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UNIQUE FEATURES OF THE PATHOLOGY OF ORNAMENTAL PLANTS

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Kenneth F. Baker and R. G. Linderman[1, 2]

Ornamental Plants Research Laboratory, US Department of Agriculture, SEA, AR, Oregon State University, Corvallis, Oregon 97330

This paper is concerned with the vast and diverse array of ornamental plants which have high unit value and usually are short-term crops intensively cultivated on small acreages. The first paper (30) in this series on unique features of the pathology of various crops dealt with a relatively few types of forest trees which have comparatively low unit/year value, and are long-term, large-acreage crops receiving limited cultivation. These two papers thus present polar extremes of crop types and of applied plant pathology.

Webster's *Third New International Dictionary* defines an ornamental as "a plant cultivated for its beauty rather than for use." Ornamentals have been referred to as "amenity crops" (22), in the sense that they contribute "to physical or material comfort or convenience or to a pleasant and agreeable life," but this overlooks their usefulness. Ornamental plantings used to control erosion, to provide shade and ameliorate the environment around a home through control of temperature, wind, and traffic noise, to reduce headlight glare on highways, and to help purify the atmosphere of pollutants have become necessities of modern life.

[1]M. T. Fossum kindly provided data on the value of the industry. Figures for 1977 were calculated from the 1970 percentages of each crop type (24) and the floriculture crop value for 1977 (25).

[2]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the US Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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THE ORNAMENTAL PLANT INDUSTRY

The wholesale value of ornamental crops reportedly doubled at seven year intervals for the past two decades; in 1977, US florist and nursery plants were estimated to be worth nearly $1.6 billion (25). It is estimated that these plants generate $4.8 billion in retail sales. This industry includes an extraordinary group of crops of the following six general types.

1. *Floriculture crops* include cut flowers, pot plants, and foliage plants produced in glass-, cloth-, or lathhouses, or outdoors. The flowers and some plants are discarded after use. Commercial production of cuttings for growing-on is also included in this category. In 1977 the wholesale value of US floriculture crops, representing 62.2% of the total industry, was estimated to be $1.0 billion (25). The wholesale value in 1970 was $485 million in nearly 8000 establishments, principally in California, Florida, Ohio, Pennsylvania, New York, Colorado, Michigan, Illinois, New Jersey, and Massachusetts (24). Other than an 881% increase in foliage plants, there was only modest increase in floriculture crops in the period, 1970–1977.

2. *Bedding plants* grown under glass for outdoor planting are largely annuals that are replaced yearly. This sector of the industry is expanding rapidly, and the wholesale value in the United States in 1977 was estimated to be $81.5 million, exclusive of vegetable transplants ($31.5 million) (19). This is an 80% increase over the 1970 value of $44.8 million (49).

3. *Nursery crops*, including trees, shrubs, vines, and perennials, are produced outdoors and transplanted to gardens and parks. Although the nursery life of most of these plants is but 1 to 5 years, they are long-lived and remain for many years once transplanted. Accordingly, they command relatively high prices. Some nursery plants are started as cuttings in glasshouses and then transplanted to the field or outdoor containers. The wholesale value of these crops in the United States in 1977 was estimated to be 36.3% of the industry or $576.8 million (24, 25).

4. *Bulb crops*, including bulbs, rhizomes, tubers, and corms are produced outdoors and sold for long-term planting in gardens and parks, or for short-term planting for cut-flower production of for pot plants (type 1, generally discarded after use). The wholesale value of this group of crops in the United States in 1977 was estimated to be 1.3% of the total industry or $20.8 million (24, 25).

5. *Seed crops*, including annuals, perennials, and grasses, produced in fields or under glass (high-value specialty crops) and sold for producing bedding plants (type 2), flowers (type 1), or turf (type 6), or for direct seeding in gardens or parks. Most of these plants are annuals that are discarded after use. The wholesale value of this group of crops (exclusive of grass seed) in the United States in 1977 was estimated to be 0.2% of the

total industry or $3.2 million (24, 25). However, California, the principal seed-producing state, alone reported $5.3 million in 1975 (43).

6. *Turf grasses* produced in turf or sod farms or in nurseries, are cut as a layer and transplanted to yards, parks, golf courses, and athletic fields where they become perennial lawns. In 1977, 1200 companies in the United States reportedly produced 135,000 acres of sod valued at $225 million (51). Turf was estimated at $11 million wholesale value in California in 1976 (43).

EVOLUTION OF THE ORNAMENTAL PLANT INDUSTRY

The early production of ornamental plants developed as a sideline to growing vegetables, fruit and nut trees, and field crops. With increasing demand, companies were formed that specialized in producing seeds, bulbs, and nursery stock; in the United States this stage was reached by the mid-1700s (11, 29). Training was by the apprentice system, imparting rules-of-thumb arrived at by trial and error. These "secrets" often only represented a practice used on a particularly successful crop, although that practice may have had nothing to do with the success of the crop. For example, the success of such a crop may actually have been due to the fortuitous absence of soilborne pathogens usually present.

The rule-of-thumb system continued until the twentieth century, and still persists among some untrained growers. "Root action," evidenced by new white root tips when the plant was knocked out of the container, was emphasized in growing, particularly in fertilizing and watering practices. This useful concept unfortunately has declined with the increase of technical knowledge and methods.

With the adoption of technological improvements in growing and marketing, particularly since the 1940s, a higher level of skills and training has developed in the industry. The atmosphere of constant improvement in growing practices has resulted in better growers; "how" has been replaced by "why." Agricultural Experiment Stations and Extension Services have played important roles in this improvement through their research, publications, and short courses (3).

Because of relatively limited rapid transportation prior to the 1930s, each grower tended to propagate and grow most of the plants he marketed. Such extensive and generalized production lessened the opportunity for developing specialized knowledge of each crop. Individuals in the industry have now shifted to intensive specialized production of a few crops, with cuttings, seedlings, and lining-out stock obtained from specialist propagators for growing-on or finishing. This shift has given rise to large companies concerned solely with production of propagules. Many crops (chrysanthemum, carnation, poinsettia, geranium, azalea) are now produced to a large extent from propagules from one or a few sources. While this led to improvement in quality, it exposed the industry to the possibility of disease epidemics, some of which are discussed below.

Disease Epidemics and Grower Response

The chrysanthemum, a short-day, fall-flowering plant, has long been grown in gardens and as a florist cut-flower. In the 1930s foliage diseases of this plant were controlled by fungicide applications, and verticillium wilt was minimized by using one of the few available resistant varieties and by careful irrigation to avoid overwatering.

In 1943, Dimock (20) developed the cultured-cutting technique to provide *Verticillium*-free chrysanthemums for research purposes. This method was commercialized by Yoder Brothers Inc., Barberton, Ohio, who parlayed it into a large business. Soil fumigation came into use about that same time and, in conjunction with pathogen-free cuttings, provided *the* method for control of verticillium wilt. Since resistance to *Verticillium* was no longer necessary, the number and types of available varieties increased. Commercial day-length manipulation to control chrysanthemum flowering came in the late 1940s and extended the chrysanthemum season. Precise dependable scheduling of the crop was then a reality, but the buying public regarded the chrysanthemum as a fall flower and was slow to accept it in other seasons. Acceptance was general by 1970, however, and year 'round pot chrysanthemums became big business.

Concentration of propagation in a single company set the stage for, and also the recovery from, the national epidemic of the "stunt disease" in 1947–1950. This disease is a prime example of the rapid rise and decline of an epidemic of a major crop. The disease, first observed in 1945 and still unimportant in 1946 (21), appeared nationally in the United States in 1947, so severely reducing plant size and flower quality that the chrysanthemum industry was seriously threatened (8, 9, 33). From 30 to 100% of the plants were affected; 90% infection was common (12). The highly infectious viroid that caused the disease was spread by contact during routine handling, had a 3 to 8 month incubation period, and conspicuous symptoms appeared only at flowering. Therefore, plants kept vegetative for cutting production became infected during production handling, but remained symptomless. Since a high percentage of the cuttings used commercially in the United States then came from one company, and symptoms could not be detected until the cuttings flowered, the disease appeared more or less simultaneously throughout the United States in 1947–1948, causing widespread concern.

Before the causal agent was identified, the company established a strict system for production of cuttings aimed at eliminating transmission of whatever agent might be involved (12, 44). So carefully was this program carried out that cuttings distributed in late 1949 carried little infection, and by 1950 the disease was reduced to minor importance (10). The staff of the company (Yoder Brothers Inc.) and the research team involved (A. W. Dimock, J. R. Keller, and Kenneth Post at Cornell University, and Philip Brierley and F. F. Smith of the US Department of Agriculture in Beltsville) deserve great credit for this remarkable accomplishment. It should be emphasized that, although this concentration of cutting production in one establishment largely made the epidemic possible, this same concentration made possible the rapid production and distribution of clean stock and the abatement of the disease. In general, the ornamental industry is financially and organizationally able to rapidly take the necessary steps to deal with an epidemic.

Another example of the sudden occurrence and disappearance of a major disease epidemic of an ornamental crop was the cylindrocladium disease of glasshouse azaleas. The occurrence of the disease in the mid-1960s coincided with the rapid expansion of the flowering pot-azalea as a florist item, due largely to development of many new cultivars with horticulturally desirable characteristics (e.g. large flowers, compact growth, and good forcing predictability).

Cuttings were propagated, and liners were shipped primarily from large growers in the southeastern United States to growers in many other states to be forced. Unfortunately, several of the new cultivars were especially susceptible to *Cylindrocladium scoparium,* a pathogen first described on azaleas in 1955 but quiescent until the 1960s. During shipment and subsequent forcing, many of the liners suddenly began to wilt. Since the wilt and root rot symptoms were similar to those caused by *Phytophthora* spp., diagnosis, and therefore control recommendations, often were incorrect. Before long, the industry was faced with a disease that had been spread throughout the United States. Linderman (35) demonstrated in the late 1960s and early 1970s that the leafspot disease, which occurred primarily in the southeastern areas where propagating was done, and the root rot wilt disease, which occurred in other areas where the plants were forced, were two phases of the same disease simply separated geographically. Some 30–60% of the liners being shipped were infected but symptomless. Infections had occurred during propagation, but not to the extent that the infected plants would be detected and discarded. These facts pointed the way to appropriate control measures. Highly susceptible cultivars were eliminated from the trade where possible, no infected cuttings were used in propagation, stock plants were sprayed regularly with foliage fungicides, and softwood cuttings were taken from production plants that had been less exposed to aerial inoculum than had stock plants. The application of the new systemic fungicide, benomyl, also played a key role in checking the dispersal of infected but symptomless liners. By 1973–1974 the cylindrocladium disease had practically disappeared, but in the process several azalea growers went out of the azalea business.

Growers of rose rootstocks in Washington, Oregon, and California suffered from a disease panic in 1929–1932. Although rose mosaic had been present in commercial stocks without causing serious losses, papers published (42, 54) in 1930 suggested that damage might be far greater than had been thought. A brief survey (42) of all rose understocks on the Pacific Coast reported that 10 to 100% of the plants were virus infected. Michigan rose growers met in 1930 and, after hearing R. Nelson present the results of his survey, adopted a resolution stating that "Grafting stock of Roses grown in North America . . . may be and apparently is largely affected by this disease; and whereas foreign-grown stock seems to be quite free of the disease," they requested "the State Board of Agriculture to investigate the situation and, if deemed necessary, to proclaim a quarantine against Rose stocks coming into the state of Michigan unless certified as clean. . . ." (56). White (55), Milbrath (38, 39), and Weiss & McWhorter (52) immediately expressed doubts about whether symptoms of the virus could have been distinguished from insect and other injuries during the survey, and whether foreign stocks were actually free of the virus.

Eastern growers of glasshouse roses, who were then grafting commercial varieties on these rootstocks, widely canceled orders for material from the West Coast and used unsurveyed stocks from France. The incidence of mosaic in glasshouse roses was little affected, but the western growers of rose rootstocks sustained heavy losses. D. G. Milbrath, pathologist with the California Department of Agriculture, was said to have fittingly summed up the brief inspection tour of West Coast roses as "more of an athletic feat than a scientific accomplishment." This situation arose because insufficient knowledge of symptoms of the disease in the field, as distinct from insect and other injuries, led to an inaccurate survey. Apparently even immaturity of understocks at time of digging, a condition that could lead to plant death, was confused with mosaic (13). The rose mosaic problem reappeared in 1977, when an eastern state inspector ordered a rose shipment destroyed because of mosaic.

It is of interest to note that on October 27, 1948, a meeting of northern California chrysanthemum growers similarly discussed the advisability of imposing an embargo against eastern chrysanthemum cuttings because of stunt disease. In this instance cooler judgment prevailed, and eastern cuttings continued to be used.

Improvements in Culture

The chrysanthemum story illustrates how integrated simultaneous developments in plant pathology, horticulture, soils, and marketing may completely change an agricultural industry. These developments, however, must occur as part of the overall picture, and each must be compatible with the others. For example, light-weight soil mixes such as U. C. Mixes, Jiffy Mix, and Peat-Lite came into general use after 1957 (2), making it economic to ship pot plants, even by air. With the longer flower life of potted chrysanthemums, compared with the cut-flower crop, the increased availability resulting from cheaper transportation, and a wider selection of varieties, the year 'round chrysanthemum became the most popular florist crop, surpassing the rose and the carnation. By 1970 the estimated wholesale value of pot chrysanthemums in the United States reached $35 million (24). It should be noted that when year 'round culture of a crop is achieved, the host-free period is eliminated from the disease cycle, and the hazard of a potential disease epidemic is increased.

It is not worthwhile to introduce pathogen-free propagules into the culture of a crop without the concomitant adoption of soil treatments and sanitary procedures. Some growers at first insist that it is not worthwhile to use healthy cuttings because the soil is infested, or that it is not useful to treat the soil because their propagules are infected. For example, healthy geranium cuttings were developed at the University of California, Los Angeles, in the mid 1950s. These were released to commercial propagators in southern California, but the plants from clean cuttings were quickly contaminated due to inadequate field sanitation. The Carefree geraniums, grown from seed, were released by Pennsylvania State University in the early 1960s in response to the need for pathogen-free propagules; they have since been greatly improved, especially in the rapidity of growth. A market for geraniums from cuttings still persisted, however, and several companies now produce cuttings from culture-indexed stock grown under glass instead of in the field. Apical-meristem culture also is now being used to develop virus-free geraniums for cutting propagation.

The increased cost of labor has made mechanization and labor-saving methods necessary. Modern growing tends to be a production-line operation, particularly in the production of bedding plants and pot chrysanthemums. The time required to produce a marketable plant has been steadily reduced. As with mechanized production lines in other industries, vulnerability of the establishment to labor troubles and to disease losses is increased. Since plant materials must be uniform and production needs to be scheduled in such assembly-line methods, slow growth, small sickly plants, or undependable supply are not acceptable. Mechanization therefore depends upon standardized methods for producing healthy plants (2).

The progress from relatively primitive, apprentice-type production, through technological improvements to the modern, specialized, highly technical operation often leads to large corporate business. However, there is still a place in the business for the grower who carefully operates a small establishment, particularly for specialty items that require more attention than a large operation is willing to give.

DEVELOPMENT OF THE PATHOLOGY OF ORNAMENTAL PLANTS

Studies on the diseases of ornamental plants in the United States began about 1880 (3). B. D. Halsted might justifiably be regarded as the first American pathologist of ornamentals because of his many publications from the New Jersey Agricultural Experiment Station from 1890 to 1905.

Cook (17) nonetheless found in 1916 "a very meager literature on the diseases of ornamental plants" because most people did not consider ornamentals to be economically important, and growers had learned to live with plant diseases without help from pathologists. These conditions have changed completely, particularly since the 1940s. White (53) had reported in 1930 that "Plant pathology as related to ornamental plant materials is the most recent field of the science to be seriously considered."

The Census of Agriculture has provided information on the importance of the ornamental plant industry. Growers have become organized and seek assistance on disease problems of their plants. Pathologists have found, once they establish cooperative relationships with growers, that disease problems of ornamentals are unusually rewarding subjects of study.

The number of pathologists concerned with diseases of ornamentals increased greatly as the industry expanded and became an economically significant segment of agricultural production, but most of them still devote only part time to these crops. Apparently R. P. White (1927, New Jersey), P. E. Tilford (1930, Ohio), A. W. Dimock (1938, New York), and K. F. Baker (1939, California) were the first to devote full time to these crops.

Expressed as full-time equivalents, there were 5.4 pathologists involved in research, extension, and teaching in the pathology of floriculture crops in the United States in 1925, and 14 in 1939. By 1957 this had risen to 61.6, involving 91 people, 41 of whom were full time (3). These data excluded workers dealing with woody nursery crops and turf. Figures on the number of pathologists now working on all ornamentals are unavailable, but the number involved in 1957 certainly has been maintained or possibly increased, although not at a rate comparable to the 1944–1957 period. The 1974 *Directory of the American Phytopathological Society* listed 179 US members who indicated activity and/or interest in diseases of ornamental plants; they were mostly affiliated with state Agricultural Experiment Stations, state Departments of Agriculture, US Department of Agriculture, private companies, or were consultants. States having four or more pathologists of ornamental plants were California, Florida, Pennsylvania, Ohio, Oregon, North Carolina, Wisconsin, Virginia, Illinois, Maryland, New York, Washington, Georgia, and Alabama. During the period 1957–1974, there probably has been a greater increase in pathologists of nursery crops and turf than of floriculture crops.

An increasing number of journals on ornamental crops have appeared that serve scientists, extension workers, and growers. Numerous trade journals publish semitechnical and popular papers on diseases of ornamentals. There have also been an increasing number of journals, annuals, and yearbooks published by societies specializing in a given crop or group of related plants. Commercial companies now issue technical publications, and State Agricultural Experiment Stations publish journals that present their research on ornamental plants. In several states the Agricultural Extension Service, at both state and county levels publishes small magazines providing current information to growers. Many state Florist Associations, beginning with Ohio in 1929, usually in cooperation with the state Extension Service, have published magazines reporting new investigations. There were 75 of these various publications in 1957 that contained papers on floricultural pathology (3). Papers on the pathology of all ornamentals probably appear today in well over 100 such restricted publications. Since experimental results often appear first in such journals, and all too frequently nowhere else, it is difficult, even for the specialist pathologist, to keep abreast of new developments on diseases of ornamentals. Probably less than one fourth of the US papers on pathology of ornamentals are published in the journal, *Phytopathology.* Other pathologists rarely or never see these restricted publications, and therefore may not realize the volume of research on diseases of ornamentals. However, the important diseases of the 50 major ornamentals are as well understood today as those of comparable vegetable, fruit, or cereal crops.

UNIQUE FEATURES OF ORNAMENTAL PLANTS AND THEIR PATHOLOGY

Ornamental plants differ from other crops in a number of ways that have determined the character and evolution of the industry during recent decades, and have directly or indirectly influenced the pathology of these plants. These unique features have placed unusual demands on, and have presented opportunities to, growers as well as pathologists.

Diversity of Crops, and Transitory Cultivars

The complex of crop types described above is further complicated by the diversity of plants included. It is estimated that at least 1100 genera of plants are grown as ornamentals, most of them infrequently or rarely. There were representatives of about 250 genera sold on the Los Angeles flower market in the 1950s; this probably is typical of most large markets. Some genera of ornamentals include many species, and the number of cultivars may be very high. For example, approximately 20,000 varieties of roses (1), 7000 of gladiolus, and 300 of sweet pea have been developed and named. Because of the large number of ornamentals, the minor diseases of major crops and the major diseases of minor crops often have received minimal attention.

New plant novelties are a prominent aspect of ornamentals, particularly in floriculture crops, bedding plants, and seed crops. Breeders of these crops emphasize the introduction of new varieties to the market each year rather than the improvement of existing lines or the development of varieties resistant to diseases or insects. The All American Trials for annuals and roses, for example, effectively emphasize newness rather than quality improvement. This continuing introduction of new varieties tends to shorten the market life of existing cultivars, and to make uneconomic the time-consuming and expensive development of varieties resistant to disease. It may also deter investigations on resistance of ornamentals by plant pathologists.

Because of the large number of closely similar cultivars, there is a tendency to substitute one for another in filling orders; this has been observed among sweet pea varieties, for example. This varietal uncertainty further lessens interest in developing disease-resistant varieties, and brings into question the practical value of publishing studies evaluating disease resistance or tolerance of cultivars of ornamentals to a given disease. This does not imply, however, that such information is useless.

It was found (K. F. Baker and W. C. Snyder, unpublished data) in several years of observations in California sweet pea seedfields, where pea enation mosaic infects all the plants each year, that cultivars with certain pigments in the petals tended not to show flower breaking. White or cream varieties with white seeds did not show the red color breaking of petals, whereas white or cream varieties with black seeds did; clear blue varities did not show the reddish color breaks common on cultivars with petals of a slight reddish cast. Some cultivars also were severely stunted (shock effect) following aphid transmission of the virus in the seedling stage, but other more tolerant cultivars were almost unaffected. This information was used by breeders, who tended to select away from lines that showed shock effect and conspicuous color breaking. This information thus indirectly benefited the home grower. Had these varietal differences been published, however, they might have confused gardeners because cultivars might be substituted, and would likely become unavailable in a few years. It is not surprising, therefore, that resistant varieties are much less useful and less used in ornamentals than in other annual crops such as vegetables or cereals.

The larger the number of cultivars of a plant grown, the less likely it is that a new variety will have a significant impact on the industry. The emphasis in new releases is on improved horticultural qualities such as plant size and shape, color and size of flowers, and time of flowering, rather than disease resistance. Even when resistance or tolerance to a major disease is mentioned, such cultivars or species may not be chosen by growers unless they can be directly substituted for the most popular cultivars. Thus, the marked tolerance of the rhododendron cultivar Caroline to the widespread severe phytophthora root rot and wilt disease (32) did not greatly change its popularity in the trade. Its resistance to the phytophthora disease has not even been communicated to the consuming public, who may not care about its resistance if its appearance is the major consideration.

It appears that the challenge of breeding or selecting for disease resistance in ornamental plants, where hundreds of commercial cultivars are already grown, is not taken up by breeders or pathologists largely because the returns are too small. This is not to say, however, that researchers have not identified resistance in many ornamental crops, although such resistance was often specific for a given organism in a given localized environment. As examples, resistance has been reported in snapdragons to rust; chrysanthemums to verticillium wilt; roses to powdery mildew, rust, and black spot; gladioli to fusarium yellows; woody plants to armillaria root rot; begonias to pythium root rot; mimosas to fusarium wilt; lilies tolerant of mosaic and fusarium basal rot; sweet peas tolerant of mosaic. Resistance as a type of disease control is destined to assume greater importance in ornamentals as in other crops, but will likely have the greatest impact in crops where relatively few commercial cultivars are grown, where the disease has had a sustained and substantial economic impact, and where a direct substitution of the resistant plant for existing horticulturally desirable, but susceptible, cultivars is possible.

Attempts are being made to increase the reliability of varietal names of ornamentals. Thus, the Royal Horticultural Society in England has attemped to standardize sweet pea cultivars; the American Rose Society, rose varieties; and the Florida Agricultural Experiment Station, camellia varieties. The plant patent laws for vegetatively propagated ornamentals, and the development of F_1 hybrids in ornamentals grown from seed also tend to make cultivars less transitory by protecting the originator. It is doubtful, however, whether any other crop group presents such an extensive array of plants, or is plagued by so many transitory varieties.

Many genera of cultivated ornamentals have species native to or established in some part of this country, often in proximity to commercial plantings. Pathogens on these wild species constitute a reservoir of inoculum for the cultivated crops. The spread of snapdragon rust, *Puccinia antirrhini,* from wild *Antirrhinum* spp. to cultivated snapdragon in California by 1879, and subsequently over much of the world, is a case in point. With the recent strong interest in commercial cultivation of native plants for landscape purposes, the disease hazards are increased. Growers expecting such plants to be more disease tolerant than existing cultivars or species have sometimes been disappointed (36).

High Crop Value in Relation to Disease Control

Perhaps the feature of ornamental plants that has most influenced the approaches to control of their diseases is their comparatively high value. Ornamentals range from those of very high to quite low unit/year value. The annual wholesale value of potted chrysanthemums averaged $3.09 per square foot of production space in 1977 (19), or more than $134,000 per acre. Potted lilies averaged $115,000, and foliage and bedding plants $96,000 per acre. On the other hand, the value of field-grown ornamentals per acre/year may be lower, but still higher than field-grown food and fiber crops. Growers estimate the wholesale acre/year value for rhododendron to be $14,000, shade trees $7500, and bulb crops $5000–$15,000. By comparison, the value for strawberries is $5550, potatoes $860, cotton $300, dry beans $180, and wheat $86 (48).

Several significant features of the pathology of ornamentals, and particularly of floriculture pathology, result from this high unit value per year. The more intensive the cultivation, and the more valuable a crop is, the higher is the tolerable cost of production and of disease control. Thus, low-value field and forest crops perhaps justify only 0.5 to 5.0% of the production cost for disease and pest control. The grower of such a crop usually will hesitate to apply a control procedure unless its economic success has been thoroughly demonstrated. The level of control required is accordingly less than that for high-value crops, and maximum net return, rather than perfect disease control, is sought. Thus, sugar beets given a single application of wettable sulfur to control powdery mildew when it first appears each year give 91.6% of the sugar yield of beets given three additional applications (31).

For median-value vegetable and tree fruit crops, a grower may be willing to spend up to 10% of production cost for plant protection, and to venture into developing or testing a new method of control.

In contrast to the above, growers of high-value crops such as glasshouse plants or field-grown strawberries may willingly spend up to 20% of production cost for disease and pest control. For example, a California flower-seed grower had a field of new tetraploid snapdragon varieties that were to be introduced on the market. Because the fleshy flowers remained moist and did not abscise, and the weather was cool and foggy, infection with *Botrytis cinerea* was common, spreading from the corolla through the pedicel to the main stem, girdling it. To save this valuable seed crop, the grower removed each infected flower by hand, excising lesions of the main stem with a scalpel and painting the wound with a thick Bordeaux mixture.

The more valuable the crop, or the greater its volume of production, the more likely that its disease problems will be investigated. Thus, there have been about 500 papers published on black spot (*Marssonina rosae*) of roses, and more than 175 on snapdragon rust (*Puccinia antirrhini*).

The more difficult a crop is to grow, the higher its value, the greater is the investment risk involved, and the fewer the growers who will successfully produce it. The grower who can produce it has less competition than does one who grows a relatively easy, dependable crop. In the same way, a grower who can dependably produce a crop better than his competitors may have a natural monopoly, but the risk is increased. A grower in Rhinecliff, New York, for many years produced superior F_1 hybrid anemones, and a Washington, DC grower produced exceptional F_1 pansies for cut flowers (45). Disease or changed consumer fancy in such a specialized crop monopoly can be economically ruinous. One needs only to recall that freesias and sweet peas are no longer popular and are now little grown.

The risk factor associated with growing a specialized monopoly crop is reduced as new technology becomes available. Pot chrysanthemum today is such a crop, with diseases largely eliminated and the culture know-how reduced essentially to following published tables (27, 57). This was not always so. Prior to the availability of *Verticillium*-free cuttings and the use of chloropicrin soil fumigation, growing chrysanthemums was a risky business. A grower in the San Francisco area had a local monopoly growing the highly *Verticillium*-susceptible, large-flowered Pocket cultivars of chrysanthemum by critically controlling soil moisture levels. However, the introduction of clean cuttings and soil fumigation nullified the risk, many new local growers produced chrysanthemums, and he lost his competitive advantage.

When culture-indexed chrysanthemum cuttings were placed on the national market, their natural monopoly was not exploited, there was no publicity campaign and only a slight increase in price. The commendable philosophy was that the cost of producing cuttings was also reduced by the disease control effected, and that the old price still made the venture economical. Since no special claims were made for the cuttings, grower complaints and lawsuites were lessened. The subsequent rise of the pot chrysanthemum business indicates the correctness of the analysis.

PIONEERING NEW METHODS OF DISEASE CONTROL The high unit/year value of ornamental crops has required and attracted growers with technical training and experience. Such growers are likely to seek and use disease-control information. It is not surprising, therefore, that several important techniques of disease control have come from studies on pathology of ornamental crops. Dimock's (20) method for obtaining culture-indexed cuttings of chrysanthemum free of *V. albo-atrum* was later adapted to sweet potato and rose. This remained the standard commercial method until the apical meristem technique came into use, following the work of F. Quak (46) in 1954 for obtaining virus-free cuttings of carnation. This technique has since been widely adapted to other commercial crops such as strawberry, sweet potato, and fruit trees, sometimes in conjunction with heat treatment. A spin-off from meristem culturing is the tissue-culture method of rapid propagation and development of pathogen-free propagules of ferns, lilies, orchids, and potato. The novelty "Plants in Vitro" of Oakdell Inc., Apopka, Florida has applied these techniques; a variety of plants are widely sold as cultured meristems in test tubes and, after several months, can be planted out by the purchaser.

The virus indexing of cuttings by grafting onto an indicator variety that dependably exhibits marked symptoms (12, 33, 44) came into extensive, continuing, commercial use following the development of the chrysanthemum-stunt control program, and has since been applied to many other crops.

Although thermotherapy of plants had been used much earlier by J. L. Jensen for control of late blight of potato (*Phytophthora infestans*), and by G. Wilbrink for sereh disease of sugarcane, its application against aster yellows of *Impatiens* by Kunkel in 1941 (34) stimulated studies on its use against other plant pathogens.

Steam treatment of commercial glasshouse soil was pioneered by the Rudd Brothers in the Chicago area in 1893 (47). Over 60 years later, Baker & Olsen developed the aerated steam treatment of soil for floriculture crops (7).

The concept that, in the final analysis, the sources of plant pathogens are the soil (including water and nonliving organic matter) and living plants, and that disease control can be achieved by using pathogen-free soil and propagules, coupled with careful sanitation, was first commercially exploited in management of ornamentals (2), and has been emphasized in the pathology of ornamentals.

The important point is that the above methods were developed for high-value crops that would justify the expense, and were used by progressive growers likely to be found in this business. The methods were then adapted for other less valuable agricultural crops.

High Capital Investment

There is high capital investment in commercial glasshouses and in equipment for mechanizing production of ornamentals. In the United States in 1970 there were 49,000 acres of glass and plastic houses producing floriculture crops, more than 325 acres of cloth houses, and over 24,000 acres of outdoor-grown floriculture crops (24).

The ornamental industry has become highly mechanized. Glasshouses, soil handling equipment, moving belts and rollers, boilers for heating glasshouses and for soil steaming, air conditioning equipment, automatic seed planters and transplanting devices, refrigerated storage rooms, controlled environment growth rooms, spray equipment, irrigation equipment, fertilizer injectors, tissue-culture facilities, and large paved areas to control mud and avoid dust contamination, plus many types of mobile carts and trucks, are considered to be standard in the trade. Often a repair shop is maintained on the premises.

The high capital investment and high risk in many segments of the ornamental industry have made disease loss intolerable; a crop failure may jeopardize the whole enterprise. Only intelligent, knowledgeable, and conscientious growers generally enter the ornamental plant business and remain in it. The competition is intense in cheap, low-quality, easily grown crops, but somewhat less in high-value, high-quality, difficult crops.

Controlled Environment

Ornamental plants are grown under stricter environmental control than almost any other crops. Light intensity, daylength, temperature, humidity, water quality (ion content), quantity, and application method (subirrigation, drip, mist, constant level, capillary), soil type, time of planting, fertilizer application (liquid, dry, slow-release), atmospheric pollution (carbon filtration to remove smog), CO_2 amendment, and freedom from pathogens, inter alia, can be controlled to best suit the crop. The decision to provide such control hinges largely on the cost-benefit ratio and on the grower's aggressiveness.

The benefit changes with time, however, necessitating continuous adaptation. Early glasshouse rose growers had to spray with fungicides to control black spot (*Marssonina rosae*) because the plants were syringed with water to control red spider mites, and the water spread the spores and provided favorable conditions for infection. With the development of adequate miticides, syringing ceased, and fungicide spraying became unnecessary under glass. With current restrictions on the use of chemicals it is uncertain whether a reversion to syringing may become necessary. Gray mold (*Botrytis cinerea*) on a series of glasshouse crops, such as snapdragon, has been controlled effectively by applying heat at night, with the ventilators "cracked" to permit moist warm air to escape, thus avoiding condensation on the plants. With the current emphasis on energy conservation, heating is reduced and the gray-mold problem is returning. Will this lead to attempted fungicidal control, with its attendant restriction? Very few control methods long remain satisfactory, but where it is economical, disease control in glasshouses by environmental manipulation has proved reliable, and generally is the method of choice. Certainly pathologists working on glasshouse crops are blessed with a greater variety of potential disease-control methods than are available for other groups of crops.

An outbreak of downy mildew (*Peronospora sparsa*) on glasshouse roses in San Leandro, California in 1951 illustrated the effectiveness of properly applied environmental control. Heavy rainfall flooded the glasshouse area and quenched the boilers in the basement. To conserve the sun's heat in the glasshouses, the vents mistakenly were kept closed, and the humidity became very high. Downy mildew rapidly developed and defoliated the plants. With the boilers back in operation, the ventilators were kept open and the houses dried out. The roses were severely pruned, and the new growth, developed under drier conditions, produced an excellent crop.

Control of relative humidity has played a key role in minimizing plant disease of ornamentals. Glasshouses can be kept drier during rainy weather than can lathhouses. Azalea flower blight (*Ovulinia azaleae*) and flower blight of camellia (*Sclerotinia camelliae*), often destructive in southern California under lath, are less common outdoors, and are rare under glass, due largely to the different humidity levels maintained.

Because space is valuable, both floriculture and nursery crops are grown closely spaced, often in blocks of a single variety. They are "forced" by controlling temperature, light, nutrients, and irrigation. These conditions may favor pathogen spread through the tops (rusts, powdery mildews, foliar nematode) or at the soil surface (*Rhizoctonia solani*). However, because the soil and plant propagules usually are pathogen-free, such epidemics are no longer common.

The glasshouse roof and walls provide partial barriers to pathogen and insect spread, but may favor their increase once they are introduced. Moistened pads, through which air is pulled into the house, are commonly used for cooling in warm months. The effectiveness of these pads in filtering out insects may be enhanced by spraying them with a nonvolatile insecticide. However, these pads may increase the relative humidity, and harbor and support pathogens, as in fusarium stub dieback of carnation (*F. roseum* 'Graminearum') (41). The glasshouse, when the ventilators are closed, also serves as a fumigation chamber for insect control, and for control of powdery mildew (*Sphaerotheca pannosa* var. *rosae*) on rose (18). Furthermore, the tightness of glasshouses makes possible charcoal filtration banks for smog control for sensitive plants (28).

The controlled environment involved in growing many ornamentals offers unusual opportunities for biological control (5). For example, treating soil with aerated steam eliminates pathogens, while leaving the soil biologically buffered against pathogen reinvasion (4). Soil that has been steam-treated or fumigated can be inoculated with beneficial microorganisms capable of protecting host plants (15) or increasing their growth (14). Soil mixes can readily be amended with substrates that favor the antagonists, and can be held at soil temperature or moisture favorable to them. The potential has been demonstrated for inoculating seed to control damping-off (15), and for inoculating roots at transplanting with antagonists to control crowngall (*Agrobacterium tumefaciens*) of nursery stock (40).

Emphasis on Elimination of Disease

The emphasis in disease control in ornamentals is on elimination of the causal agent, more than with most other crop plants. This is accomplished by planting healthy propagules in treated soil, and maintaining this pathogen-free condition by careful sanitation. These points have been discussed in other sections of this paper.

High Standards for Crop Quality

ACCEPTABLE LEVEL OF DISEASE CONTROL The acceptable level of disease control in ornamentals varies with the crop and its intended use. Those ornamental plants grown primarily for their appearance require essentially perfect disease control because blemishes are unacceptable on a plant whose raison d'être is its beauty. However, certain strictures on methods of disease control are imposed. Visible spray residues on flowers or foliage are unacceptable, particularly for floriculture crops. Spotting of foliage by residue from the water sometimes requires either deionizing the water used in misting, or washing the plants before sale. Any material that injures or discolors flowers cannot be used. This dilemma is resolved whenever possible in commercial growing by avoiding application of chemicals to the tops, relying on disease avoidance through use of pathogen-free planting material and soil, and by environmental manipulation.

In gardens a different problem is faced. So few plants of one kind may be grown that to obtain and use the preferred chemical for disease control may not be worthwhile. The solution often is to use a less effective but wider-spectrum material that can be used on several kinds of plants.

The performance and beauty of many ornamentals depend on the quality of the planting stock. The amount of infection tolerated on that stock sometimes depends on the intended use of the crop. Slight fusarium basal rot (*F. oxysporum* f. sp. *lilii*) can be tolerated in potted Easter lilies because the plants usually are discarded after Easter anyway. For garden lilies, where good flowering performance is required year after year, any infection is intolerable. That the product of ornamentals is the plant itself, rather than its fruit or nuts, emphasizes the requirement of an unblemished crop, particularly for long-term nursery crops such as trees and shrubs. Consumer expectations generally are higher for plants they buy, despite subsequent mistreatment, than for mechanical products.

ECONOMICS OF DISEASES OF ORNAMENTAL PLANTS There are several types of disease losses of ornamental plants, some obvious and immediate, others obscure and delayed.

Diseases have played a significant role in the development of the ornamentals industry. These diseases have extracted a significant toll in terms of direct losses and costs to control them. According to 1965 estimates in California (16), disease losses on ornamentals ranged from 3.2% for bedding plants to 14.5% for bulb crops grown as pot plants, exclusive of control costs. The average loss for ornamentals was 7.1%. Considering the estimated wholesale value of the national industry to be approximately $1.6 billion (25), these direct annual disease losses could amount to $50—200 million, or $100 million on the average, despite excellent control of the major diseases.

Obviously decreased yield or lowered grade of the product generally are the reasons for applying disease control. However, these factors may be less important in the total picture than are other less obvious results of disease. Disease may cause a significant decline in plant productivity. A relatively small loss of leaf area may cause a disproportionate diminution of root area or effectiveness (37). *Pythium* and *Phytophthora* spp. usually infect tips of rootlets, and thus reduce plant growth through loss of the sites of amino acid and hormone synthesis, as well as of absorption area (5). Such root "nibblers" may cause greater aggregate crop loss than pathogens that kill some of the plants.

The reputation of a grower or area as a dependable, continuing source of high-quality material is an important intangible asset for highly specialized intensive crops such as ornamentals. Once this reputation is lost it may not be regained. Thus, Easter lily bulbs in the United States were largely supplied by Bermuda up to 1920, and by Japan prior to the 1950s. However, the stock was so badly infected by viruses that, when bulbs with less virus infection became available from Oregon, northern California, and Washington, they largely displaced Japanese bulbs from the market. Similarly, geranium cuttings were produced in the field in southern California and shipped to eastern growers until the 1950s. Because of low quality of the cuttings and high incidence of bacterial blight (*Xanthomonas pelargonii*), gray mold (*Botrytis cinerea*), and other diseases, this market was largely lost when geraniums were developed that bred true from seed, and pathogen-free cuttings were produced under glass. Freesias were grown from corms produced in the field in California until varieties that bred true from seed became available from the Netherlands in the 1950s. Because of poor flower quality due to virus infection of the corm-grown freesias, the flowers declined in popularity after 1930, and despite the improved quality of the seed-propagated freesias the market has not been regained.

If an area gets a reputation for an inferior product, it can market only at uneconomically low prices, or may be forced to dump the crop. Thus, aster growers near Redondo Beach, California in 1946 were unable to sell their crop to wholesalers who refused to risk shipment because *Stemphylium callistephi* caused petal and leaf spots during transit. Garden stocks in southern California in 1952–1953 were similarly downgraded and rejected because of *Botrytis cinerea* that spread during shipment.

The cost of the disease control procedure obviously must be included in the economic loss from disease, although that cost is usually not recognized because it is built into production costs. The immediate loss from a disease epidemic, such as that of chrysanthemum stunt, is too obvious to require discussion, although the continuing cost of controlling the disease is enormous, yet often forgotten.

Before the 1950s field growers of crops susceptible to soilborne pathogens moved to new land when the soil became infested. Aster growers in southern California moved their crop every 3–4 years because of fusarium wilt (*F. oxysporum* f. sp. *callistephi*). Some who produced bulb crops, such as gladiolus and lilies, did the same thing. Growers really do not face up to a disease problem by running away. With the increasing scarcity of land, and the advent of economic soil treatments in the 1950s, this migratory production largely ceased, and the quality of both the growers and crops improved. The poorer growers simply changed crops, usually to a less profitable one, or sold the land for real estate development. Neither of these solutions is very satisfactory for plant pathologists or, in the long run, for the industry.

There were interesting illustrations of the Law of Lesser Concessions during the period of acceptance of field soil treatment. Growers first accepted the relatively inexpensive treatments with D-D or EDB and found that their use was economically profitable. They were then willing to try more expensive treatments with chloropicrin or methyl bromide in the hope of even greater profit. The even more expensive use of plastic tarps over treated soil to retain the gases was adopted later. The same law seems to govern the use of propagator-grown pathogen-free stock. At first, a grower may buy a small number of clean cuttings, grow them, and use cuttings from this stock for a few years. When it becomes clear that the second- or third-year crop has severe disease losses, he may decide to propagate from them for only one year. It finally becomes evident to the grower that it is better to have the propagator produce the cuttings, and for him to raise the crop. New growers, even today, tend to progress through such stages in adopting a control practice. A procedure that cannot be adopted in stages wins acceptance more slowly than one that can. A similar progression in application is evident in the adoption on a low-value crop of a control practice found to be profitable on a high-value crop.

The environmental tolerance of a plant is diminished by plant disease, making the crop more difficult to grow. Heather (*Erica* spp.) grown in soil infested with *Phytophthora cinnamomi* must be grown at as low soil moisture as possible. This is difficult to do, and plant growth is reduced because the moisture level is below that best for that crop. Foliage plants in soil infested with *Pythium* spp., *Rhizoctonia solani,* or *Xanthomonas* spp. sustain heavy losses when propagated or grown under overhead mist irrigation. Eliminating the pathogens, however, allows these plants to be grown under warm, moist, fertile conditions without disease development. If *Verticillium albo-atrum* is present in garden soil, only resistant varieties of chrysanthemum can be successfully grown, a severe restriction. When *Pythium ultimum, Rhizoctonia solani,* and excess soluble salts occur together in a soil, it is impossible, simply by controlling irrigation, to produce seedlings in it, since excessive moisture favors *Pythium,* deficient moisture augments salinity injury, and intermediate moisture favors *Rhizoctonia* (2).

Modern mechanized plant production requires close scheduling of the crop, an impossibility with capricious disease occurrence. Furthermore, it is impossible to properly evaluate the efficacy of a culture practice if the plants are diseased. It is as impossible to evaluate fertilizer or irrigation practices on plants that have root disease as it would be to conduct nutritional studies for normal humans on subjects with stomach ulcers. Growers cannot properly evaluate culture and learn from experience unless the plants are free of pathogens. The better growers always get greater benefits from disease control than do poor growers because the plants make maximal growth in response to freedom from disease.

Some chemical applications only temporarily inhibit a pathogen (e.g. Dexon on *Pythium* and *Phytophthora* spp., PCNB on *Rhizoctonia solani*), which resumes growth when the chemical breaks down. Such suppression of a soilborne pathogen by a nurseryman (even out of ignorance) is unethical and should be illegal, because the disease is simply checked in the nursery, only to cause greater damage in the uncontrolled environment of the garden when the plants are sold. Even worse, the garden soil may become infested, impairing plant growth there more or less permanently.

Mobility and Multiple Handling of the Living Plants

Living ornamental plants, and the propagules used to produce them, are shipped around far more than are other agricultural crops. With most other crops it is the produce (e.g. grain, tubers, fruit) that is shipped, and these products are inherently more durable than are living plants.

The well-known production of bulbs in the Netherlands for sale and use in the temperate areas of the world has required special handling and storage to avoid diseases. The Netherlands Bulb Research Center at Lisse was established to study these problems.

In recent years, there has been deep and growing concern in the floriculture industry about the volume of cut flowers (carnations, chrysanthemums, roses) grown in Colombia and marketed in the United States. In 1977, 34% of the carnations and 1.8% of the roses marketed in the United States came from Colombia. Israel is rapidly increasing its shipments of carnations and roses to the United States (50). This development has come about because of cheaper labor and lower heating costs than in the United States. In 1976, flowers and foliage worth $42 million were shipped into the United States from 33 countries, particularly Columbia, Guatemala, and Mexico (23). Orchids, anthuriums, and other tropical flowers and foliage are grown in Hawaii and airlifted to the mainland. Flowers grown in North Africa and Israel are marketed in Europe.

This movement of living plants and propagules provides a method, par excellence, for transport of plant pathogens and insects. For example, it was by this means that ascochyta ray blight (*Mycosphaerella ligulicola*) of chrysanthemum spread over the world. Confined to a small area in North Carolina, South Carolina, and Mississippi for over 40 years, the pathogen began to spread in the 1950s. This disease spread began when Florida started to ship chrysanthemum flowers in the late 1940s, and intensified with the development of a major propagation industry there after 1957 (6).

Australia has taken the sensible position that only six cuttings of a given plant variety may be imported; these are kept under quarantine until found to be free of pathogens, and then are used for propagation.

The shipment of symptomless carriers is particularly hazardous. Many viruses or viroids (e.g. chrysanthemum stunt) have long symptomless incubation periods, and fungal (*Cylindrocladium* on azalea) or bacterial (bacterial blight of geranium) pathogens may be carried externally, or may have infected the plant with symptoms not yet evident. On the other hand, some pathogens may destroy the plant during shipment. *Phytophthora cinnamomi* may kill choisya and daphne plants during marketing, and *Xanthomonas pelargonii* may kill a geranium before it can be planted, or soon thereafter.

During growing and shipping, plants pass through numerous hands (propagator, grower, wholesaler, shipper, retailer, and consumer) and are exposed to a variety of environmental conditions, many of them unfavorable. Plants may be over- or underwatered, exposed to insufficient light, excessively dry air, excessive or deficient nutrients, air pollutants (smog, ethylene), and temperatures that are too high or too low. These stresses weaken the plant and may favor attack by pathogens. For example, overwatering may favor *Pythium* root pathogens, and ethylene may hasten senescence and predispose a plant to *Botrytis cinerea.* Because of the number of agencies involved in moving a plant to the consumer, it often becomes legally impossible to determine the one responsible for the disease condition.

PROBLEMS OF THE URBAN ORNAMENTAL INDUSTRY

Many establishments producing ornamental plants, originally well out in the country, have become engulfed by urban sprawl. This has produced special problems unique to the floriculture and nursery industry. The establishment, surrounded by homes, may be taxed at the residence rate to force them to leave. The area may be rezoned for residences, also forcing a move. Homeowners in the area may resent the truck traffic necessary to the business, and may resort to one of these procedures to correct it. The surrounding homes often preclude expansion of the business, making it either remain static or move. If it remains, space becomes a limiting factor, precluding the possibility of storage of soil and other materials. A Sacramento, California grower has not paved the level area where his container-grown plants are placed, despite the obvious advantages of avoiding contamination by soilborne pathogens and of diminishing mud and dust, because to do so would place the establishment in a higher tax frame.

The use of soil fumigation in urban areas is so risky that insurance against suits by neighbors is essentially unobtainable. Some growers have been subjected to lawsuits from neighbors with fancied or real respiratory problems attributed to chemicals used by the establishment. Prior to the adoption of noncomposted light-weight soil mixes, it was customary to have compost piles containing manure. This led to objectionable odors and flies that aroused opposition from neighbors. This was often an important factor in causing the establishment to adopt noncomposted mixes. This change also made it unnecessary to stockpile large quantities of materials that monopolized a substantial part of the available space.

Ornamental plants frequently are so adversely affected by atmospheric pollutants from industry or from automobile traffic that the kinds of crops grown are sharply restricted. For example, *Cattleya* orchids are very sensitive to ethylene, a common pollutant, the flowers developing dry-sepal disease and becoming unmarketable. In one instance the concentration of this gas was related to the use of gas heaters in surrounding homes during cold weather.

Fortunately, if an establishment is forced to move, the increased value of the property when sold for residences usually makes possible starting anew in a modern well-equipped facility.

Trees and shrubs planted in city streets and parks are subjected to unusually severe unfavorable or injurious environmental stresses such as high temperatures, air and water pollution, soil compaction and high moisture content, wind stress, construction damage, salting of streets, and light effects. These present unique and difficult problems for the urban plant pathologist. Breeding and selection of trees and shrubs for these special stress sites is under way (26, 31a).

CONCLUSIONS AND PROSPECTS

Pathologists, faced with the great diversity and transitory nature of ornamental plant cultivars, and the necessity of producing an unblemished disease-free product, have emphasized the planting of pathogen-free propagules in treated soil, reinforced with careful sanitation and manipulation of the environment for disease control. Many formerly important diseases of major ornamentals have thus become exceedingly rare and reduced to unimportance.

The high valuation of most ornamentals and the carefully regulated conditions for their growth make possible a wide range of unique procedures for disease control. A number of techniques thus developed (e.g. culture-indexed cuttings, apical meristem cultures, improvements in tissue culture methods, virus indexing by grafting on indicator plants, soil steaming, and the development of aerated steam for treating soil and propagules) have also proved useful for controlling diseases of other crop plants.

The pathology of ornamental plants includes a very wide range of diseases and crops, with great opportunity for imaginative research and exploration of new methods of disease control. The pathologist working with ornamentals will be challenged by the energy crisis and increasing restrictions on the use of pesticides. However, a bright prospect especially available to him is the potential application of biological control methods made possible by the regulated environment that allows for ecological manipulation of micoorganisms (5).

With the increasing world population and consequent food scarcity there will be pressures, as during World War II, to lessen research on ornamentals and devote it to food crops. However, with disappearing beauty in much of the world today, the demand for ornamentals around the home probably will increase. Diseases of ornamental plants will thus continue to provide a fruitful and stimulating field of study for plant pathologists.

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