Production of Flower Bulbs in Regions with Warm Climates

R. Kamenetsky
Department of Ornamental Horticulture
ARO, the Volcani Center
P.O. Box 6, Bet Dagan 50250
Israel

Keywords: ornamental bulbs, cut flowers, potted plants, Israel, South Africa, South America, Asia

Abstract
The cultivation of ornamental bulbs is no longer limited to countries with a moderate climate. The production of high-quality bulbs and flowers in warm regions has become important during the last decade, and is encouraged by relatively cheap labor and the expansion of international trade. In spite of the fact that for commercial bulb production in warm-climate areas, species without chilling requirements are more suitable, thermo-periodic bulbs might also be grown successfully. Moreover, the potential for flower production in these regions is evident: since the light intensity is relatively high and winter temperatures are appropriate for flower development, cut flowers and potted plants can be produced in these areas during the off-season, and transported to markets in other countries. The Israeli experience in bulb and flower production provides a good example of the development of special strategies for warm climates. Bulbs of Hippeastrum, Narcissus, Anemone, Ranunculus, Ornithogalum and other species, adapted to relatively high temperatures, are grown commercially on a large scale. At the same time, the production of thermo-periodic bulbs with chilling requirements (Tulipa, Allium, Eremurus) allows us to meet specific market demands. Greenhouse flowers, produced during the winter and early spring are sold at high prices in the international market, but their production requires precise knowledge of the flowering physiology of the species, as well as a high level of growth technologies. Various aspects of the development of bulb and flower production in warm countries, as well as the research needed for this branch of the ornamental industry, will be discussed.

INTRODUCTION
For many years, the cultivation of flower bulbs was a prerogative of the developed ornamental horticulture in countries with moderate climates. Four centuries of bulb production, breeding, development of new products and bulb trade led to the clear leadership of the Netherlands in this domain, and a large public sometimes regards Holland as a primary center of bulb origin and diversity. However, as a result of globalization of the horticultural trade, transfer of knowledge and economic progress of the developing countries, bulb production is no longer limited to countries with a moderate climate. The production of bulbs and flowers of high quality in regions with warm climates has become important during the last decade, and is encouraged by relatively cheap land and low labor costs, and the expansion of international trade. With the development of landscape architecture and private gardening in warm-climate regions, bulbs became popular in the southern parts of the USA and Europe, as well as in Asian countries and Australia.

An analysis of world flower bulb production reveals that six genera (Gladiolus, Hyacinthus, Iris, Lilium, Narcissus and Tulipa) still occupy 90% of reported production acreage (Le Nard and De Hertogh, 2002). Most of these traditional crops are produced in temperate-climate regions. As the global demand for flower bulbs continues to increase, it is obvious that further marketing and production efforts are needed, not only for the leading genera, but also for the great diversity to be found among several hundred other
genera. Thus, in a new production area with warm climate, the main efforts need to be focused on the development of new commercial crops and suitable methods for their production. At the same time, special techniques could be developed for the successful growing of the “top six”.

Horticulturally, ornamental geophytes are utilized mainly for: (1) commercial flower production, including outdoor and forced cut flowers and potted plants, and (2) landscaping, including private gardening. For both purposes, commercial production of good-quality propagation material is a necessary condition.

Species without chilling requirements, originated from subtropical and arid regions, appear to be more suitable for commercial bulb production in warm-climate areas, although thermo-periodic bulbs might also be grown successfully. Moreover, the potential for flower production in these regions is evident: since the light intensity is relatively high and winter temperatures are appropriate for flower development, cut flowers and potted plants can be produced in these areas during cooler countries’ off-season, and transported to markets in other countries.

Being a significant center of ornamental horticulture in a warm-climate region, Israel invests considerable efforts in development of flower crops suitable for cultivation under warm conditions, as well as in the development of new technologies for crop cultivation, storage and transportation. Ornamental bulbs are one of the central elements of the ornamental industry in Israel, which serves as a good example of the development of special strategies for warm climates. In this paper, some examples of bulb and flower production in Israel and other warm-climate countries will serve to illustrate the possibilities for cultivating ornamental bulbs in these regions.

**BULB PRODUCTION**

**Flower Bulbs without Chilling Requirements**

Many of the native Israeli bulbous plants were introduced into cultivation and transferred to Europe and Asia hundreds of years ago. Today these species are successfully grown in Israel for flower bulb production. The best known examples are *Anemone coronaria*, *Hyacinthus orientalis*, *Narcissus tazetta*, *Ranunculus asiaticus*, and *Cyclamen persicum*. In addition, flower bulbs originated from South Africa (*Ornithogalum dubium*, *O. thyrsoides*, *Bulbinella latifolia*), South America (*Amaryllis, Leucocoryne purpurea, Eucrosia aurantiaca*) or Australia (*Anigozanthos*) have been successfully introduced into commercial production.

1. **Narcissus tazetta** (paper-white) known as ‘Galilee’ bulbs, flowers in wild populations in Israel in late autumn or winter. This species has a long history of commercial exploitation – the flowers were collected in wild populations in the Scilly Isles and shipped to London around Christmas time as early as the 19th Century. Today, *Narcissus tazetta* leads flower bulb production in Israel, with 25 million bulbs exported for dry sales and flower production in 2003. The most popular local varieties of narcissus are ‘Ziva’ and ‘Galilee’. The annual growth cycle of *Narcissus* is naturally adapted to the environmental conditions in Israel: bulbs are planted in October-November, when the soil temperatures decrease, and, after flowering, the plants grow through the winter, until the harvest in late spring. The temperature conditions of the mild Mediterranean winter, with average temperatures about 8/17°C (night/day), fulfill the plant’s requirements for flowering. Warmer spring temperatures provide the signal for bulbing and dormancy induction.

   The annual life cycle of narcissus presents a classic example of the “Mediterranean” type of bulb (Rees, 1972). Similar annual cycles characterize *Cyclamen persicum, Anemone coronaria*, and *Ranunculus asiaticus*.

2. **Ranunculus and Anemone** are cultivated in Israel and other Mediterranean areas (southern France and Italy), South Africa, California and Japan. Both crops are naturally adapted to survive summer drought and high temperatures. During their annual life cycle they enter dormancy for 5-6 months, and active growth occurs when temperatures are falling. In horticultural practice both crops are propagated mainly by seeds. Commercial
products – crowns with tuberous roots of *Ranunculus* or corms of *Anemone* – are usually formed after one season of growing as seedlings. In *Ranunculus*, vegetative multiplication by division of crowns with tuberous roots or in tissue culture is also possible, but because of disease and virus problems, basic multiplication is conducted by seeds. In 2003, 4.5 million *Anemone* corms were marketed from Israel for cut flower production, and about 20 million *Ranunculus* units were marketed for dry sale.

3. *Hippeastrum*, a popular flower bulb, originated from South America, is well-adapted for the Israeli climatic conditions. About 2 million bulbs were exported from Israel in 2003 for dry sales and potting. Initially, bulb production of *Hippeastrum* was conducted outdoors, but in recent years most of the production has been in soil-heated greenhouses (I. Gernstein, Agrexco, pers. comm.), and the resulting increased production costs necessitated an optimization of the growing method. For propagation, twin-scales are prepared from large mother bulbs and are incubated in wet vermiculite for about 3 months. The production of marketable bulbs, suitable for Christmas forcing, is conducted in two growing seasons in a greenhouse in which the soil is heated to 20°C. Bulbs are planted in the fall and harvested in June-August. The harvested bulbs are stored at 9°C or 13°C for 2 months prior to planting (Sandler-Ziv et al., 1997).

Bulbs of *Hippeastrum* are also produced on a large scale in South Africa and Japan (Okubo, 1992). In South Africa, most of production is in outdoor fields. After harvest, bulbs are stored successively at 27, 13 and 7°C to prevent flower development and emergence. In Japan, bulbs are planted in March-April, and lifted in November. During the winter, the bulbs remain outdoors (Okubo, 1992).

4. *Ornithogalum dubium*, a frost-sensitive bulbous plant, native to South Africa, was introduced into Israel about 15 years ago. Cooperative efforts of private growers, research scientists and extension service specialists enabled fast and effective development of this crop in Israel, and in 2003 more than 2.5 million bulbs were exported for potting and cut-flower production. *O. dubium* is a bulbous species, commercially propagated by seeding. Seedlings are able to flower in their first year of development, and this characteristic facilitates the breeding and selection process, as well as the expansion of commercial production. At the initial stage of crop development, the flower colors, plant heights, and flowering times of the plants produced from seeds, were highly variable (De Hertogh and Gallitano, 1997). Later, several lines were established and raised, that enabled the production of uniform cut flowers and flowering pot-plants. Tissue culturing of selected clones also helped to stabilize the main characteristics (Ziv and Lilien-Kipnis, 1997). Temperature regimes during the storage and growth stages were studied, in order to optimize forcing programs (De Hertogh and Gallitano, 1997; Luria et al., 2002).

Other flower bulbs grown in Israel for export include *Liatris* (11 million units), *Zantedeschia aethiopica* (0.75 million), *Lilium longiflorum* (0.25 million), *Leucojum aestivum* (0.5 million) and *Canna* (0.4 million).

In general, there are an increasing number of reports of successful production of flower bulbs in countries with warm climates. In Australia, outdoor production of gladiolus and clivia is widely practiced. Most subtropical bulb production is located in northern New South Wales and southern Queensland, while gladiolus corm production is located mainly in southern Queensland (http://www.library.uq.edu.au/gatton/eres/mod7.html). South African companies produce *Amaryllis* (*Hippeastrum*), *Gladiolus*, *Zantedeschia* and *Nerine*, and other species (Niederwieser et al., 2002). The flower industry in northeastern Asia is also developing quickly and is introducing new bulbous crops into commercial production (Okhawa, 2000).

*Curcuma* species, tropical herbaceous crop that is used as cut flowers, landscape plants and potted plants, can be grown in a warm, humid climate with a minimum winter temperature of 15°C. Among this group, *Curcuma alismatifolia* (Siam Tulip), originated from Thailand is probably the most popular. Another species, *C. longa*, a native of India, is widely cultivated throughout India, Fiji and Queensland, Australia, for its underground stems, which are used for the production of turmeric. *C. petiolata* and *C. roscoena*, both natives of Burma, are grown for their ornamental leaves and flowers. The beautiful
inflorescence and luxuriant foliage of *C. zedoaria* (a traditional source of Zedoary spice, tonic, and perfume) also offer potential in floriculture (Maciel and Criley, 2003).

*Polianthes tuberosa* (tuberose) originated in Central America, and was domesticated by the pre-Columbian Indians of Mexico. Tuberose was among the first plants taken back to the Old World, but it is not known as wild plants. This plant possesses a magical scent and is used for cut-flower production and as a source of perfume in many warm countries. The long spikes of fragrant flowers are excellent for use as cut flowers. This is one of the most important floral crops in Taiwan. Two major cultivars, ‘Single’ and ‘Double’ are cultivated for commercial production, and breeding programs were conducted to broaden the utilization of tuberose (Shen et al., 2003).

**Flower Bulbs with Chilling Requirements**

Numerous publications describe the physiological requirements and production systems of the common hardy flower bulbs under temperate-climate conditions (De Hertogh and Le Nard, 1993; Halevy, 1985, 1989). Bulbs with chilling requirements are produced mainly in the Netherlands, the USA, and several countries of Eastern Europe and the Southern Hemisphere. Because of their physiological traits, these bulbs are injured by drought and high growth temperatures. In addition, higher growth temperatures facilitate bacterial and viral infections, thus making bulb growing in warm regions more challenging.

From the marketing point of view, growing thermo-periodic bulbs in warm-climate regions might have several advantages. Off-season bulb production could facilitate original solutions for off-season flower production. A good example of this strategy is the production of flower bulbs in southern France and in Italy, where a special group of Single Late tulip cultivars under the common name of ‘French Tulips’ was developed. These cultivars are well-suited for the Mediterranean climate – they have high light intensity requirements and relatively modest chilling requirements. Among the best examples of this group are ‘Renown’, ‘Menton’, and ‘Maureen’. The bulbs are ready for harvest considerably earlier than those of their “Dutch” relatives, and thus can be used for early forcing and quality fresh flower production during the winter.

The production of propagating material of *Eremurus* and *Tulipa* in Israel is another example of sophisticated marketing thinking. In this case, the chilling requirements of the bulbs are provided artificially before their planting in November-December. After planting, the plants are grown through the winter and harvested in May. *Aconitum, Allium aflatunense*, and *Iris* species are also grown in Israel by means of this technology, mainly as a source for local cut-flower production. However, this technology requires precise knowledge of plant physiology and of the temperature requirements during storage and growth. Since these requirements are usually variety-specific, the development of horticultural practice requires careful evaluation of prospective varieties, physiological experiments and accumulation of knowledge for each selected cultivar.

**USE OF FLOWER BULBS IN WARM REGIONS**

**Flower Bulbs for Landscaping and Gardening**

Flower bulbs imported from Holland are ideal for the gardens in northern countries because of their thermo-periodic cycle (spring sprouting, growth, bloom and dormancy stages), but they have rather limited applications in warmer climates. *Gladiolus, Hyacinthus, Iris, Lilium, Narcissus*, and *Tulipa* still remain the most popular spring flowers in warm regions, and The International Flower Bulb Centre (http://www.bulbsonline.org) and numerous other sources provide extensive information needed for growing bulbs in warm regions. Although the techniques of artificial cooling, and growing through the winter work well, and the imported bulbs flower in March or April, they behave as an annual crop under southern conditions, and will usually die after one growing season (Howard, 2001; Ogden, 1994).

Improvements in the standard of living in warm-climate countries have enhanced
the public demand for perennial bulbs for landscaping and gardening. Species originated from warm-climate regions (e.g., *Agapanthus*, *Clivia*, *Crinum*, *Hymenocallis*, *Leucocoryne*, *Narcissus*, *Ornithogalum*, *Pancratium*, *Zantedeschia*, *Zephyranthes*) are recommended for gardens in the southern states of the USA (Howard, 2001; Ogden, 1994). These species have also become increasingly popular for gardening in Australia, South Africa, Asia and the Mediterranean region.

In choosing a selection of bulbs for landscaping and perennialization (naturalization) in warm regions, a distinction should be drawn between dry and humid climates. Usually, species originated from Mediterranean regions are not tolerant of humid summer conditions. Careful evaluation of potential species is needed in each climatic region.

**Cut-flower and Flowering Pot-plant Production**

Regions with a warm climate have many advantages for flower production. The most significant of these advantages are the relatively high winter temperatures and the high light intensity. In many countries, inexpensive land and labor also play important roles in the development of ornamental horticulture. At the same time, since ornamental horticulture is a “high-tech” activity, programmed forcing of flower bulbs demands extensive knowledge of the interactions between environmental conditions and crops, and of plant protection. Lack of knowledge of plant physiology, plant protection and growth technology can become the biggest disadvantages in flower production.

Bulbs with chilling requirements (tulips, lilies, hyacinths) are forced in many countries with warm climate, both for local markets and for export. Examples of successful cooperation within the European market are the early harvest of *Tulipa* and *Allium* cut flowers in outdoor fields in southern Italy, greenhouse production of lilies in Spain, and *Eremurus*, *Allium* and *Peony* production in Israel. The chilling requirements of these species are fulfilled either during the winter (as in outdoor production in Italy and Israel), or by controlled cold storage of the bulbs prior to planting.

In Israel, peonies were developed as a cut-flower crop. Cut peony flowers are highly valued in the market, but in Europe and the USA they are available only for a short period in the late spring and early summer. Development of this crop necessitated evaluation of the growth cycle of peonies in Israel and study of the effect of environmental conditions on flower development. Morphological studies revealed that flower bud initiation in the underground renewal buds does not depend on photoperiod; it begins in late summer and continues until the plants enter dormancy in November (Barzilay et al., 2002). The release from dormancy requires the accumulation of a certain number of chill units, which varies among cultivars. Moderate temperatures are required for stem elongation and anthesis, but high growing temperatures lead to flower bud abortion (Kamenetsky et al., 2003). Based on this information, three methods of peony growing were developed (Halevy et al., 2005):

1. Plants are grown outdoors in the cooler, higher regions of Israel. Flowering occurs in April-May.
2. Field-grown plants in uncovered greenhouses are exposed to natural winter low temperatures until they have received a predetermined number of chill units. They are then drenched with GA₃ and the greenhouses are covered with plastic sheets. These plants flower about 1 month earlier than untreated plants grown in open fields.
3. Plants are grown in containers. Following exposure to 2-4°C for 6 to 10 weeks in late autumn, the containerized plants are drenched with GA₃, and moved to unheated greenhouses where they grow and bloom. This method enables an early crop to be obtained in January-March.

Flower bulbs produced in warm regions can also be used for flower production. In this case, storage temperatures have a minor effect, whereas the growth environment markedly affects flower production. This was shown for cut flowers of *Cyrtanthus elatus* (Clark et al., 2002) and for potted plants of *Ornithogalum dubium*, *Scilla peruviana*, *Ranunculus asiaticus*, produced in Israel and recently evaluated for flowering potential in
INTRODUCTION AND DEVELOPMENT OF NEW FLOWER BULBS

Market saturation with traditional plants has forced increasing interest in novelties, and more and more countries are looking to their native flora as a source of potential ornamental crops. A major reason for genetic resource conservation is to ensure that the diversity will be available for future breeding programs and sustainable production, in order that the industry be able to react sufficiently quickly and efficiently. Regions where intensive work is being undertaken include Israel (Halevy, 2000), Australia (Plummer et al., 2000), South Africa, and Northeast Asia (Japan, Korea, China and Taiwan) (Okhawa, 2000). A special Ornamental Plant Germplasm Center was created in the USA in conjunction with the USDA National Plant Germplasm System and Ohio State University (Tay, 2003). At the same time, in most countries lack of knowledge about indigenous plant genetic resources still hinders the development of new crops (FAO, 1998).

The Middle East and Central Asia are the source of almost all “classic” bulbous crops, and many useful species can be still found in these regions. The wild Allium species have the potential to become new and interesting plants that could increase the variety of cultivated flower bulbs (Kamenetsky and Fritsch, 2002). A special collection of ornamental Allium species was created in Israel to be used for the evaluation and development of new ornamental crops (Kamenetsky, 1993). Mediterranean species of Scilla, Pancratium, Iris, Fritillaria also have remarkable potential (Halevy, 2000).

The flora of South Africa, which includes more than 2700 flower bulb species, provided global horticulture with the well known Gladiolus, Freesia, Nerine and Calla, but many more species are still awaiting evaluation, breeding and development. Many species are cultivated as special bulbs, e.g., Ixia, Agapanthus, Gloriosa, Cyrtanthus, Lachenalia, Babiana, and the list includes many more (Du Plessis and Duncan, 1989; Ehlers et al., 2002; Niederwieser et al., 2002).

South America contains a fascinating bulbous flora, whose resources are still not fully explored. The collection of ornamental Alstroemeria and Hippeastrum species native to Brazil, started in 1989, aimed to create different types of plants and flowers from those then existing as commercial varieties. Other interesting genera have been collected because of their showy flowers or aspects of growth habit; they include Griffinia (Amaryllidaceae), Neomarica (Iridaceae), Gomphrena (Amaranthaceae) (Tombolato and Matthes, 1998). New varieties of Eucrosia (Roh et al., 1992; Meerow et al., 1992) were developed and are already produced commercially.

Research projects on the breeding, propagation, physiology, micropropagation and production of flowering geophytes from Chile have been in progress for several years. Various interspecific and intraspecific hybrids of Alstroemeria species have been bred by means of a combination of traditional and biotechnological techniques. Other species that are being bred and studied include Conanthera bifolia, C. campanulata, C. trimaculata, several Rhodophiala spp., Zephyra elegans, Leontochir ovallei, Pasithea coeruela, and Herbetria lahue. Genotypic differences were evaluated for the uniquely Chilean species Leucocoryne coquimbensis, L. coquimbensis alba, L. purpurea, and L. ixioides, which have tremendous potential and value for breeding and development (Bridgen et al., 2002).

In Japan, an endangered species, Arisaema sikokianum, endemic to Shikoku and Honsyu Islands, was evaluated for its commercial potential (Fukai et al., 2002).

The Australian native plant, Kangaroo Paw Anigozanthos (Haemodoraceae) was grown mainly outdoors until a few years ago, but recently introduced high-yielding interspecific hybrids are now grown indoors for year-round production. These new hybrids are propagated by in vitro tissue culture (Halevy, 1999).

The utilization of bulbs from warm-climate regions could be greatly expanded by increased plant evaluation and effective collaboration among researchers, extension specialists and growers. Obviously, questions of knowledge transfer, legal aspects, and sharing of benefits should be treated according to the Convention of Biological Diversity (1992, http://www.biodiv.org/convention/articles.asp) and taken into consideration in
MARKET AND TRADE
The floricultural sector is experiencing rapid changes all over the world. Globalization and increasing competition have led to the development of new production centers in addition to the traditional ones, such as the Netherlands, USA, Israel, Japan, Italy, and Colombia. Floricultural production in Latin America, Africa, and Asia is increasing very quickly, and China, India, Malaysia, Pakistan, Taiwan, Thailand, Singapore, Sri Lanka, and Vietnam are new entrants into this field.

It is to be expected that the north-south axis will be important to the export market. Africa will increasingly export to Europe, and South America to the USA and Canada. Within Asia, there will be a growing interregional trade with upcoming countries like Malaysia, Thailand and the Philippines. Australia and New Zealand have possibilities for entering the niche market in Asia with high-quality products (de Groot, 1999).

CONCLUSIONS
The objectives of the research and development of flower bulbs in warm-climate regions fall into several groups:
1. The improvement of existing crops, suitable for warm climates. The development of quality products has to fulfill the expectations of consumers regarding quality and environmentally sustainable production, in combination with the price.
2. Promotion of a new horticultural use for existing and well known varieties (including bulbs with chilling requirements), and extension of their areas of production. Knowledge transfer and development of the scientific and technical basis is necessary for progress towards new, environmentally friendly and economically viable systems in the new warm-climate production areas.
3. Research on potentially useful new species and their development as new commercial crops and novel products.

ACKNOWLEDGEMENTS
The author would like to thank Dr. Nakdimon Umiel, Dr. Avner Cohen, Amalia Barzilay and Dorit Sandler-Ziv (ARO, The Volcani Center, Israel), Gideon Luria (Ministry of Agriculture of Israel), Itzik Gerstein and Theo De Langen (Agrexco, Israel) for their contribution in collecting data for this manuscript.

Literature Cited
FAO, Rome.