

On 30 April 1970, growing medium was removed from the previously potted bulbs and bulbs from both sources were placed in polythene lined boxes, the roots being covered with peat which had been taken from the dry bale and moistened with water to 80% V/V as recommended by Roberts (pers. com.) The bulbs were held in storage cabinets at 11.1°C until 29 May 1970 when they were dipped for ½ hour in:

Parathion	25%	e.c.	2000 ppm a.i.
Benomyl	50%	w.p.	1000 ppm a.i.

After air drying, bulbs were replaced in the boxes with fresh moist peat and stored in the laboratory at 14.5°C.

On 9 June 1970, the bulbs were divided into two groups, one half being potted into moist soiless growing Medium B in black planter bags of 2.24 l. capacity; the bags were partially filled with medium, the bulb apex being just below the surface; the upper part of the bags were folded over the medium to restrict loss of moisture. These are referred to as "Pot" bulbs.

The 216 bulbs not potted (Dry Bulbs) were held in the storage boxes and all bulbs were then placed in a "Lloyd" cabinet (Appendix 3) held at 18.3°C for 3 weeks. On 30 June 1970, after 21 days of storage, all bulbs were removed from the cabinet, the dry bulbs were potted into growing medium and half each of both dry and pot bulbs were placed in "Lloyd" cabinets maintained respectively at 1.7°C and 7.8°C.

After 48 days of storage, 36 bulbs of each treatment were removed and placed in randomised plots of 4 blocks in a glasshouse maintained at 12°C Night/18.3°C day temperature, on a sand base.

A further 72 bulbs were removed after 62 days in storage and finally after 76 days in storage the last groups of bulbs were placed in the glasshouse.

Before placing in the glasshouse the planter bags were filled with growing medium to 3 cms. of the top.

On 16 October, all bulbs were transferred to an unheated glasshouse with louvre and extractor fan ventilation (Appendix 2) mean night temperature was 16.7°C and mean day temperature 22.2°C rising to 26.7°C at the termination of the experiment. Planter bags were placed on a sand base thus acting as a form of supplementary capillary watering and the bags were hand watered whenever it appeared necessary. The medium was maintained as far as possible at "Container capacity" (Bunt 1975).

5.3.3. RECORDS AND RESULTS

The results were subjected to analysis of variance estimating the influence of each factor and their interaction. There was no block effect at any growth stage. As in other experiments records of growth stages were maintained, namely emergence, visible flower bud and anthesis with stages totalled (See Table 5.3.1)

The one factor which was significant at all stages was the length of time or number of days the bulbs were in cool store at both temperatures. At least to the stage of visible flower bud the longer the storage period, the more rapid the subsequent development; the advancement was such that bulbs stored for 76 days flowered in a shorter period than those cool stored for 48 or 62 days.

The individual factors and their interaction were most evident in the number of days to emergence, where these are now considered.

Table 5.3.1

Results: mean of 4 replications per treatment

Storage method	Potted bulbs						Dry stored bulbs					
temperature °C	1.7			7.8			1.7			7.8		
Period (Days)	48	62	76	48	62	76	48	62	76	48	62	76
Glasshouse to emergence	32.3	26.2	19.3	27.5	15.1	16.9	36.9	28.5	22.8	32.3	26.1	11.3
Emergence to visible bud	29.3	28.6	23.3	35.6	35.9	30.3	25.5	24.8	21.7	29.4	27.7	27.5
Visible bud to anthesis	60.0	61.9	64.2	60.1	63.8	61.0	59.9	60.2	61.9	58.5	58.9	62.7
Glasshouse to visible bud	61.6	55.3	42.5	61.8	51.0	47.3	62.4	53.3	44.6	61.7	53.9	38.6
Glasshouse to anthesis	121.6	117.8	106.9	122.2	112.4	108.3	112.6	113.6	106.4	120.3	112.5	101.5

5.3.3.2 Planting to Emergence

At this stage of growth, each factor is significant and there is an interaction between these treatments. These results are listed in Table 5.3.2.

Table 5.3.2

Effect of interaction of days in store, temperature and method of storage on number of days to shoot emergence.

	Temperature °C				
	1.7		7.8		
Days	Potted	Dry	Potted	Dry	se df 33
48	32.3	36.9	27.5	32.3	± 2.48
62	26.6	28.5	15.1	26.1	
76	19.3	22.8	16.9	11.3	
Storage temperature mean	27.7		21.5		± 1.01

Potted bulbs except for those stored for 76 days at the higher temperature emerged earlier than dry stored bulbs, and bulbs stored at 1.7°C emerged later than those stored at 7.8°C.

5.3.3.3 Emergence to visible flower bud

The individual factors related to storage, namely length, temperature and method were all highly significant during the period emergence to visible flower bud. There were however, no interactions between these factors. These are tabulated in Table 5.3.3.

Table 5.3.3

Effect of duration, method and temperature of storage on number of days from emergence to visible flower bud.

Duration			Method		
Days		se d 15	Potted	Dry	se df 23
48	29.9				
62	29.2		30.5	26.1	± 0.75
76	25.7	± 0.91			

Temperature °C		
1.7	7.8	se.d f 23
25.5	31.0	± 0.75

During this period of growth dry bulbs stored at the lower temperature achieved the stage of visible flower bud more rapidly.

5.3.3.4 Glasshouse to visible flower bud

When considering the whole period from placing the bulbs in the glasshouse to visible flower bud, only the number of days in store and this combined with temperature and method of storage are highly significant.

Results are tabulated in Table 5.3.4.

Table 5.3.4

Effects of interaction of duration, temperature and method of storage on number of days between housing and visible flower bud formation.

	Temperature °C				
	1.7		7.8		se df 23
Duration	Potted	Dry	Potted	Dry	
48	61.6	62.5	61.8	61.7	
62	55.3	53.3	51.1	53.9	
76	42.5	44.6	47.3	38.6	± 1.91

It can be inferred that the duration of storage is the major factor producing rapid development to this growth stage.

5.3.3.5 Visible flower bud to anthesis

During this period of growth, the factors influencing the plants at earlier stages tend to disappear. However, the duration of storage is still highly significant although in the reverse direction that the longer the bulbs were stored the longer the plants required to achieve anthesis. There was also highly significant interaction between duration, method and temperature of storage.

This stage is tabulated in Table 5.3.5.

Table 5.3.5

Effect of interaction of duration, temperature and method of storage on number of days from visible flower bud to anthesis.

	Method				
	Potted		Dry		
	Temperature °C		Temperature °C		
Duration	1.7	7.8	1.7	7.8	se. df 15
48	60.0	60.1	59.9	58.5	
62	61.9	63.8	60.2	58.9	
76	64.2	61.0	61.9	62.7	±1.33

5.3.3.6 Total time to anthesis

When considering the impact of various factors on the number of days to anthesis, only length of storage and method of storage were highly significant and temperature of storage significant. There were no significant interactions. Here again, the bulbs stored for 76 days flowered more rapidly than those stored 48 or 62 days and bulbs not potted before storage flowered earlier than those potted. Warm temperature storage only hastens flowering by approximately one day.

Results are tabulated in Table 5.3.6

Table 5.3.6

Effect of duration, method and temperature of storage on number of days to anthesis.

Duration		se.df 15	Method		se.df 23
Days			Potted	Dry	
48	122.1		115.2	112.9	±0.74
62	114.7				
76	105.7	±0.96			

Temperature °C		se.df 23
1.7	7.8	
114.8	113.3	±0.78

5.3.3.7 Extended or delayed flowering

Of the plants which had been stored at 7.8°C for 48 days, 5 showed extended flowering, both a first and second flowering on the one stem and 7 showed delayed flowering, indicating that storage for this period at that temperature was marginally vernalizing or the plants partially devernalized after removal from store.

5.3.4 DISCUSSION

The method of controlled temperature forcing proposed by De Hertogh et. (1969) was developed as a modification of Natural Cooling (Box and Payne 1967) in which bulbs are planted in their flowering containers and held at above freezing temperatures until brought into the glasshouse for forcing. By potting prior to cooling, root growth is stimulated and the placing in warmer temperatures subsequently is a natural transition for plants, whereas precooling followed by planting requires the plants both to form roots and aerial growth concurrently.

Since *L. longiflorum* can be considered a plastic plant in relation to ultimate flower numbers. the use of CTF is advantageous in increasing the number of flowers and producing a more shapely plant with an adequate number of leaves.

In contrast *L. auratum* 'Little Gem' is a more stable plant when considered from the viewpoint of flower numbers, plant height and number of leaves, as shown in experiments I and II.

In this experiment, the only significant response obtained by potting the bulbs prior to storage at 18.3°C for three weeks as compared with storing the bulbs in moist peat for the same period, was in emergence, where potted bulbs emerged more rapidly.

The two temperatures of cool storage namely 1.7°C and 7.8°C were both higher and lower than those normally recommended for *L. longiflorum* (5°C). Although the higher temperature is similar to that experienced by bulbs placed in frames the previous year. As would be expected the warmer temperature stimulated emergence but this advance disappeared during the subsequent growth stages.

The one factor which proved most significant at all stages of growth was the length of time the bulbs were held in cool storage. There was fourteen days interval between each of the three periods and the longer the storage period the sooner the shoots emerged and showed visible flower buds, however in no instance was the difference as much as fourteen days between any two periods. In fact those bulbs stored for 76 days flowered only sixteen days earlier than those cooled for 48 days. Storage for 48 days at 7.8°C may prove to be a marginal period of time at that temperature as some plants showed extended or secondary flowering.

In considering the practical aspects of CTF, it was found that the physical handling of potted plants was laborious, while the space taken up by the containers and the difficulty in stacking would limit the number that could be stored. Unless large stores are available and mechanical handling is used, the technique of potting prior to storage as compared with moist storage of bulbs, has little to commend it.

5.3.5 CONCLUSIONS

When storing bulbs at a warm temperature for three weeks prior to cool storage, potting of the bulbs was not advantageous as compared with storing the bulbs in moist peat. There was no difference in the number of days to anthesis of bulbs stored at 1.7°C or 7.8°C however, bulbs cool stored for 76 days as compared with 48 or 62 days emerged and flowered significantly earlier. The higher temperature for the shortest cool storage period was marginally vernalizing.

Experiment IV

5.4.1 OBJECT

Since previous experiments had been carried out at different temperatures for varying periods, this experiment was conducted to confirm the influence of different storage periods at one temperature on *L. auratum* 'Little Gem' bulbs produced in two ways.

5.4.2 MATERIALS AND METHODS

5.4.2.1 Plant Material

L. auratum 'Little Gem' bulbs were selected from two sources; 50 bulbs grown in the previous year and held in pots outdoors (pot bulbs) and 100 bulbs (soil bulbs) grown from bulblets in the open ground in the Department of Horticulture field area.

5.4.2.2 Bulb Treatment

On 10 May 1972, all bulbs were washed free of growing medium or soil, dipped for ½ hour in benomyl (50% w.p.) 1000 ppm a.i. active ingredient placed in wooden boxes and covered with clean peat moistened with an equal volume of water. All bulbs appeared healthy with clean scales and basal roots.

On 12 May 1972. the bulbs were placed in a "Lloyd" storage cabinet maintained at $5 \pm 1^{o}C$.

On 19 June 1972, 38 days after storage, 15 pot bulbs and 30 soil bulbs were removed from store and as the roots appeared water soaked were dipped in benomyl 2000 ppm a.i. for ½ hour. The bulbs were all potted in soiless medium B in 15 cm diameter rigid plastic pots and placed on a sand bench in the heated glasshouse in a 3 randomised block of 5 and 10 bulbs respectively.

On 5 July 1972, after 54 days in cool store, two groups of bulbs were treated similarly and placed in the glasshouse.

Finally on 20 July 1972, 69 days after storage, a third group of 15 and 30 bulbs were treated in the same way. As some bulb scales showed a soft rot, identified by Dr K.S. Milne as a bacterial infection, all pots were drenched Cuprovit (50% Cu) at 14 gms per litre applying 250 ml. per pot. This treatment was repeated on 15 October. Subsequent growth appeared satisfactory.

Glasshouse temperatures were maintained at a minimum of $13^{o}C$ night temperature ventilation at $21^{o}C$ day with shading from 10 October 1972.

5.4.3 RESULTS

All plants grew satisfactorily and achieved anthesis. As in previous years, records were maintained of emergence, emergence to visible flower bud and visible flower bud to anthesis. Similarly numbers of days from housing to visible flower bud and total time to anthesis from housing were summed.

Results were subjected to analysis of variance, for the stages of growth, source of bulbs, interaction between storage period and source and finally block effects. Blocks were not significant at any stage of growth or between the two groups of bulbs. Results are summarised in table 5.4.1. Detailed results are stated in Appendix 11 and analysis in Appendix 12.

Table 5.4.1

Mean number of days to achieve different growth stages by bulbs of two origins stored for three periods before planting.

Origin of bulbs	Field grown			Pot grown			Significance		
Days storage	38	54	69	38	54	69	Source	Period	Inter-action
Growth stage									
P. to em.	56.7	44.5	34.6	55.3	38.5	34.3	NS	xxx	NS
Em to vfb.	44.5	32.4	36.5	28.6	27.7	21.1	xxx	xx	x
Vfb to An.	65.4	69.1	66.3	84.1	67.2	55.4		xxx	NS
P. to vfb.	101.3	76.9	71.1	73.5	70.9	72.6	xxx	xxx	x
P. to An	166.6	146.0	137.5	157.6	138.1	128.0	xxx	xxx	NS

Significance level

xxx = P. 001

xx = P. 01

x = P. 05

NS = Non Significant

5.4.3.1 Planting to Emergence

The experiment confirmed that the longer the storage period the more rapid the emergence, the advancement being more evident between the first and median period of storage than between the median and final period. Emergence of pot or field grown bulbs did not differ significantly within any one storage period.

5.4.3.2 Emergence to visible flower bud

Development to visible flower bud was more rapid in those bulbs which received longer storage periods and took place sooner in the pot grown bulbs as compared with soil grown bulbs.

5.4.3.3 Planting to visible flower bud

Pot grown bulbs reached the stage of visible flower bud significantly sooner than field grown bulbs and inversely to storage period; there was also an interaction between origin of bulbs and storage period.

5.4.3.4 Visible flower bud to anthesis

During this period of growth, as in previous years, the influence of storage period was not evident; however, the field grown bulbs achieved anthesis significantly sooner than pot grown bulbs.

5.4.3.5 Planting to anthesis

When summing the total period of growth, pot grown bulbs flowered in shorter time than field grown bulbs. Their more rapid emergence and attainment of VFB offsetting the longer period from VFB to anthesis.

As previously the longer the bulbs were stored before planting the sooner they flowered, the advancement in flowering being greater between the first and second period than between the second and third period.

5.4.4 DISCUSSION

Development within lilies is a continuing process and transition from the vegatative to floral condition is temperature dependent. The length of storage at the selected temperature of this experiment was adequately vernalizing and therefore this period and the origin of the bulbs were the independent variables.

Unless the change from vegetative to reproductive stage in the growing apex is determined microscopically, in a large number of bulbs. this will only be observed after completion and by a macroscopic change in the shape of the apex. However, when recorded in a large number of bulbs, the reproductive stage can be adequately determined.

That this stage occured more rapidly in bulbs previously grown in the greenhouse as compared with field production, suggests that the plants had achieved complete maturity prior to the commencement of this experiment. The more rapid achievement of floral development confirms the results obtained in Experiment II. In that experiment however, the period from visible flower bud to anthesis of the younger bulbs was not significantly shorter as in the current experiment. Similarly in Experiment III, potted bulbs stored at 7.8^{o}C took a longer time between the stage emergence to visible flower bud than dry stored bulbs.

The other factor could be the size of the bulbs initially in that the field grown bulbs were smaller than the pot grown bulbs. However, this aspect was not determined as bulbs were not selected on a weight basis.

5.4.5 CONCLUSIONS

The extension of storage period at 5 ^{o}C hastened the growth and development of bulbs to the stage of visible flower bud particularly when the storage period was extended from 38 to 54 days, with a lesser advancement subsequently to 69 days. Bulbs which had been grown in the open ground as compared with those previously grown in pots developed more slowly to visible flower bud stage, but flowered more rapidly, however this advance was not sufficient to offset the longer time taken in the earlier stages of growth.

Experiment V

5.5.1 OBJECT

To observe the influence of a range of storage temperatures on the growth and flowering of *Lilium x parkmanni* 'Little Robin'

5.5.2 MATERIALS AND METHOD

5.5.2.1 Plant Material

Previous experiments had been conducted on *L. auratum* 'Little Gem'. During 1973 and 1974 the stock of bulbs had not been maintained and had become infected with a range of virus diseases identified by visual symptoms and further bulbs were not available. The cultivar selected for further experiments, *L. x parkmanni* 'Little Robin' had 'Little Gem' as one parent, was dwarf and more floriferous than its parent and the flowers were more brightly coloured; an inheritance from the *L.speciosum* genes of its other parent, *L. x parkmanni* 'Excelsior'.

5.5.2.2 Bulb Treatment

The bulbs had been grown at Kimbolton by Dr J.S. Yeates and brought to Palmerston North on 22 May 1975 where they were held in damp sawdust in an unheated glasshouse for 54 days until collected for this experiment on 15 July 1975.

On receipt, 100 bulbs were selected and dipped for ½ hour in

Captafol (50% wp)	10,000 ppm a.i.
Thionazin (43% cc)	4,300 pppm a.i.

After air drying the bulbs were replaced in clean moist sawdust and held in an unheated room at $12 \pm 2^{o}C$.

Twenty three days after receipt, on 7 August 1975, the bulbs were divided into 5 sets of twenty bulbs placed in polythene bags and controlled temperature storage applied.

5.5.2.3 Treatments

Five treatments were selected.

Continuous warm storage	(A)
Warm storage followed by cool storage	(B)
Continuous ambient storage	(C)
Ambient storage followed by cool storage	(D)
Continuous cool storage	(E)

Ambient storage = temperature of an unheated bulb store.

Temperatures in ^{o}C of treatments applied in "Lloyd" cabinets were: Warm 19.5, Ambient 12, Cool 4, all $\pm$ $^{o}1^{o}C$.

Periods of first, second and continuous storage treatments being 14, 42 and 56 days respectively.

On removal from storage, bulbs were planted 4 cm. deep into 4.5 l. planter bags in Medium B (Appendix 1) and placed on sand beds in an unheated glasshouse (Appendix 2) on 2 October 1975 in 4 blocks, plots being randomised in the blocks. Temperature in the glasshouse ranged from 15 - $25^{o}C$ as recorded on a Casella thermograph. Light intensity and incoming radiation was reduced by suspending black polypropylene mesh cloth 2.2m. above the plants to provide 50% shade. Additionally on 2 December, the glass was sprayed with white oil bound paint diluted 1 : 4 with hot water.

Aphids, identified as *Macrosiphon spp.* were observed on two plants on 26 November and the house was fumigated with dichlorvos 100% w/v as Vapona (R) by evaporating 5 ml of the concentrate for $106m^3$ area on an electric hot plate. A subsequent development of the aphids on 10 December was controlled by spraying with menazon 0.1% a.i.

5.5.3 RECORDS AND RESULTS

Records were maintained of number of days to emergence, emergence to visible flower bud, visible flower bud to anthesis; days from planting to visible flower bud and planting to anthesis were summed.

Bulbs were weighed prior to planting and number of flowers per bulb recorded; stem length from base to first pedicel was measured at senescence. Results were subjected to analysis of variance (Appendix 14)

5.5.3.1 Days to emergence

This experiment was carried out later in the season than in previous years and pre-storage temperatures had not been cold enough to inhibit growth. In all treatments, some stem emergence from the bulb had taken place by the time the bulbs were removed from their storage treatments. (Table 5.5.1)

Table 5.5.1

Shoot length in mm. after storage for 56 days; mean of 5 bulbs per block each treatment.

	Block				
Treatment	I	II	III	IV	Mean
A	67.7	70.8	64.4	61.3	66.05
B	32.4	38.8	37.8	37.5	36.6
C	53.8	61.3	74.0	67.3	64.1
D	33.6	29.0	23.0	29.3	28.7
E	23.5	23.2	18.0	23.0	22.0
Total	211.0	223.1	217.2	218.4	
Mean	42.2	44.6	43.4	43.7	

Shoots had tended to emerge at various angles and not necessarily at right angles to the bulb. As far as possible at planting the bulb was placed so that the stems were vertical as previous observations had shown that lily stems are not strongly phototropic, and when growing at an angle will continue in the initial direction until obstructed by a barrier such as the side of the container.

Shoots of bulbs which had been stored continuously at ambient temperatures, emerged significantly earlier than those in any other

treatment. Particularly with treatment A (continuous warm storage) there was a wide variation in time between one block and another (Block I 5 days. Block IV 18.3 days) as compared with any other treatment.

Overall, however, there was no block effect on any treatment or at any stage of growth throughout the experiment.

5.5.3.2 Emergence to visible flower bud

While the stages of emergence and anthesis can be relatively accurately recorded, the growth stage "visible flower bud" is slightly less exact. In *L. auratum* 'Little Gem', there is a distinct change in the stem apex from a circular to an oval, a dorsi-ventral expansion. In *L. x parkmanni* 'Little Robin', this stage is considered achieved when the apical leaves, previously enfolding the apex, opened in the centre. The developing flower buds are exposed and can be observed when looking into the apex from above.

Although this appears to be a subjective decision, the number of days from emergence to visible flower bud appear to be consistent; while subsequently the apex opens fully, the flower buds emerge and achieve anthesis at a consistent time interval in any one treatment.

In this experiment bulbs which had received continuous cold storage achieved this stage significantly earlier ($p=001$) than those of other treatments despite the shoots emerging later than any other treatment.

When summing the number of days from planting there was no significant difference between any treatment, as occurred in experiments previously.

5.5.3.3 Visible flower bud to anthesis

This stage was achieved in all treatments with the continuously cold stored bulbs reaching anthesis significantly earlier ($P.05$) than other bulbs. However, 12 of the 20 bulbs continuously

warm stored showed rosetting during growth with death and abscission of the lower stem leaves. At anthesis the stems were significantly shorter (p.01) than the other treatments (Table 5.5.2)

Table 5.5.2

Stem lengths in cms. at senescence; mean of 4 blocks per treatment.

Treatment	Length in cms.	Significance
A	35.9	xx
B	44.7	NS
C	49.3	NS
D	48.6	NS
E	48.4	NS

Rosetting is indicated by very short internodes and leaves congesting at the apex. It was considered that this condition might be due to an inhibition of gibberellic acid synthesis by the warm temperatures or a lack of cold temperatures.

To test this hypothesis, 5 plants of Block III showing this condition to a lesser or greater degree were selected on 4 December. Two were sprayed with G A 3 at 100 ppm dissolved in 25% ethanol, two with 25% ethanol and one unsprayed.

Plants were measured 4 times over an 11 day interval, measurement being from the stem base at the medium surface to the tip of the uppermost bract. Results are given in Table 5.5.3 and indicated that one spray of G A 3 at this strength did not overcome rosetting.

Table 5.5.3

Influence of application of G A 3 on rosetting.
Height of plants in mm.

Days from spraying	Treatment				
	GA	GA	ETOH	ETOH	Unsprayed
0	136	78	172	98	95
4	157	80	189	102	103
7	202	84	247	150	154
11	226	70[a]	287	165	175
Total shoot extension	90	-8	115	63	80

(a) Rosette condition maintained.

5.5.3.4 Planting to anthesis

There was no significant difference in number of days to anthesis from planting, flower production being satisfactory (Table 5.5.4). Those plants with multiple stems produced more flowers in total while one plant with a fasciated stem subtending 4 branches, produced a total 54 flowers. In general this cultivar is more floriferous than its parent *L. auratum* 'Little Gem'.

Table 5.5.4

Effect of treatments on growth stages in number of days.

Treatment	P-Em	Em-Vfb	P-Vfb	Vfb-An	p-An
A	11.2	28.4	39.7	66.7	106.4
B	9.8	27.0	36.8	72.6	109.5
C	6.3	27.6	33.9	72.7	106.7
D	12.7	23.4	36.1	73.5	109.7
E	15.0	22.2	37.2	73.9	111.1
Significance	x	xx	N.S.	xx	x

Significance level

xxx = P. .001

x = P. .05

N.S.= Non significant

5.5.3.5 Ratio of bulb weight to flower production

The ratio of number of flowers to bulb weight was calculated by dividing the number of flowers into the total bulb weight in grams, omitting fasciated plants. The lower the ratio, the more floriferous the plants, but there appears to be no pattern discernible relating to treatment, nor relating to individual bulb weights. (Table 5.5.5)

Table 5.5.5

Ratio of bulb weight in gms. to individual flowers.

Treatment	Block					
	I	II	III	IV	Σ	$\bar{x}$
A	16.5	13.6	16.8	9.4	56.3	14.1
B	12.00	14.6	11.5	10.3	48.4	12.1
C	13.8	14.3	12.2	10.1	50.4	12.6
D	12.3	13.2	12.8	9.7	48.0	12.0
E	16.4	14.0	14.5	13.1	58.0	14.5
	71.0	67.7	67.8	52.6	261.1	65.3
$\bar{x}$	14.2	13.5	13.6	10.5		

5.5.3.6 Stem height

Stem height was acceptable in all treatments except treatment A where the stems were significantly shorter. The plants appeared squat and unattractive (Table 5.5.6). This is shown in photograph 5.

Table 5.5.6

Stem length in cms. (Fasciated stems omitted)

Blocks / Treatment	I	II	III	IV	Σ	$\bar{x}$	
A	32.7	36.4	42.3	32.3	143.7	35.9	x
B	39.5	47.5	45.9	45.8	178.7	44.7	
C	48.0	47.4	48.9	52.7	197.0	49.2	
D	51.6	55.2	46.2	45.5	198.5	49.6	
E	53.4	45.6	44.6	50.1	193.7	48.4	
	225.2	232.1	227.9	226.4			
$\bar{x}$	45.0	46.4	45.6	45.3			

5.5.4 DISCUSSION

5.5.4.1 Flower induction treatment

This experiment was carried out later in the season than in previous years. It is possible that as a result of late harvesting of the bulbs, they had received some cool temperature influence prior to harvesting. This effect has been recorded in Easter lilies by Smith (1963) who showed that West Coast (U.S.A.) bulbs lifted on 30 September and given no cool storage, flowered in 268 days, while those lifted on 6 November, flowered in 147 days.

The cool temperature effect might have been continued subsequent to harvesting although the bulbs were held above the mean outdoor ambient temperature as recorded in 1969. Apart from the imposed cool treatment at $4^{o}C$, storage at $12^{o}C$ is not considered vernalizing for many plants responding to this treatment, while in *L. longiflorum*

this temperature exceeds the desirable level of 7.5 - 10°C recommended for bulbs grown in Florida.

The temperature 19.5°C is considered almost a devernalizing level as Smith (1963) showed that Croft lilies maintained at 15°C required 411 days to reach the stage of first flower.

The period of 42 days storage was sufficiently long to achieve vernalization as experienced with *L. auratum* 'Little Gem' in Experiments I and III.

Since the bulbs were grown after planting during a period exceeding 12 hours daylight, but not the long day period of 16 hours used by Roh and Wilkins (1976), this might also partially replace vernalization; though it could be considered an additive rather than a promoting effect on flower initiation.

The rapid achievement of the stage visible flower bud by bulbs stored continuously at 4°C indicates the enhancing effect of continuous cool storage, but since this was only 6 days earlier than bulbs stored continuously at 19.5°C, the effect was offset when compared with number of days to anthesis. That 19.5°C is not entirely a vernalizing temperature, is indicated by the rosetting and shorter stems of many of the plants held at this temperature, and delayed senescence of the foliage.

5.5.5 CONCLUSION

When *L. x parkmanni* 'Little Robin' bulbs are stored for 42 days at 4 and 12°C, the plants receive adequate vernalization; storage at 19.5 or 12°C for 12 days prior to storage at 4°C did not hasten anthesis. A continuous temperature of 19.5°C was only partially vernalizing, with plant height being reduced and plants being of a less desirable habit.

Photograph 5

L. x parkmanni 'Little Robin': Influence of preplanting storage temperatures, left to right:

19.5°C for 56 days
19.5°C for 14 days, 4°C for 42 days
12°C for 56 days
12°C for 14 days, 4°C for 42 days
4°C for 56 days

measure in cms.


A
B
C
D
E

Experiment VI

5.6.1 OBJECT

To observe the influence of temperature on growth and flowering of *L. parkmanii* 'Little Robin'.

Introduction

In previous experiments, bulbs of *L. auratum* 'Little Gem' and *L. parkmanii* 'Little Robin' had been stored at different temperatures and for different periods prior to their emergence. Subsequently, the plants had all been grown to anthesis at the same temperature in glasshouses, except in Experiment I when glasshouse and outdoor culture were compared.

With availability of growth cabinets providing a controlled environment of light and temperature, it was decided to investigate the influence of growing temperatures from post storage to a stage approaching anthesis. Previous experiments having shown that the stage from visible flower bud to anthesis was independent of the previous storage temperatures provided a sufficiently long cool storage period had been experienced.

5.6.2 MATERIALS AND METHODS

5.6.2.1 Plant Material

32 bulbs from Groups B,C,D and E of the previous year's experiments were removed from the unheated glasshouse on 18 May 1976. The flower stem and surplus growing medium were removed and the bulbs repotted in Planter bag size 8 (4.5 l. cap) using medium B. The apex of the bulbs was exposed. The medium was moist; all potted bulbs were placed in a "Lloyd" cabinet at 7.0°C for 64 days.

On 21 July 1976, they were divided into 2 groups of 16 plants containing approximately equal numbers of plants from each of the previous season's treatment.

One group was placed in a "Temperzone" growth cabinet (Appendix 4) maintained at a constant temperature of 15°C and the other group

in a similar cabinet at 22°C with no diurnal variation. Lighting period was 16 hours light and 8 hours dark with a light intensity of 334W at plant level.

The medium was kept moist by manual watering as required.

After 22 days, 8 bulbs from each cabinet were transferred to the other cabinet, the remainder being held at the same temperature.

On 9 September, 29 days subsequent, all plants were transferred to a heated glasshouse, heating being supplied merely to maintain a minimum of 15°C, ventilation being provided at 25°C.

The plants were set out in 4 blocks with 2 plants per treatment per block and stood on a sand base.

5.6.3 RECORDS & RESULTS

Observations and recordings were made of number of days to emergence of stem, visible flower bud and anthesis and the stages summed.

Growth rate in each cabinet was measured for 5 days on each of 5 stems between 6 and 11 August, using a Mitutoyo Dial Caliper D 15. Measurements being taken from the base of the stem to the apex of the uppermost leaf. At this time leaves were still unfolding at the stem apex. (Table 5.6.1)

Table 5.6.1

Mean growth rate in height in millimeters per day of 5 plants each at 2 temperatures.

Cabinet temperature °C	15	22
	5.1	7.6
	3.9	8.9
	3.7	6.5
	4.9	7.6
	5.2	8.1
$\bar{x}$	4.6	7.7

At the end of the experiment, the stem length from stem base to first subtending bract leaf was also measured by placing the stems along a metric ruler.

Between 3 September and 5 September, due to a malfunction in the cabinet at 22°C, the lights did not switch off, and the temperature rose to 28°C, causing an epinastic response on plants at the most advanced stage of development. Subsequently these plants grew and flowered normally when transferred to the glasshouse.

As large bulbs had been used in the experiment, a total of 18 plants produced more than one flower stem and 14 plants flowered on a single stem..

5.6.3.1 Days to emergence

No emergence of shoots took place during storage at 7°C for 64 days, as compared with Experiment IV when shoot emergence occurred at all temperatures during storage.

There was no significant difference between those bulbs stored at 15°C and those at 22°C. As emergence took place before bulbs were interchanged between the two temperatures, there could be no interaction at this stage. This stage is recorded in Table 5.6.2.

Table 5.6.2

Mean days to emergence at two growing temperatures.

Temperature °C	15	22	Se, df 12	Sign
	14.2	11.6	±21	

5.6.3.2 Emergence to visible flower bud

The transfer of bulbs between the two temperatures was effected before flower buds were visibly observed. All bulbs which originally grew at 22°C achieved this stage significantly earlier than those originally grown at 15°C. This stage is recorded in Table 5.6.3

Table 5.6.3

Mean days from emergence to visible flower bud at two temperatures continuously or interchanged.

Temperature °C	1st	15	22	Interaction	Se df 12
2nd					
15		26.0	24.9		
22		21.7	18.9 xx	NS	±1.14

5.6.3.3 End of storage to visible flower bud

When the number of days to visible flower bud are calculated from the end of storage, bulbs grown at 15°C continuously achieved this stage significantly longer than those grown at 22°C continuously while there was no interaction.

Results are tabulated in Table 5.6.4.

Table 5.6.4

Mean days from end of storage to visible flower bud when grown at two temperatures continuously or interchanged

Temperature °C	1st	15	22	Interaction	Se df 12
2nd					
15		40.3 xx	35.1		
22		36.0	31.8 x	N.S.	±1.29

5.6.3.4 Visible flower bud to anthesis

The plants were transferred to the glasshouse approximately 15 days after visible flower bud stage; hence the influence of earlier applied temperatures on different growth stages should be apparent. All previous experiments had shown that the post visible flower bud development was independant of previous treatments. Anthesis of bulbs grown at 22°C for the second period was significantly ($p=.01$) earlier than those grown at 15°C for the same time.

Results are stated in Table 5.6.5

Table 5.6.5

Mean days from visible flower bud to anthesis when grown at two temperatures continuously or interchanged.

Temperature 1st / 2nd	15	22	Interaction	Se. df 12
15	58.2	55.6		
22	52.7 xx	53.6 xx	N.S.	±1.19

5.6.3.5 Anthesis from end of cool storage

Plants achieved anthesis in this experiment more rapidly than in any other experiment conducted by the author. Those plants grown at 22°C continuously flowered significantly quicker (p .001) while those grown at 15°C continuously flowered significantly later (p .01). There was no interaction between first and second temperatures. Results are stated in Table 5.6.6.

Table 5.6.6

Mean days from end of cool storage to anthesis when grown at two temperatures continuously or interchanged.

Temperature 1st / 2nd	15	22	Interaction	Se df 12
15	98.5 xx	90.7	N.S.	
22	88.6	85.3 xxx		±1.55

5.6.3.6 Mean stem height

Differences in stem height between treatments were not significant. The mean height of all stems being 34.1 cm.

5.6.4 DISCUSSION

Temperature distinctions were strictly maintained in this experiment; temperatures of 15 or 22°C being constantly maintained both day and night. There was no effect of temperature on emergence

though from that stage to visible flower bud the difference in growth stage between the continuous low or high temperatures was 8.5 days. Where plants were interchanged, there was no significant difference in time.

The advance in growth and achievement of anthesis was continued during the transfer to greenhouse conditions.

However, this phase was only 30 - 40 days as compared with the 51 days in the growth chambers. Although both the advance and delay in flowering were significant, the considerable input of energy required at the higher temperature does not justify its use; similarly this experiment confirms that these plants are relatively stable in their growth rates and although temperature dependant, the rate of development does not have an absolute level.

5.6.5 CONCLUSIONS

After adequate cool storage, rate of development of the plant to anthesis is directly related to the temperature at which the plants are grown. However, a differential of 7^{o}C for 50 days hastened flowering at the higher temperature by only 13 days in a 91 day growing period.

Photograph 6

Experiment 6: Plants in growth cabinet

Photograph 7

Experiment 6: Blocks 3 and 4 in glasshouse.


IIIB1
IIE2
IIC2
IIC4
IVC2
IVE4

CHAPTER SIX

DISCUSSION & CONCLUSIONS

6.1 INTRODUCTION

With modern techniques of plant production, it is essential that the growth of the selected plant should be predictable and carried out according to a schedule. Assuming that environmental factors are controlled, it is most desirable that the growth and development of the plants should be understood so that the effect of environmental changes can be anticipated. In the case of bulbous plants, development and flowering can be programmed, in particular by the application of specific temperatures initially to the resting stage and subsequently to the shoot after emergence.

6.2 COOL TEMPERATURE EFFECTS

Under natural conditions, lilies are subject to chilling during their dormant period in winter; this can be replaced by artificially applied cool temperatures of 3 to 12°C, a minimum period being 35 days though desirably this should be extended to 45 days.

The upper limit of temperature is related to the species and cultivar, thus in *L. longiflorum* 5-7°C appear to be optimum, while in *L. auratum* 'Little Gem', 8°C was maximum and in *L. x parkmanni* 'Little Robin', 12°C was tolerated. Similarly the maturity of the bulbs and temperatures experienced prior to harvest must also be taken into consideration.

Although inadequate vernalization, either too short a period of cool temperature, less than 30 days, or too high a storage temperature such as 19°C did not inhibit subsequent flowering in Oriental lilies, flowering was irregular and growth habit was less desirable.

6.2.1 Growth to anthesis

Since the application of cool temperatures is inductive only its effect is evidenced only from the period of shoot emergence to

complete floral formation. Subsequent growth to anthesis is dependant on the temperature imposed on the plants, provided day length and light intensity are not limiting. In the Oriental lilies, this number of days to anthesis from visible flower bud development remained consistent, between 51 and 74 days and was independant of either the prior storage temperature or number of days in store. Roh and Wilkins (1973) confirmed that at consistent temperatures of 21.1, 26.7 and 32.2°C. the time to anthesis from visible bud stage was respectively 28, 25 and 24 days in *L. longiflorum* 'Ace' while those grown continuously at 15.6°C required 50 days to flower.

However with *L. x parkmanni* 'Little Robin' grown at 15 and 22°C for a period extending from planting to well developed flowers, there was an advance in flowering of 13 days in the plants grown at the higher temperature.

6.3 CULTIVATION PERIODS

6.3.1 Total cultivation period

Although the period required from end of storage to visible flower bud development is inversely related to the number of days the bulbs are stored, the total cultivation period from commencement of storage to anthesis is similar for all storage times and temperatures with any one set of bulbs.

With *L. auratum* 'Little Gem', there was a differential of 12 days in total cultivation period between those stored for 48 and 75 days at 1.7°C (Experiment III); those bulbs stored for the longer time requiring a longer total cultivation period.

Similarly with *L. x parkmanni* 'Little Robin' stored for 56 days at 4.4 or 12°C, there was a difference of 4 days only in total cultivation period.

6.3.2 Cultivation after storage

When the length of time of cultivation in the glasshouse is considered, bulbs stored for the longest period flowered sooner

than bulbs stored for other periods (Experiments I, II, III and IV) due to the more rapid growth in the earlier stages of development.

In these experiments, the difference in the glasshouse cultivation period varied between 4 and 12 days when storage periods were 14 days apart and the bulbs adequately vernalized (45 days or more). The cultivation time ranged from 107 to 138 days with *L. auratum* 'Little Gem', the longer time being required when bulb storage commenced in mid-May, soon after harvesting.

This compares favourably with the glasshouse cultivation time required in Western Europe, where, after cool storage at 2.2°C, the forcing period for *L. auratum* cultivars ranges from 116 to 130 days (Anon 1968).

The length of storage has a greater influence on cultivation time than the storage temperature; even a differential of 8°C in cool storage temperatures (4 and 12°C) produced a difference of only 4 days in flowering time (Experiment V)

Therefore from an economic aspect, bulbs should be stored for as long a time as is consistent with their flowering at the required time.

6.4 BLUEPRINT GROWING

The principle of blueprint growing infers the grower should have control of the major environmental factors affecting growth of the plants.

Under modern methods of plant production with automatic control of heating, watering, ventilation and CO_2 levels, the main environmental factors can be programmed, monitored and controlled by the producer.

Assuming that these techniques are available, it is possible to draw up a partial blueprint for the production of these dwarf Oriental lilies at specific times. Having decided the date at which the plants are to be marketed, the grower would then count back the number of days of greenhouse production required; this would determine the date the bulbs would be removed from cool store or from natural storage outside. As suggested earlier, an optimum artificial cool storage

period would be 45 days.

While potting of the bulbs is required when the plants are given natural outdoor storage, under New Zealand conditions of production, pre-potting prior to artifical cool storage is not justified for economic reasons (Experiment III).

6.5 FUTURE RESEARCH

6.5.1 Long term cool storage

The experiments so far carried out can provide flowering Oriental lily pot plants from November through to February; it would be desirable to extend the flowering period and preferably to produce these plants in mid-winter. This requires the use of plants grown the previous season. Bulbs would need to be held in moist cold storage at 0-1^{o}C until 3 to 4 months before they are brought into a greenhouse. Long storage e.g. 6-9 months at this temperature would impose adequate vernalization and plants would grow rapidly subsequently. Further experiments are required to determine the exact length of cultivation period to extend the blueprint method throughout the year.

6.5.2 Bulb production

At the present time, the number of bulbs available and the price of individual bulbs limit the possibility of producing these plants in commercial quantities.

The supply of bulblets need not be limiting as these are produced both naturally and in quantities by scale propagation. Adequately large and floriferous bulbs can be grown in two seasons of field culture. This compares favourably with the propagation period required to increase *Narcissus* bulbs in quantity from limited parent material, where three seasons of growth are desirable to produce large flowering bulbs from the parent bulbs.

6.5.3 Genetic aspects

It was earlier stated that the strong fragrance of *Lilium* 'Little Rascal' strain limits their use in domestic premises. It appears desirable that further breeding should be undertaken to reduce their scent to an acceptable level; *L. speciosum* cultivars in general are much less fragrant than those of *L. auratum*. Further breeding with the former species, but retaining the recessive dwarfing gene of *L. auratum* 'Little Gem' appears to be a desirable activity.

6.6 Temperature responses of other geophytes

Concurrently with the later experiments conducted with the lilies, investigations were also undertaken on the influence of cool storage on the flowering of other geophytes, namely *Narcissus* tulips, bulbous irises and freesias from corms.

In colder climates the bulbs are cool stored, and then forced in heated glasshouses (De Hertogh 1974, 1977, De Pagter, 1972); freesias are grown consistently at cooler temperatures in the glasshouse. In the Manawatu and regions where mean winter air temperatures and soil temperatures at 10 cm depth do not fall below 8°C, it was found that glasshouse forcing had an effect but that flowering was also markedly advanced when cool stored bulbs were grown unprotected outdoors. When protected by polythene film this effect was further enhanced but of considerable commercial importance was the the improvement in quality and cleanliness of the flower. Glasshouse culture was practised with *Iris* 'Wedgwood' which has a higher mean temperature requirement than other Dutch iris, tulips and corm freesias; outdoor or protected culture was carried out on these plants and also on *Narcissus* cultivars. Responses to storage treatments and coverage are stated in Table 6.1

Table 6.1

Influence of storage temperatures prior to planting on days to 50% anthesis under three cultural conditions with four species of geophytes.

Cultivar year	Storage Temp °C	Storage Time weeks	Cultural conditions Days to 50% anthesis G'House	Film	Unprot.	Advance to 50% anthesis Storage	Cover
Iris 'Wedgwood'	8.9	7	52	82	-		30
1971	amb*	7	a	140		58	
1975	8.5	6	56		b	89	
	amb	6	a		145		
1976	9.0	7	50	108	132		58, 24
	amb	7	a	134	148	26,16	
Narcissus	8.5	7			86	50	
'Fortune' 1975	amb	7			136		
1976	9.0	7		76	92	42,40	16
	amb			118	132		14
N. 'Dutchmaster'	8.5	6.5	a		70	46	
1975	amb	6.5	a		116		
Tulip 'Apeldoorn'	5	10	44	70	98	26,28	
1976	9	7	84b	78	105	54	27
	amb	7	114b	132	-	14	
T.'Advance	9	7	-	119	133	28,21	14
1976	amb	7		147	154		7
Freesia corms	8.5	4	110			-10	
'Rynvelts Gold'	8.5	4+7c	100		130		+30
1975	amb	4	b		161	31	
1976	9.0	7d	98	135		-12	37
	9.0	7e	86	114		47	28
	amb	7d	133		182		49

amb* = Ambient temperature of ventilated, unheated bulb store

a = Bulbs failed to flower or flowers frosted

b = Flowers failed to emerge or aborted

c = 4 weeks at 8.5°C, 7 weeks outdoors

d = Corms stored in dry pumice

e = Corms stored in moist pumice

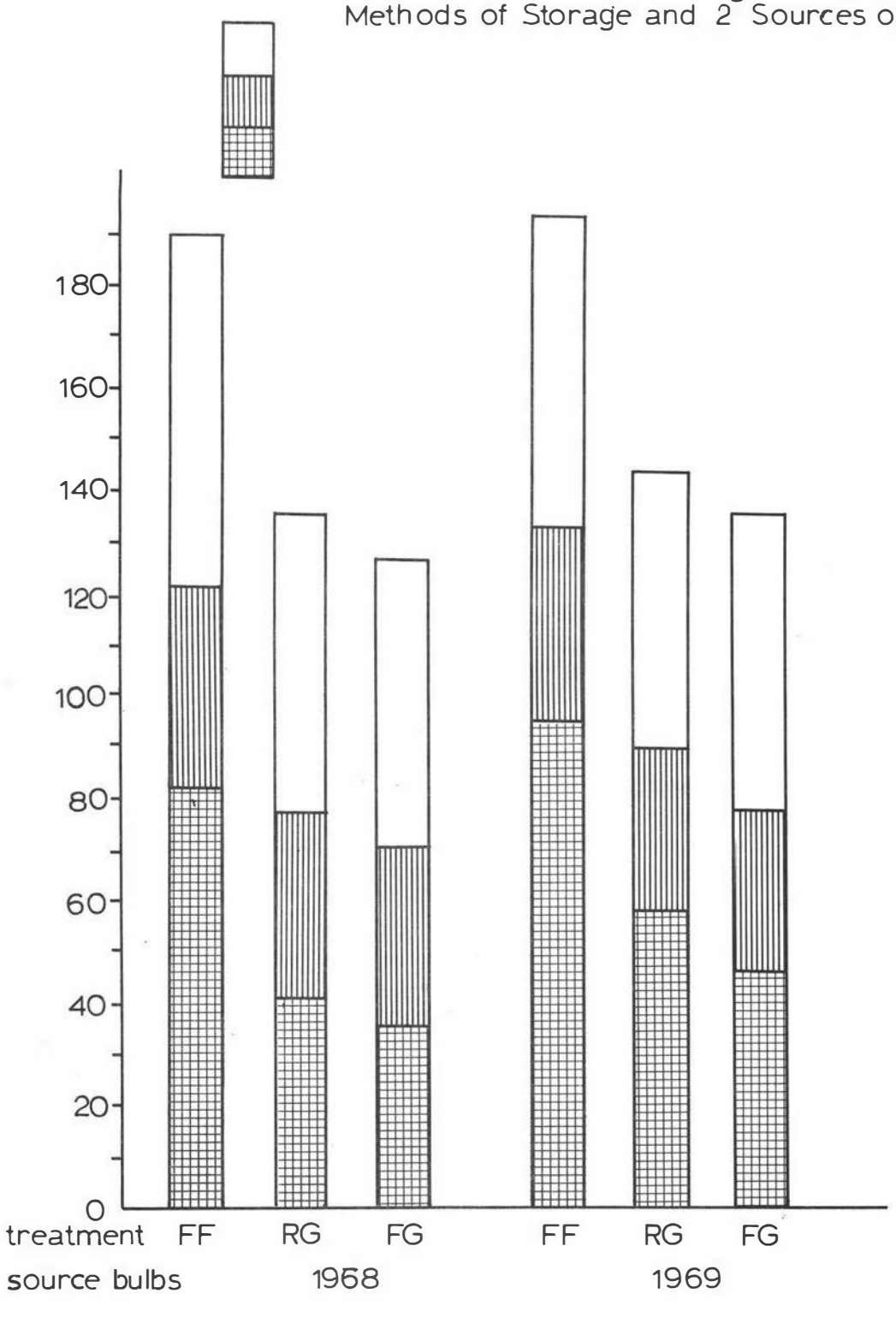
The results show that the influence of pretreatment was in most instances greater than the effect of protecting the plants after emergence and that adequate cool storage with these plants as with lilies was essential when the bulbs were grown in a heated glasshouse.

In considering the influence of cool storage on the different species, it can be appreciated that in *Narcissus*, other than *N. tazetta*, and tulips cool storage replaces natural chilling but is not a vernalization process. Particularly in tulips the bulbs require adequate chilling to achieve anthesis; shoot emergence can be stimulated by high temperatures but flowers abort.

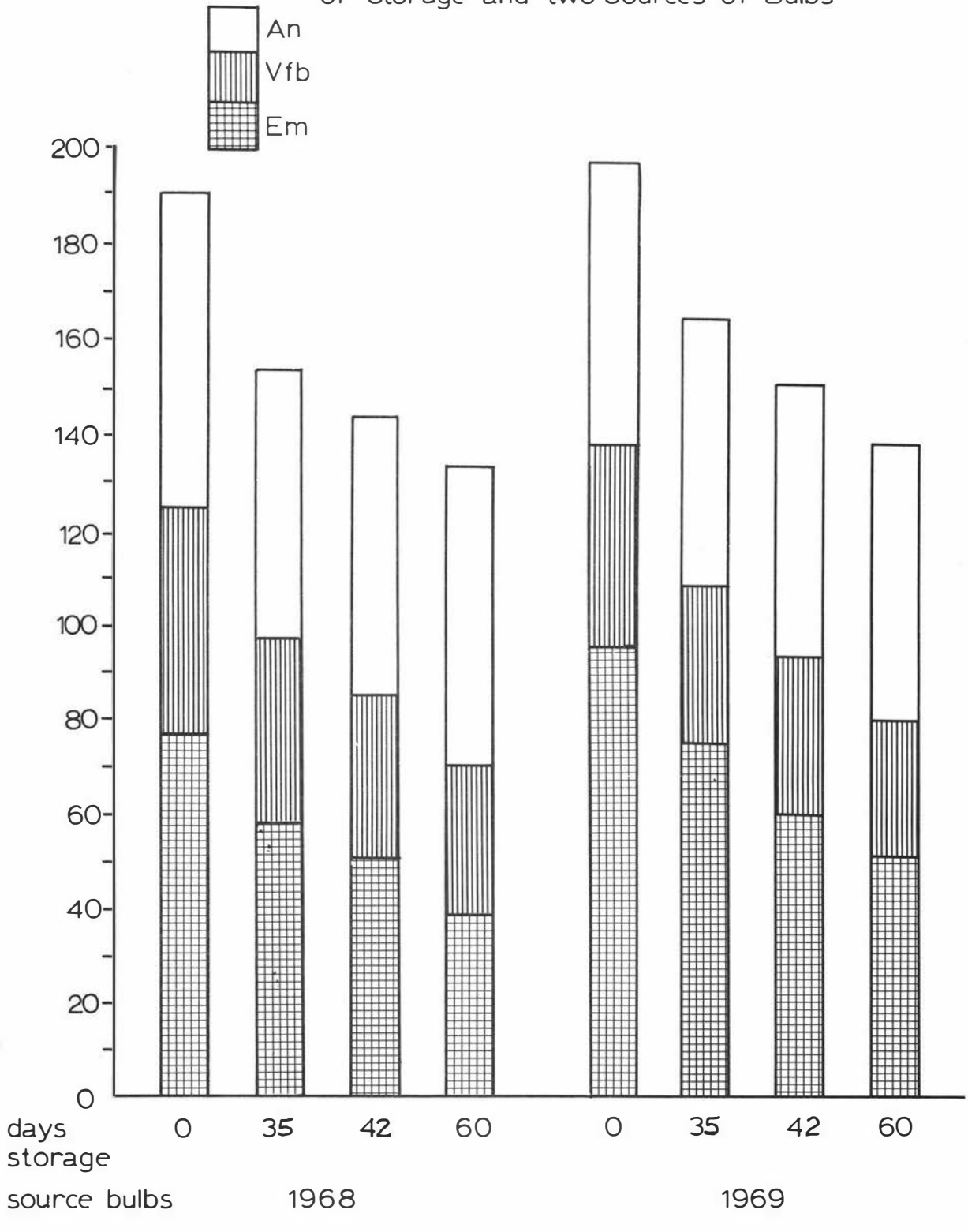
Contrastingly in bulbous iris, as with lilies, cool temperatures are vernalizing and if the bulbs are held at temperatures above 20°C, flower formation is inhibited. The response of corm freesias is interesting in that cool moist storage is more promotive than cool dry storage and both treatments advance flowering as compared with cultivation at ambient temperatures; the influence of the temperature appears to be carried forward almost as a vernalizing effect, but unlike lilies it cannot be replaced by long days after emergence.

The application of appropriate storage treatments to these plants has the two fold effect of extending the flowering season of these plants and supplying the market with a wider range of cut flowers particularly in winter and early spring.

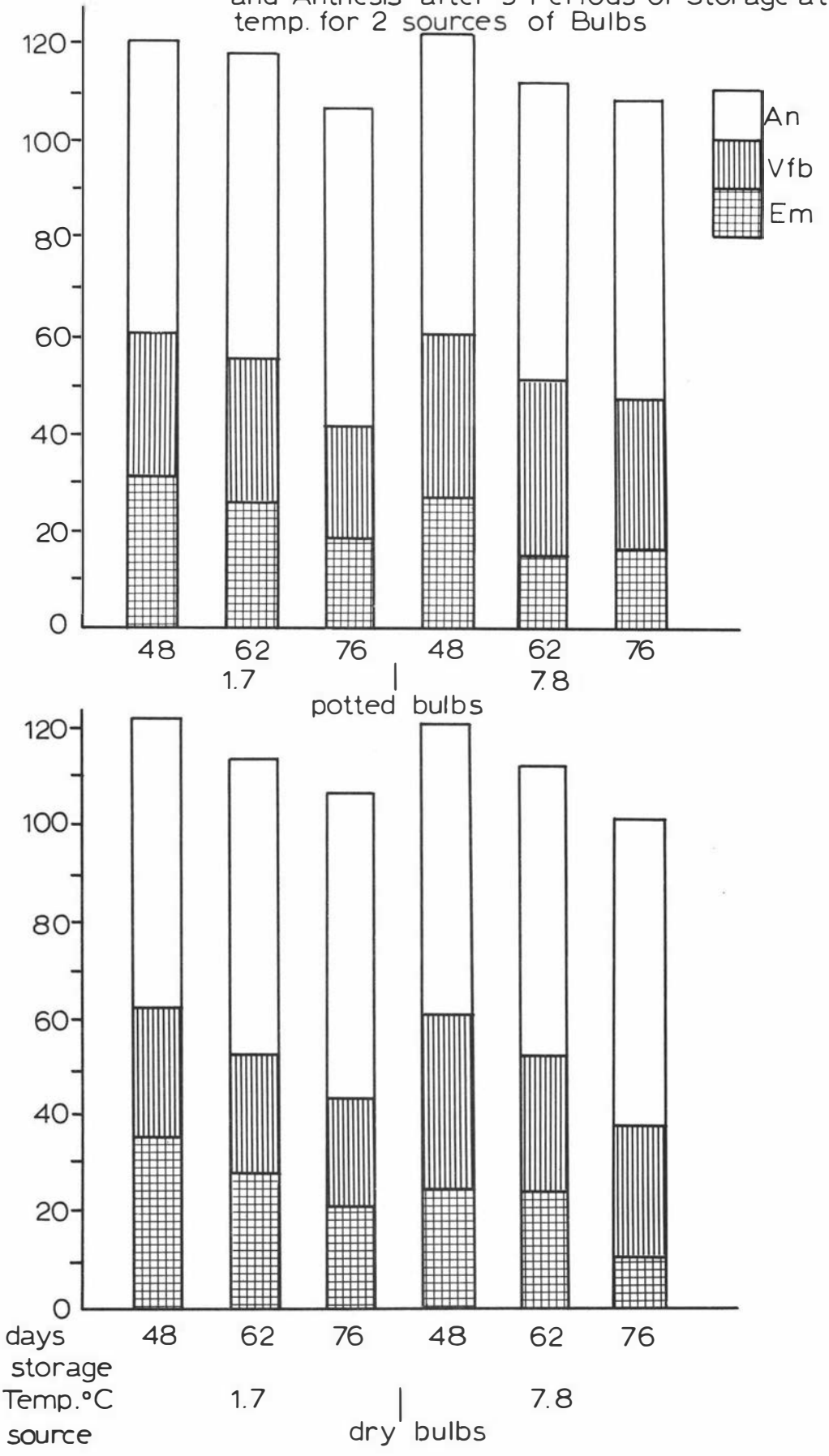
Expt. 2 Mean Days to Emergence, Visible Flower Bud and Anthesis all Storage Periods, 3 Methods of Storage and 2 Sources of Bulbs



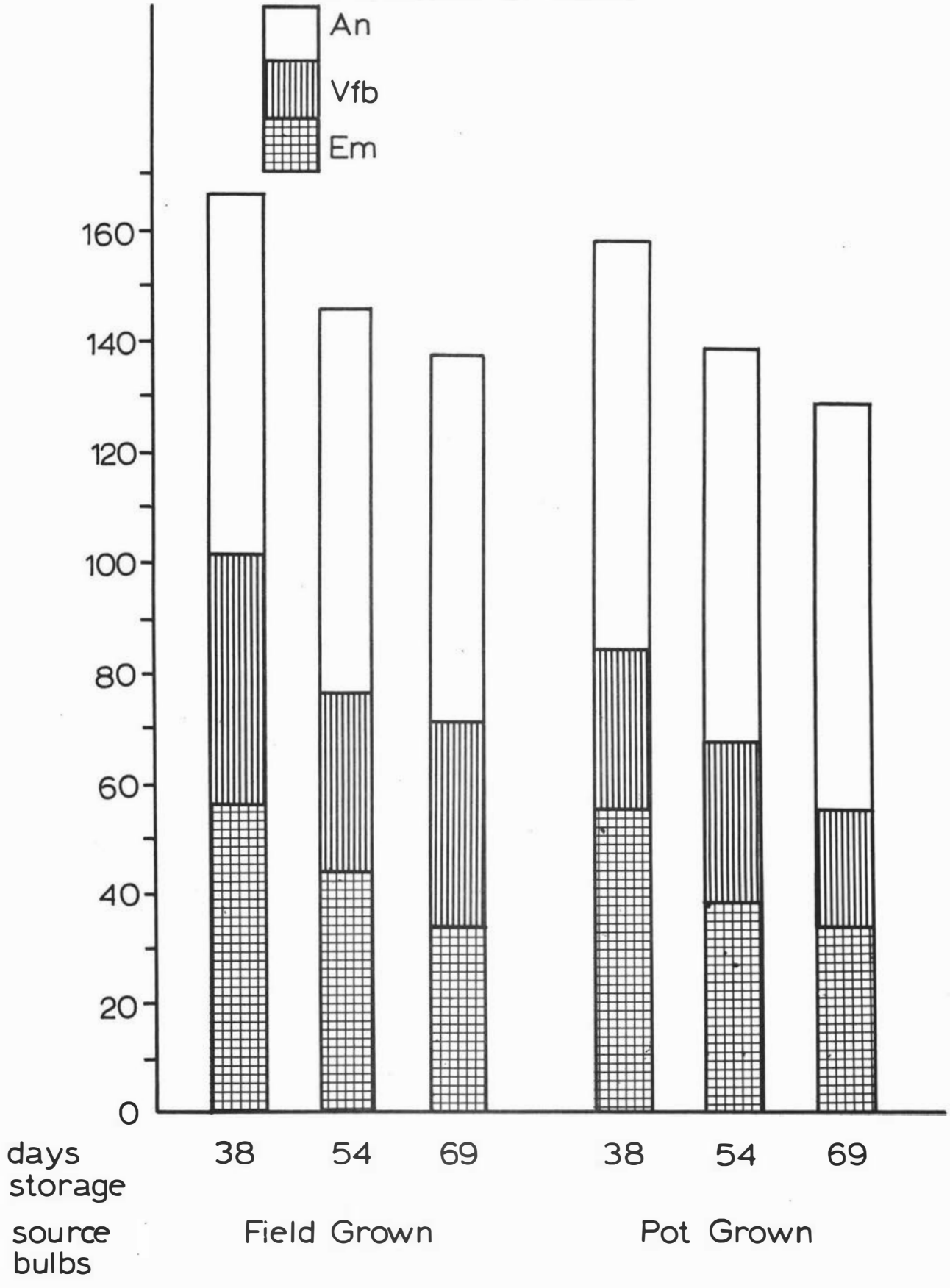
Expt. 2 Mean Days to Emergence, Visible Flower Bud and Anthesis 4 Storage Periods, all Methods of Storage and two Sources of Bulbs



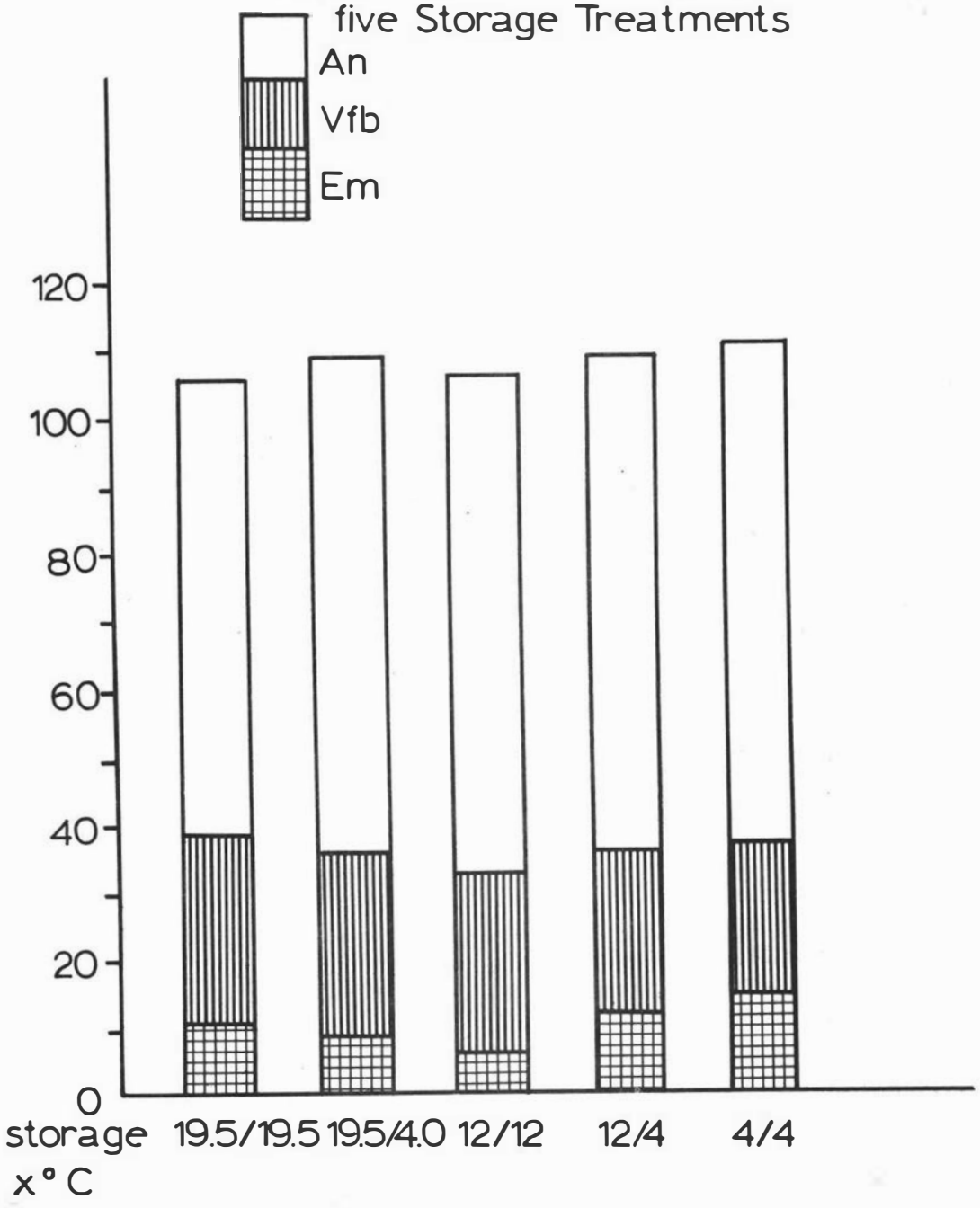
Expt.3 Mean Days to Emergence, Visible Flower Bud and Anthesis after 3 Periods of Storage at 2 temp. for 2 sources of Bulbs



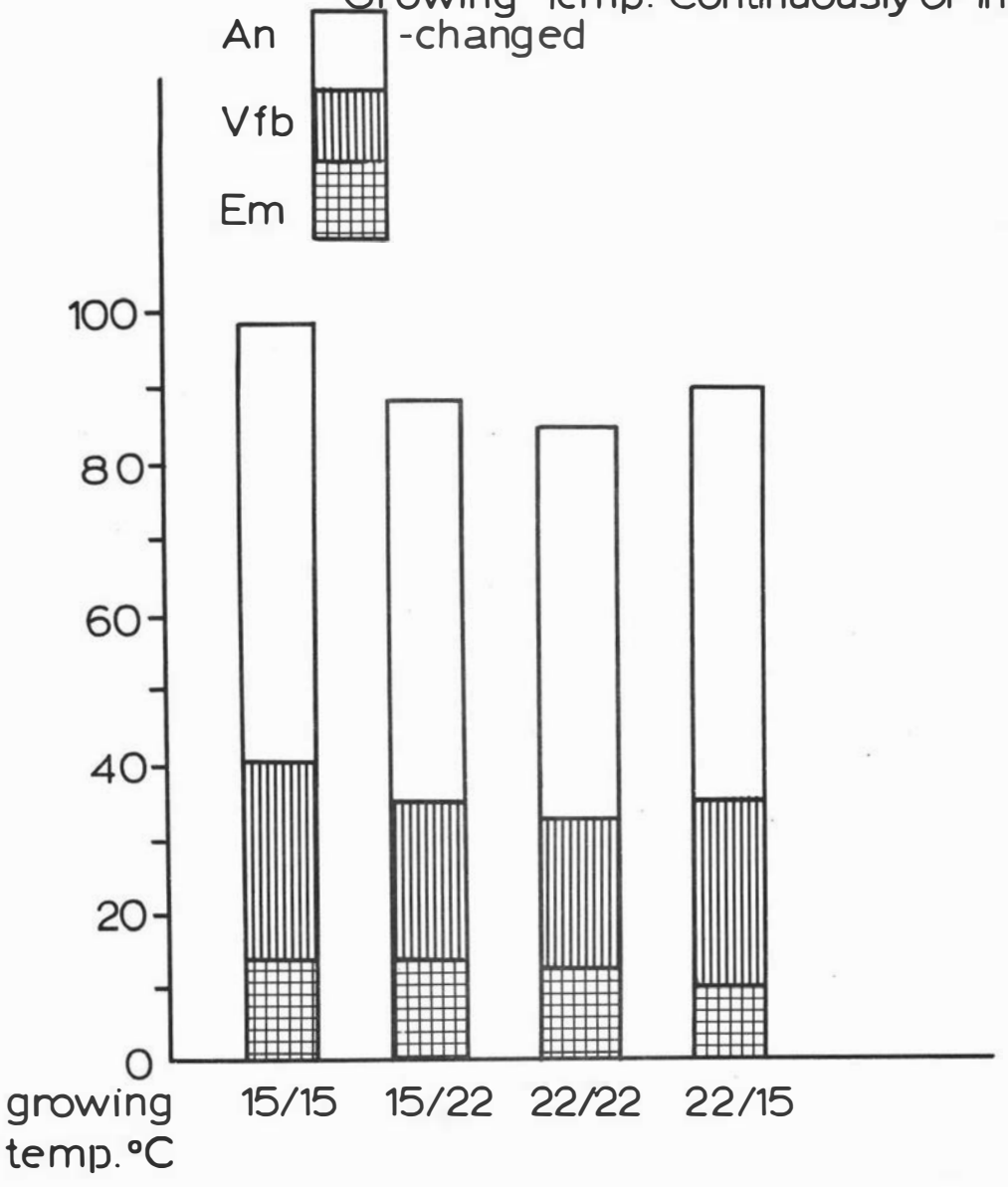
Expt. 4 Mean Days to Emergence, Visible Flower Bud and Anthesis for three Storage Periods and two Sources of Bulbs



Expt. 5 Mean Number of Days to Emergence, Visible Flower Bud and Anthesis following five Storage Treatments



Expt.6 Mean Days to Emergence, Visible Flower Bud and Anthesis at two Growing Temp. Continuously or Inter-changed



A P P E N D I X 1

GROWING MEDIA

The growing media used in the experiments were adapted from the "U.C - type Soil Mix C" (Matkin and Chandler 1957) and comprised equal parts moss peat and coarse sand (1.0 - 0.25 mm diameter).

Lime and nutrients were added in the following quantities:

For experiments I and II (Medium A)

Material	g/100 l.
Finely ground limestone	300
Single superphosphate	150
Ureaformaldehyde	75
Potassium nitrate	15
Potassium sulphate	15

For experiments III - VI (Medium B)

	Material	g/100 l.
	Dolomite limestone	300
	Single superphosphate	150
a)	Osmocote^{R}	300
	Potassium sulphate	15
b)	Frit 503^{R}	10

a) Encapsulated fertiliser with formula 18N. 2.6 P. 10 K.

b) Fritted traces elements comprising 8% Fe, 7.5% Mn, 7.0% Zn, 3.0% Cu, 3.0% B, 0.2% Mo.

A P P E N D I X 2

GLASSHOUSES USED IN EXPERIMENTS

In Experiments I, II and VI, plants were grown in the original glasshouses situated on the Massey University Campus.

The glasshouse selected was of traditional timber and glass construction of the vinery shape orientated North and South, the dimension being 5.3 metres wide x 7.1 metres in length, with a soil base.

Ventilation was at eaves and ridge manually controlled and heating was from a hot water boiler with 2 x 5 cm pipes along the outer walls.

The glasshouse used for Experiments III, IV and V was of aluminium frame and large panes of glass orientated East and West with dimensions of 6.2 x 6.2 metres, height to eaves 2.6 metres and height to ridge 3.7 metres. The base was of concrete.

Ventilation comprised two extractor fans at eave height at the East end and three louvres at floor level at the West end. These were operated by hydraulic rams at preset temperatures which were measured by a termistor suspended 50 cm above the plants. Heating was not used during these experiments.

A P P E N D I X 3

LLOYD STORAGE CABINETS

Apart from Experiments I and II when a domestic refrigerator was used, bulbs stored at specific temperatures were placed in specially constructed controlled temperature storage cabinets, called "Lloyd" cabinets in the text.

Construction of the cabinet comprised an inner and outer case of sheet steel separated by 10 cm thickness of polystyrene sheet.

Temperatures were controlled with a Honeywell Remote Bulb thermostat, type T991. 250W refrigeration was maintained by a Tecumseh Condensing Unit associated with a Bonaire Forced Draught Coil. Defrosting cycle was ½ hour in every 24 hours controlled by a Sangamo Weston 24 hour dial Synchronous time switch. Heating was obtained with a ½ kw. Heatway unit.

Two of the four cabinets were constructed through a grant from the University Grants Committee Research Fund; for which grateful thanks are acknowledged.

A P P E N D I X 4

CONTROLLED ENVIRONMENT CABINETS

During Experiment VI, plants were placed in controlled environment cabinets during part of their growing cycle. These are Temperzone cabinets manufactured by Temperzone Ltd, Auckland, described by Wratt (1977) having the following controls and characteristics:

Lighting

6 x 375W Philips HPI/T mercury iodide high-pressure lamps.

2 x 1000W Philips tungsten halogen lamps.

Measurements of energy flux density (W/m^2) at bench height in the cabinet read:

Bandwidth nm	H.P.I. 6 x 375W	Tungsten 2 x 1000W	Total
380-700 (PAR)	136	57	193
700-400	29	112	141
Total	165	169	334

Heat of the lamps is absorbed by a water bath screen.

Air circulation and heating

Air was circulated between the growth chamber itself and the airconditioning system at a speed of 0.3-0.5m/sec. A complete air change was made once a day by opening the door; this being sufficient with these plants to maintain the O_2/CO_2 rates. The desired temperature was maintained by the air conditioning unit. Temperatures were checked.

Humidity

Humidity was maintained by Humidity Control Units at 60-80% RH.

A P P E N D I X 5

DIMENSIONS OF THE FLOWER

During Experiment V. measurements were made of two individual flowers of L. 'Little Robin'. Length and breadth of the floral organs were measured by placing each part onto squared paper, measurements being taken of the length from base to apex and breadth at the widest portion. The ratio of length to breadth was calculated.

Length and breadth in mm and ratio of parts of 2 flowers (A and B) of L. 'Little Robin'.

	A			B		
	length	breadth	ratio	length	breadth	ratio
Plant part						
Subtending leaf	108	69	1.57	87	48	1.8
Bract	100	34	2.94	98	32	3.06
Pedicel	58	5	11.60	59	5	11.80
Outer tepals ($\bar{x}$ 3)	83	37	2.25	91	39	2.33
Inner tepals ($\bar{x}$ 3)	77	51	1.52	83	54	1.53
Filament ($\bar{x}$ 6)	57	3	19.0	56	3	18.67
Anther ($\bar{x}$ 6)	15	5	3.0	15	5	3.0
Ovary	22	5	4.44	22	5	4.44
Style	35	3	11.66	39	3	13.00
Stigma	5	8	0.62	5	9	0.56

The three outer perianth segments (tepals) are longer and narrower than the three inner segments, while the bract is similar in relation to adjacent foliage leaves. The anthesis recurve after dehiscence and mean measurements of 6 undehisced anthesis gave length, breadth and ratio of 22, 5 and 4.4.

A P P E N D I X 6

FULL FORMULAS OF ACTIVE INGREDIENTS OF THERAPEUTANTS USED IN EXPERIMENTS

Active ingredient	Formula
Benomyl	Methy N - benzimidazol - 2 - Yl- N - (butyl carbamoyl)
Captafol	N - (1,1,2,2 - tetrachloroethylthio) cyclohex - 4 - ene-1, 2-dicarboxyimide
Captan	N - (trichloromethylthio) cyclohex - 4 - ene - 1, 2 - dicarboxyimide
Cuprovit	Copper oxychloride
Dichlorvos	2, 2 - dichlorovinyl dimethyl phosphate
Maldison	S - (1, 2 - di (ethoxycarbonyl)ethyl) dimethyl phosphorothiolothionate
Menazon	S - (4, 6 - diamino - 1, 3, 5 - triazin 2 - ylmethyl) dimethyl phosphorothiolothionate
Parathion	diethyl 4 - nitrophenyl phosphorothionate
Thionazin	diethyl O - 2 - pyrazinyl phosphorothionate

A P P E N D I X 7

EXPERIMENT I. *L. AURATUM* 'LITTLE GEM'

Numbers of days from placing in glasshouse to emergence, emergence to anthesis, housing to anthesis, initial bulb weight, lifted bulb weight, change in weight in grams and height of stem at anthesis in cms.

Days potted to housing	g-cm days	em-an days	g-em days	in-wt. g.	lift wt. g.	change g.	ht cm.
	57	86	143	48.5	107.8	59.3	26.3
56	57	86	143	32.2	142.2	110.2	26.3
	57	86	143	32.6	133.4	100.8	28.7
	57	88	145	29.3	61.1	31.8	25.0
	77	76	153	45.7	88.9	43.2	24.5
	33	83	116	42.7	144.8	102.1	25.7
91	42	81	123	25.9	101.8	75.9	25.0
	33	83	116	25.5	72.2	46.7	28.2
	27	82	109	22.3	125.2	102.9	27.0
	28	78	106	35.2	163.6	128.4	30.6
106	29	81	110	31.8	104.5	72.7	33.1
	25	85	110	39.6	107.4	67.8	27.0
	28	78	106	46.4	118.3	71.9	25.7
	23	74	97	34.2	114.2	80.0	26.3
	31	75	106	37.0	95.1	58.1	24.5
	31	75	106	31.6	139.7	108.1	28.2
118	32	76	108	28.3	115.3	87.0	28.2
	31	74	105	29.1	122.4	93.3	27.5
	30	73	103	-	-	-	23.3

Continued...

Days potted to housing	g-cm	em-an	g-em	in-wt.	lift wt.	change	ht cm.
			81	27.7	110.3	82.6	25.7
			81	32.2	131.9	99.7	30.6
141			83	44.6	171.4	126.8	28.2
			82	43.9	138.9	95.0	31.3
			82	38.9	165.5	126.6	31.8
			68	42.2	152.6	110.4	30.6
			66	33.2	89.7	55.5	23.9
162			68	47.4	148.2	100.6	29.4
			68	65.1	176.3	111.2	31.8
Continuous			243	36.4	176.5	140.1	20.8
			247	51.9	226.4	174.5	25.1
Outdoors			246	24.1	132.5	108.4	22.0
			237	38.3	155.3	117.0	21.4

A P P E N D I X 8

EXPERIMENT I

Analysis of Variance — Housing to emergence

Treatments

No. of days from housing to emergence

1 = 56

2 = 91

3 = 105

4 = 118

Homogeneity of variances

Variance	DF	SS	VAR
1	4	320.0000	80.0000
2	3	114.7500	38.2500
3	4	25.2000	6.3000
4	4	2.0000	0.5000
Pool	15	461.9500	30.7967

Chi - square = 18.361 Probability 0.001

Individual variances are heterogeneous

Significant differences between ranked means

F test for population differences = 39.00 xxxx

Means ranked in descending order

(1) 61.00 (2) 33.75 (3) 31.00 (4) 26.60

I	J	t. test	Significance	Test Df
1	2	5.390	xxx	7
1	4	7.477	xxx	4
1	3	7.886	xxx	5
2	4	0.885	NS	3
2	3	2.173	NS	4
4	3	3.773	x	5

Continued...

Homogeneity of variances — Emergence to anthesis

Variance	DF	SS	VAR
1	4	91.2000	22.8000
2	3	2.7500	0.9167
3	4	66.8000	16.7000
4	4	5.2000	1.3000
Pool	15	169.9500	11.0633

Chi - square = 11.497 Probability = 0.010

Individual variances are heterogeneous

Significant differences amongst marked means

F test for population differences = 7.00 xxx

Means ranked in descending order

(1) 84.4000 (2) 82.2500 (3) 79.2000 (4) 74.600

I	J	*t* - Test	Significance	Test Df
1	2	0.982	NS	4
1	3	1.850	NS	8
1	4	4.376	x	4
2	3	1.614	NS	4
2	4	10.938	xxxx	7
3	4	2.424	NS	5

A P P E N D I X 9

EXPERIMENT II

Mean number of days to various growth stages for four storage periods, three cultural methods and two sources of bulbs.

Planting to emergence

Source of bulbs	1968			1969		
Treatments	FF	RG	FG	FF	RG	FG
Days storage						
0	111.7	43.0	-	125.7	64.8	-
32	83.5	49.7	42.7	97.7	72.5	57.6
45	74.6	41.2	38.3	83.0	52.1	47.0
60	59.0	32.6	27.4	72.8	45.8	36.4

Emergence to visible flower bud

0	43.7	52.2	-	40.7	46.1	-
32	40.5	35.0	40.2	36.7	26.5	33.2
45	37.0	31.0	35.1	41.6	26.2	31.7
60	37.0	24.8	31.6	33.8	25.0	28.6

Planting to visible flower bud

0	155.4	95.2	-	166.4	110.9	-
32	124.0	84.7	82.9	134.4	99.0	90.8
45	111.6	72.2	73.4	124.6	78.3	78.7
60	96.0	57.4	59.0	106.6	70.8	65.0

Visible flower bud to anthesis

0	68.5	63.4	-	62.2	56.3	-
32	68.2	51.5	51.5	61.5	51.0	55.6
45	67.3	55.4	53.8	59.0	55.1	56.7
60	67.5	61.0	58.2	60.4	51.6	60.9

Continued ...

Planting to anthesis

	1968			1969		
Treatments	FF	RG	FG	FF	RG	FG
Days storage						
0	224.0	158.6	-	228.6	167.2	-
32	192.2	136.2	134.4	195.9	150.0	146.4
45	178.9	127.6	127.2	183.6	133.4	135.4
60	163.5	118.4	117.2	167.0	122.4	125.9

A P P E N D I X 10

EXPERIMENT II

t - test significance of differences amongst ranked means.

Treatments

No.	1968 Bulbs	No.	1969 Bulbs
1	FFO	12	FFO
2	RGO	13	RGO
3	FF1	14	FF1
4	RG1	15	RG1
5	FG1	16	FG1
6	FF2	17	FF2
7	RG2	18	RG2
8	FG2	19	FG2
9	FF3	20	FF3
10	RG3	21	RG3
11	FG3	22	FG3

Planting to emergence

Ranked order of number of days.

(12)	125.69	(1)	111.75	(14)	97.73	(3)	83.50	(17)	82.78
(6)	74.67	(20)	72.80	(15)	72.20	(13)	64.78	(9)	59.00
(16)	57.67	(18)	52.11	(4)	49.75	(19)	47.00	(21)	45.86
(5)	43.80	(2)	43.00	(7)	41.14	(8)	38.20	(22)	36.43
(10)	32.17	(11)	27.44						

F - test for population differences = 247.00 xxxx

Ranked Means

12 1 14 3 17 6 20 15 13 9 16 18 4 19 21 5 2 7 8 22 10 11

Continued...

Emergence to visible flower bud

Ranked order of number of days

(2)	52.20	(13)	46.11	(1)	43.75	(17)	41.67	(12)	40.77
(3)	40.50	(5)	39.20	(9)	37.00	(6)	37.00	(14)	36.72
(4)	35.00	(8)	34.80	(20)	33.80	(16)	33.22	(19)	31.75
(11)	31.56	(7)	31.00	(22)	28.57	(15)	27.00	(18)	26.22
(21)	25.00	(10)	24.83						

F - test for population differences = 16.00 xxxx

Ranked Means

2 13 1 17 12 3 5 9 6 14 4 8 20 16 19 11 7 22 15 18 21 10

Visible flower bud to anthesis

Ranked order of number of days

(2)	68.60	(1)	68.50	(3)	68.25	(9)	67.50	(6)	67.33
(12)	62.23	(14)	61.54	(13)	61.22	(10)	61.00	(22)	60.86
(20)	60.20	(17)	59.00	(11)	58.22	(5)	57.00	(19)	56.75
(16)	55.56	(7)	55.43	(18)	55.11	(8)	53.20	(21)	51.64
(4)	51.50	(15)	51.00						

F - test for population differences = 9.00 xxxx

Ranked Means

2 1 3 9 6 12 14 13 10 22 20 17 11 5 19 16 7 18 8 21 4 15

Continued...

Planting to anthesis

Ranked order of number of days.

(12)	228.69	(1)	224.00	(14)	196.00	(3)	192.25	(17)	183.44
(6)	179.33	(13)	172.11	(20)	166.80	(2)	163.80	(9)	163.50
(15)	150.20	(16)	146.44	(5)	140.00	(4)	136.25	(19)	135.50
(18)	133.44	(7)	127.57	(8)	127.00	(22)	125.86	(21)	122.50
(10)	118.00	(11)	117.22						

F - test for population differences = 251.00 xxxx

Ranked Means

12 1 14 3 17 6 13 20 2 9 15 16 5 4 19 18 7 8 22 21 10 11

Height

Ranked order of height in cms.

(2)	38.52	(13)	37.47	(3)	28.37	(9)	27.60	(6)	27.10
(1)	27.02	(5)	26.66	(17)	26.04	(7)	25.27	(10)	25.22
(14)	24.98	(20)	24.15	(12)	24.12	(22)	24.10	(18)	23.82
(11)	23.57	(8)	22.78	(19)	22.78	(4)	22.46	(21)	22.42
(16)	22.23	(15)	20.42						

F -test for population differences = 15.00 xxxx

Ranked Means

2 13 3 9 6 1 5 17 7 10 14 20 12 22 18 11 8 19 4 21 16 15

Treatments underlined are not significantly different at P = .05

A P P E N D I X 11

EXPERIMENT III

Analysis of Variance

Treatments

	Levels of factors
T = Days of cool storage = 48, 62, 76	3
G = Temperature of cool storage = 1.7 or 7.8°C	2
S = Storage conditions = potted or dry bulbs	2

4 Blocks

Planting to emergence

Variance	Df	Ss	Ms	V.R.	Significance
T	2	1720.8779	860.4389	70.16	xx
G	1	460.0408	460.0408	37.51	xx
TG	2	13.5829	6.7914	.55	NS
S	1	136.6875	136.6875	11.15	xx
TS	2	124.0137	62.0068	5.06	x
GS	1	.0008	.0008	-	NS
TGS	2	169.7404	84.8702	6.92	xx
Error	33	404.6841	12.2631		

Emergence to visible flower bud

T	2	171.7362	85.8681	12.90	xx
G	1	357.5208	357.5208	53.70	xx
TG	2	3.8804	1.9402	--	NS
S	1	232.3200	232.3200	34.89	xx
TS	2	29.5662	14.7831	2.22	NS
GS	1	22.4133	22.4133	3.37	NS
TGS	2	4.4254	2.2127	-	NS
Error	33	219.7125	6.6579		

continued...

Planting to visible flower bud

Variance	Df	Ss	Ms	V.R.	Significance
T	2	2793.4616	1396.7308	191.36	xx
G	1	10.5469	10.5469	1.44	NS
TG	2	5.1800	2.5900	-	NS
S	1	7.7602	7.7602	-	
TS	2	37.0066	18.5033	2.54	NS
GS	1	16.6852	16.6852	2.29	
TGS	2	123.9617	61.9808	8.49	xx
Error	33	240.8652	7.2989		

Visible flower bud to anthesis

Variance	Df	Ss	Ms	V.R.	Significance
T	2	62.2212	31.1106	8.79	xx
G	1	3.4669	3.4669	-	NS
TG	2	4.8987	2.4494	-	NS
S	1	27.1502	27.1502	7.67	xx
TS	2	20.3679	10.1839	2.88	NS
GS	1	.1302	.1302	-	NS
TGS	2	28.5204	14.2602	4.03	x
Error	33	116.8402	3.5406		

Planting to anthesis

Variance	Df	Ss	Ms	V.R.	Significance
T	2	2793.4616	1396.7308	191.36	xx
G	1	10.5469	10.5469	1.44	NS
TG	2	5.1800	2.5900	-	NS
S	1	7.7602	7.7602	-	NS
TS	2	37.0066	18.5033	2.54	NS
GS	1	16.6852	16.6852	2.29	NS
TGS	2	123.9616	61.9808	8.49	xx
Error	33	240.8652	7.2989		

Continued...

Significance levels

xxx	=	P.001
xx	=	P.01
x	=	P.05
NS	=	Non significant

A P P E N D I X 12

EXPERIMENT IV

Analysis of variance, all growth stages.

Source = Field or pot grown

Treatment = Storage for 38, 54 or 69 days

Planting to emergence

	d.f.	sum of squares	mean squares	Variance ratio	Significance
Blocks	2	5.0978	2.5489	0.44	NS
Source	1	22.0005	22.0005	3.8247	NS
Treatment	2	1449.5077	724.7539	125.9950	xxx
Interaction	2	18.0211	9.0105	1.5665	NS
Error	10	57.5222	5.7522		
Total	17	1552.1494			

Emergence to visible flower bud

Blocks	2	36.4144	18.2072	2.2377	NS
Source	1	648.0000	648.0000	79.6405	xxx
Treatment	2	209.1678	104.5838	12.8536	xx
Interaction	2	120.0900	60.045	7.3797	x
Error	10	81.2072	8.1365		
Total	17	1095.0378			

Planting to visible flower bud

Blocks	2	15.2211	7.6105	1.5305	NS
Source	1	908.8006	908.8006	182.7632	xxx
Treatment	2	2736.2811	1368.1405	275.1383	xxx
Interaction	2	47.1211	23.5605	4.7381	x
Error	10	49.7256	4.9725		
Total	17	3757.1494			

Continued...

Visible flower bud to anthesis

Blocks	2	16.3333	8.1666	1.5276	NS
Source	1	135.0272	135.0272	25.2576	xxx
Treatment	2	1.5833	0.7916	0.148	NS
Interaction	2	32.6011	16.3006	3.0491	
Error	10	53.4599	5.3460		
Total	17	239.0050			

Planting to anthesis

Blocks	2	1.6845	0.8422	0.2872	NS
Source	1	338.8672	338.8672	115.5667	xxx
Treatment	2	2736.3411	1368.1706	466.5986	xxx
Interaction	2	1.4144	0.7072	0.241	NS
Error	10	29.3222	2.9322		
Total	17	3107.6294			

Significance levels

xxx = P.001
xx = P.01
x = P.05
NS = Non significant

A P P E N D I X 13

EXPERIMENT V

ANALYSIS OF VARIANCE OF STAGES OF DEVELOPMENT

Planting to emergence

Variance	D.F.	S.S.	M.S.	V.R.	Significance
Blocks	3	27.588	9.196		
Treatments	4	172.237	43.059	4.789	x
Error	12	107.887	8.9906		
Total	19	307.712			

Emergence to visible flower bud

	D.F.	S.S.	M.S.	V.R.	Significance
Blocks	3	20.548	6.849		
Treatments	4	123.443	30.861	14.467	xx
Error	12	25.597	2.133		
Total	19	169.588			

Planting to visible flower bud

	D.F.	S.S.	M.S.	V.R.	Significance
Blocks	3	22.422	7.474		
Treatments	4	68.330	17.082	2.034	NS
Error	12	100.758	8.396		
Total	19	191.510			

Continued...

Visible flower bud to anthesis

	D.F.	S.S.	M.S.	V.R.	Significance
Blocks	3	12.508	4.169		
Treatments	4	138.665	34.666	6.958	xx
Error	12	59.787	4.982		
Total	19	210.960			

Planting to anthesis

	D.F.	S.S.	M.S.	V.R.	Significance
Blocks	3	52.116	17.372		
Treatments	4	66.422	16.605	3.330	x
Error	12	59.834	4.986		
Total	19	178.372			

Significance levels

xxx = P.001
xx = P.01
x = P.05
NS = Non Significant

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