Ornamental horticulture is concerned with the cultivation, production and use of plants and flowers for enhancement of the environment indoors as well as outdoors, where well planned landscape plantings not only improve the environment but also add to the esthetic and functional value of the area. In the U.S., the term commercial floriculture crop production applies to cut flowers, potted flowering and foliage plants, and bedding plants produced in heated glass or plastic structures, or out of doors.

The early floriculture industry was first located near the large cities of Boston, New York, Philadelphia, and Washington. As the population spread west, the industry increased around cities of the mid-west and west coast. After World War II, Florida, Texas, and California developed rapidly as major centers of floriculture crop production. The spread of urban areas and improvements in transportation reduced "close proximity to market" as a key factor in site selection for a floriculture production establishment. This factor may reverse itself somewhat as transportation costs increase. The location of the floriculture industry will continue to depend on many factors, with the costs of heat and transportation being major considerations.

The value of floriculture products in 1910 in the U.S., as reported by Bailey (6) was $34,872,000, an increase of 85.9% over 1900. In 1910 there were fewer than 5,000 establishments in the U.S. and by 1950 the number approached 19,000 (23). Although the number of establishments has decreased in recent years, the average size has increased. In 1969 there were about 6300 acres of land area covered by glass or plastic houses for floriculture production. In addition, large areas are used for outdoor production in southern California and southern states, primarily Florida (66).

The floriculture industry has expanded, so the sales reported by firms producing flowering and foliage plants, bedding plants, cut flowers, and cultivated florist greens in 1969 totaled $484,669,564, according to the U.S. Census of Agriculture (4). This was a 66% increase over 1959. Floriculture crop expansion has continued with the wholesale value of cut flowers and foliage plants (as reported in the 22 states surveyed in 1975) showing a 24% increase over 1974, and a 90% increase over 1970. Foliage plant production has increased tremendously with wholesale values soaring to $187 million in 1975, a 65% increase over 1974 (5), and a 576% increase over 1970. Florida has been the leader with about $2 million sales in 1949, $16 million in 1970, and $87 million in 1975. Foliage plant production in California has expanded rapidly with a reported $46 million sales in 1975; an 1151% increase over 1970.

The tremendous increase in green plant production and sales has resulted from a rising use of green plants and from entry into the foliage plant industry by cut flower growers facing severe competition from imports, nurseriesmen reducing production of woody plants due to the slump in housing construction, and by other agricultural operators as well as conglomerates, speculators and investors who have entered the foliage plant production industry (60).

Data for bedding plant sales were not included in the 1975 Federal report but were reported in the 1969 census and totaled $44,824,024. Recent national surveys show that sales in 1975 were 92% greater than in 1974 and in 1974 were 95% greater than in 1973 (65), thus continuing a steady increase in this floriculture commodity. An excellent review and analysis of crop production and distribution for the 1945-70 period was presented by Fossum (24).

Two major changes in the last 10 years have been the increase in flower and plant production specifically for the mass market and "everyday sales," and the influx of imported cut flowers, primarily carnations and chrysanthemums, from Central and South America. Production for the mass market has led to modified cultural methods for producing large numbers of high quality, small-sized units.

Imports of cut flowers such as carnations and chrysanthemums have doubled each year since the late 1960's, and now account for a substantial share of the U.S. market. Imports increased dramatically in the 1971-74 period, with some levelling off in 1975-76 as more flowers were sent to European markets and as costs of production and marketing increased. In 1975-76 Latin American countries exported to the U.S. about 176 million carnations, over 100 million pompon chrysanthemum "stems" (about 14 million bunches averaging 7 stems per bunch), 13 million standard chrysanthemums, and 5 million roses (8, 31, 53). Sullivan and Goodrich (64) presented information on current and projected developments in supply and distribution of floriculture crops as a result of these...
new and intensified market pressures.

Although there were many new developments in floriculture crop production in the 30's and 40's, major scientific and technological advances have occurred in the last 25 to 30 years. A prime factor has been the availability since World War II of plastics of various forms and compositions. Growers have had to adjust production and marketing practices and increase efficiency to meet rising costs. Depending on the crop, cost of production of growing area is 2 to 7 dollars per sq ft per year; this is equivalent to $80,000 to $280,000 per acre.

Structures

The ready availability of plastics has revolutionized greenhouse construction. A number of types of plastics have been used — polyvinyls, Mylar, rigid PVC, and fiberglass, but for one reason or another those materials have fallen by the wayside. The original material, polyethylene sheeting, is still the most common material used and there are many hundreds of acres of polyethylene-covered greenhouses. In San Diego County, for instance, of a total 440 acres of greenhouses, 84% are polyethylene, 12% fiberglass, and about 4% glass. For the past few years added ultraviolet inhibitors have at least doubled the life of the polyethylene. The air-inflated double-layer polyethylene cover developed by W. J. Roberts of Rutgers University simplified construction and maintenance and greatly conserved heat (58, 59). The basic shape of the greenhouse has not changed, although studies have indicated that this should be considered. (2, 39).

Heating and cooling

Pad and fan cooling of greenhouses which was introduced in the late 1950's made a major impact on greenhouse operations, especially in the south central and southwestern part of the U.S. (15), making it possible to grow during the summer months when previously it was not. A well-designed pad and fan cooling system is very efficient and there has been little improvement on the original design. Growers have learned how and where to use this tool to the most economical advantage.

A spin-off of the pad and fan system has caused changes in the greenhouse ventilation system. Except for rose growers, most operators are now using fans for ventilation, to replace roof ventilators. Winter ventilation is achieved with perforated polyethylene tubes which allow the outside air to enter along the whole length of the greenhouse. This gives rapid mixing of the outside and inside air.

Hot air, hot water and steam applied in a variety of distribution units are used for heating. Until the Arab oil embargo in the early 1970's, the cost of fuel had been low enough that growers and researchers had not been particularly concerned. Today researchers supported by both government and private monies are studying improvements in the efficiency of heating of the greenhouse.

Automation

A key to the success of a number of floriculture businesses has been improved automation. Potted plant, bedding plant and foliage plant production have expanded at almost astronomical rates. In each case, the successful growers are those who have automated their operations as much as possible. Media mixing equipment, artificially lighted germination rooms, mechanized material movement, pasteurization equipment, potting machines, automatic watering, fertilizer proportioners, automatic black cloth controllers, automatic heating and cooling systems, etc. have been designed for greenhouse use. A grower of only 30 years ago would be amazed at the sophistication of the automation in the floriculture industry. The trend is for even greater automation.

Propagation

Mist. Mechanical spraying of water to maintain a film of moisture on the leaves and stems of cuttings is called "mist propagation." The water reduces transpiration and its evaporation cools the leaf, reducing cutting losses and improving rooting. Snyder (61) reported that mist in propagation was first used about 1936. In the mid-1950's intermittent misting and various control devices such as the "electronic leaf," time clocks, and/or solar controls came into use. Later, introduction of nutrients into the mist was found beneficial in offsetting the leaching effect of the mist, and stimulated rooting and subsequent growth of the cuttings (45). This technique is now standard propagation procedure for rooting cuttings of herbaceous greenhouse crops such as chrysanthemums, poinsettias, and carnations, as well as more woody plants such as azaleas, roses, and gardenias. The technique is also useful for direct rooting in pots.

Tissue culture. An innovation to floriculture is tissue culture propagation. Cell physiologists have been working in this field for many years but the floriculturist has recently recognized its usefulness. Its first use in the commercial industry is propagation (22, 44, 46). Today a majority of all commercial orchids are propagated via tissue culture. Fern production, especially on the west coast, is primarily via tissue culture. There are other crops that can
be propagated by tissue culture methods and many laboratories are studying these applications.

Tissue culture has the potential of helping control disease, especially those caused by bacteria and viruses. Care must be taken to insure that disease indexing procedures are built into the propagation system to avoid mass spread of these pathogens (36). This has occurred in the orchid industry, and today orchid viruses are a major problem whereas before tissue culture, orchid viruses were almost only of academic interest (40).

Tissue culture also is useful to plant breeders. It will be used for the care and maintenance of sterile seed lines, efficient storage of large quantities of genetic material, production of haploid plants, and chimeral engineering.

**Media**

Soil amended by peat moss, sand, perlite, and other materials is the most widely used growing medium in potted plant and cut flower production but in the last 15 years soil-less mixes have been adopted widely, especially for bedding plants and potted plants. This change has been due to the lack of and high cost of good soil, especially in the more densely populated areas, as well as to the desire and need to better standardize and automate plant production.

The University of California research on various mixtures of fine sand and peat moss, called the U.C. Mixes (7), stimulated the use of soil-less mixtures in ornamental horticulture. Because of the lack of suitable sand for the U.C. mix in other parts of the country, the peat-lite mixes consisting of 50% by volume sphagnum peat moss and 50% horticultural vermiculite (or perlite) and the proper fertilizers, lime, and wetting agents were developed (11) and are widely used because of their light weight, adaptability to automation, and the ease of transplanting. Many similar commercial mixes or modifications with soft- or hard-wood bark, granite sand, calcined clay and other amendments have evolved.

**Fertilization**

*Liquid fertilizer and proportioners.* For many years growers used dry organic or inorganic fertilizers for florists crops. In the early 1930's liquid fertilizers were applied in solution for commercial production of carnations in benches of sand rather than soil. The gravel culture (or hydroponics method) of growing carnations, roses, and gerdenias (32) was tried rather extensively by commercial growers but discontinued because of greater success with soil.

The development of reliable and efficient fertilizer proportioners and injectors and high-analysis readily-soluble fertilizers led to the standard practice of applying nutrients in solution through the watering system (9). Many growers apply a nutrient solution every time the plants are watered while others use a stronger solution at weekly or bi-weekly intervals.

*Slow-release fertilizers.* Although liquid fertilization is the most common method used in greenhouses, special fertilizers which slowly release nutrients over a 3 to 9 month period have special application, especially for potted plants and bedding plants. A single application mixed into the root medium before planting can supply nutrients some time after the plant is marketed. One type of slow-release fertilizer has granules of fertilizer coated with a semi-permeable membrane through which moisture moves in and the soluble nutrients pass out. Another type is based on low solubility of the granules with release of nutrients until there is an equilibrium between the granule and surrounding soil solution; as nutrients are absorbed by the plant, more nutrients are released by the granule.

*Carbon dioxide.* Although increased growth of cyclamen and nasturtium with CO₂-enriched atmosphere was reported as early as 1918 (20), commercial use did not occur on a large scale until after the research in Colorado about 1960 (26). The improved growth rate and increased yield and quality of flowers and stems have led to CO₂ fertilization as a standard practice (57) for many crops by maintenance of 500 to 1000 ppm CO₂ compared to the normal 300 ppm in the atmosphere.

**Soil testing and tissue analysis**

Soil testing as an important guide to the nutrient status of the soil is a standard practice in commercial floriculture. In addition to nutrient and pH determination, a test for soluble salts is an important part of the diagnosis.

Tissue analysis has been an important research tool and diagnostic technique for extension "trouble shooting." Use in crop production has been restricted primarily to long term crops such as carnations and roses, where adequate standards for interpretation have been developed (13, 48).

**Automatic watering**

Watering greenhouse crops by hand with a hose is an excessively labor-consuming and expensive operation. Subirrigation of greenhouse crops was proposed (29) in 1895 and there was a resurgence of research from 1940-48 (52), but the wide adoption of automatic and semi-automatic methods developed when it became possible to apply water to bench crops by means of a flat spray from nozzles in plastic tubing around the perimeter of the bench (42). Slow distribution through perforated plastic tubing on the soil surface also is satisfactory. Hundreds of potted plants may be watered simultaneously through small diameter plastic tubing carrying water from a plastic main to each individual pot.

*Capillary mat watering.* Although automatic capillary watering of potted plants on moist sand was demonstrated in 1948 (56), problems of construction of water tight benches and of fertilization of plants hindered its adoption. More recently capillary watering has

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Fig. 3. Dr. Elizabeth Earle, Department of Floriculture, Cornell University, inspecting chrysanthemum plant tissue cultures in liquid culture on a rotating wheel.
become a practical method for many potted crops which are set on a synthetic fibrous mat kept moist by an automatic watering system (30). The water moves from the moist mat to the root medium. Hand watering is eliminated except to establish capillarity when the pots are placed on the bench. Nutrients are supplied by mixing the proper slow release fertilizer into the medium at time of potting.

Soil disinfection

Soils for floriculture crop production are usually treated with heat or chemicals to control disease organisms, insects, weed seeds, and other pests. For greenhouse soils, steam is most widely used to raise the soil temperature to 82°C for 30 minutes but in the last 5 years aerated steam has been used to keep the temperature at a more favorable 60°C (3). Field soils usually are treated with chemicals. Peat-lite mixes generally are not treated.

Growth regulators

IBA, IAA, and NAA in solution or powder form are used as root promoters in plant propagation. 

Growth retardants, which slow cell division and/or cell elongation in the plant tissues, reduce plant height, and produce more compact and attractive plants when properly applied. Other beneficial effects of some retardants are making the leaves darker green, making the plants less susceptible to water stress, improving resistance to damage by air pollution, improving keeping quality, and stimulating flower bud initiation.

A progression of growth retardants from Amo-1618 to ancymidol has been used by flower growers; the most widely used at present are daminozide, chlormequat, and ancymidol, with some specificity for particular crops such as ancymidol for Easter lilies, chlormequat for poinsettias, and daminozide for chrysanthemums. Good reviews of the subject are those of Cathey (16, 17).

Foliar applications of chlormequat and daminozide retarded shoot growth of azaleas and helped induce flower bud initiation more quickly and uniformly (62). GA has eliminated the need for low temperature treatment necessary to overcome the dormancy of azalea flower buds (10).

Growth regulators used to kill, or inhibit the growth of, shoot apices cause branching of azaleas (63). Results with other crops have not been as satisfactory because of the difficulty of obtaining the necessary selective injury to the terminal growing point without serious damage to the remainder of the plant.

A time consuming, expensive task in production of the large-flowered chrysanthemum is the manual removal of the axillary flower buds around the terminal flower. Chemical disbudding (by causing abortion of axillary flower buds, or reducing the number that develop) without injury to the desired terminal bud, appears possible (19, 34), but variable responses due to cultivar, growth status, and environmental conditions have prevented chemical disbudding from becoming a standard commercial practice. Possibly new chemicals and techniques will be suitable (18).

Photoperiod and light

Photoperiod. In 1920, Garner and Allard formulated the principle of photoperiodism and demonstrated the effect of daylength (actually the length of the dark period) on flower bud initiation and development (25). In 1930, this daylength shortening was applied to make chrysanthemums flower ahead of the normal season (37). Further research about 1945 (49) led to flowering of the chrysanthemum all year around. Photoperiod adjustment is one of the most important methods of controlling time of flowering in commercial floriculture and is used for timing of flowering of chrysanthemum, kalanchoe, marguerite daisy, poinsettia, aster, etc. (38, 50).

Supplementary light. Dramatic improvements in the efficiency of artificial lighting sources have made feasible the supplementing of natural light in the greenhouse (35), a matter of special importance to the northern part of the U.S. Innovations in lighting have come in the high intensity discharge (HID) family of lamps. Lighting efficiency increased from 8% for incandescent lamps, to 20% for fluorescent, to 30% for high pressure sodium lamps.

The increase of productivity of roses with supplementary lighting was economical in spite of the high capital investment (27).

Temperature

Growers accurately control this important environmental factor through automatic heating, ventilating and cooling for maximum growth rate, flowering, and high quality.

For plants such as chrysanthemum, too low a temperature inhibits flower bud initiation, whereas cineraria and genista require cool temperatures for good flowering. Azalea requires warm temperatures for flower bud initiation followed by cool temperatures to mature the buds before “forcing” at warm temperatures.

Many bulbs have specific warm temperature requirements for flower bud initiation and development followed by cool temperature to induce rapid and uniform development and flowering when “forced” in the warm greenhouse. Some require a low temperature treatment (vernalization) to break dormancy.

The commercial application of temperature and daylength control for the many ornamental crops is reviewed by Laurie et al. (38) and Post (50).

Postharvest handling of cut flowers

After harvest and during the various stages of marketing, the day-to-day storage temperature for cut flowers is 2 to 5°C (except for certain orchids) to extend their lasting quality. For longer term holding, especially for holiday periods, flowers can be kept in dry storage in waterproof containers at 0.5°C with almost no aging for 1 to 4 weeks depending on the cultivar (47, 51). The same principle is used for storage of rooted cuttings.

Controlled atmosphere storage of cut flowers has not developed as a commercial practice. Hypobaric storage (12, 21) shows promise. Carnation flowers in the bud stage were stored for 9 weeks with no loss in ability to open or in subsequent shelf-life. Storage life of cuttings has been doubled.

Commercial chemical preparations called “floral preservatives” are used in the water to improve the keeping quality of cut flowers. Sucrose and 8-hydroxyquinoline sulfate in solution were found (1, 54) to be very beneficial for extending cut flower life and this combination or modifications, is widely used. Similar solutions are valuable for opening of flowers cut in the bud stage (28, 33).

Studies by many researchers (14, 28, 33, 41, 43, 55) are providing basic information on factors influencing the senescence of cut flowers and on methods of extending cut flower longevity.