NOVEL PROPAGATION TECHNIQUES

As researchers develop skills in gene identification and manipulation, they are likely to discover technique which will have broad impacts in totally unrelated fields. For example, transformation of cells at the base of a cutting, using a disarmed plasmid from a root-producing bacteria, or from an auxin-inducing fragment of the T-DNA may become a standard method for rooting certain cultivars. In this case the only plant cells which would be influenced would be those which had been treated with the special bacteria containing the root-promoting fragment from the rooty-tumor pathogen. The cut surface would receive the rooting genes which would have no effect except to induce the formation of roots.

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THE OBLIGATION OF THE PLANT PROPAGATOR

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Abstract. Because the ultimate sources of plant pathogens are previously diseased plants and the soil (including water and nonliving organic matter), propagators of pathogen-free plant materials are a primary or seminal source in modern plant production, and have special health responsibilities Pathogens must be eliminated in this culture, not inhibited or suppressed In addition to being a profitable business practice, there are very specific benefits from clean culture for both the propagator and the producer Nursery diseases have decreased in the last 27 years, but remain a lurking hazard, and growers must accordingly continue to practice clean culture In such a plant-health program, growers have an important role and they should be directly involved in the ongoing research program, as they

were in the development of the U C. System of plant culture in 1941-57 Present efforts to standardize nursery stock solely by physical characteristics miss the essential point that growth potential and plant vigor are at least as significant as size. "Root nibblers," pathogens that attack root tips and insidiously reduce plant growth but only eventually kill the plant, are largely ignored in present schemes. A combination of such physical specifications and a certification of health status can make true standardization a reality, so needed in these times of mass marketing. For both propagators and producers, a triple program of planting truly healthy propagules in clean treated soil, and practicing careful sanitation and hygiene, will keep the plant pathogens at bay in the future.

The better nurserymen and propagators now realize that plant diseases are neither inevitable nor a trivial factor in the gamble involved in producing a crop. Their activities indicate an awareness, if not a full understanding that, in the last analysis, the sources of plant disease organisms are the soil (including its water and nonliving organic matter) and previously infected plants. Only rarely does one now hear the old alibis for a diseased crop, "It was due to the weather," "It was due to the new help," "The plants were overwatered."

It is a pleasure to report that many diseases of nursery and ornamental crops have been dramatically reduced in the last 40 years. Verticillium wilt and viroid stunt diseases of chrysanthemum may not be eliminated, but they are no longer regarded as inevitable, and they are a rarity. Fusarium and bacterial wilts of carnation are no longer a threat. These troubles have been minimized by the continuing patient efforts of growers to plant clean stock in clean soil, and to support them with rigorous sanitation.

Diseases have not been eliminated from the scene, however, and one hopes that periodic small outbreaks will be sufficient to stimulate growers to continue and even improve their present efforts. The hazard is that growers will become complacent, and that a new generation of them will arise who have never seen disease epidemics and who doubt their reality, or who think they are a thing of the past. An example of this is afforded by the fire-blight disease of pear and apple trees in New Zealand. It nearly annihilated the industry in 1919-29, and then subsided for unknown reasons, even though the virulent bacteria continue to be present. The disease has remained unimportant there, but in 1972-73 mild symptoms appeared. Growers brought in specimens, and when told that they had fire blight, not knowing what that was they failed to appreciate the potential seriousness of the situation. In 40 years a new generation of growers had no knowledge of the disease. If I did not think that disease epidemics could occur again, exhortation would not be necessary. Churches have been inveighing against sin for many generations, with little result except to give the sinner a guilty conscience and thus lessen his pleasure. They have found it necessary to repeat the sermons at weekly intervals to be effective. It has been some years since I have carried this torch to you, and it now seems better strategy to try to explain why it is in growers' best interests to continue preventive measures of disease control, than to belabor your collective conscience in a revival meeting.

PROPAGATING FOR HEALTH

Growers were advised in Manual 23 (1), with reference to plant pathogens, "Don't fight 'em, eliminate 'em," advice still relevant today. One of the principal means of doing this is to use pathogen-free stock, and a number of specialist propagators now supply such stock. Increasingly, now one hears the comment from nurserymen, "I don't propagate, I buy 'em." This is a trend that can greatly help to vanquish plant disease — **if** propagators recognize that this gives them a great responsibility.

Propagators are a primary source or seminal business — the buck starts there. In general, the earlier in its life that a plant is infected by a pathogen, the worse the damage will be. This places a special burden of responsiblity on propagators who are in the clean-stock business; they must be especially careful to keep all disease out of their operation. Sanitation must be quite as good as in hospitals, and the help must be well trained and fully aware of their responsibilities.

Health, rather than disease, is the normal state for life. The pathogen-suppressive state is the normal condition of biologically buffered equilibrium. Although parasitism appears to be normal for some microorganisms, pathogenicity or the ability to produce disease, is uncommon. It is doubtful whether living things could have evolved, and quite certain that agriculture could not have developed, if this were not true. This healthful state is a result of the biological balance that has evolved in the interactions among living things. Interaction, harmful and beneficial, is the balance wheel of nature. To exist in such a complex association is to gain external protection and strength from the enhanced stability provided, as a stone gains stability and strength when built into a wall, as well as imparting these features to associated stones. The system is biologically buffered, and each organism maintains a fluctuating population density within certain definite limits. Only well-adapted and competitive living things have found an ecological niche, and to maintain possession they have had to integrate their population, timing, and activities with their associates and with the climatic cycle.

Diseases are an important factor in this plant-stabilization sequence. Because the rigorous disease control required of commercial propagators is an unnatural situation in the evolution process, requiring elimination of pathogens, it demands even greater attention to details than does routine nursery culture. As Ordish and Dufour (8) said, "farming is a most unnatural activity. Man has imposed on the environment a system of survival of what he wants to use over the Darwinian system of the fittest to survive. Consequently the farmer is engaged in a constant struggle with nature."

If one environmental factor is limiting to plant growth, the influence of other factors is altered. For example, low soil moisture affects plant growth more at high temperatures than under cool conditions because of the effect on plant transpiration. On the other hand, higher moisture has a more deleterious effect at low (but above about 4°C) than high temperatures because of waterlogged soil produced. The optimum for one factor is thus changed by variation in other factors, and if one practice is changed in grower procedures other practices may have to be adjusted. Thus, when poinsettia growers first adopted the U.C. System the plants grew too rapidly, became too tall, and the stems had to be "tromboned" before sale. Later planting solved the problem. In the same way, a disease-control procedure must fit into present grower practice or the practice must be modified before it will be acceptable.

Drenches with PCNB, Dexon, or similar chemicals may inhibit, but will not eliminate *Rhizoctonia*, *Pythium*, and *Phytophthora*, and frequent application may be required to be effective. This is disease suppression, not disease control, and should not be among the plant propagator's procedures. His responsibility is to produce pathogen-free stock, not merely to produce plants free of symptoms by suppressing disease until the plant is sold. If he fails to eliminate a pathogen, growers who buy the liners cannot rectify the defect. The use of pathogen-suppressive chemical drenches by a primary propagator to decrease disease loss in his nursery is unethical, irrational, and should be illegal. This is similar to removing crown galls or nematode galls from nursery stock, or bacterial fasciations from Esther Read daisies before sale — it is fraud, not disease control. However, the grower who is using the plants for crop production, such as a cut-flower chrysanthemum grower, may use these inhibitory materials with a clear conscience, but should use them as a secondary defense when all else has failed. This is comparable to the preferred medical practice of preventing infection, and using antibiotics as a last resort.

Alert intelligent growers play an important role in observations and in developing the working hypotheses with which all research begins. Because of their intimate daily contact with the crop, and intense personal interest in it, growers have often made early perceptive observations and have conducted far-sighted experiments that defined fruitful areas for investigation. Wise research workers pay close attention to grower observations and ideas, and encourage expression of them. Growers are an improtant part of the team, and should not be hesitant to actively participate in the investigation process.

BENEFITS FROM ELIMINATING DISEASES

1. **Greater profit:** Strawberries in California produced only about five tons per acre in the 1950's, but with present soil fumigation and use of clean stock replanted each year, yields of 30 to 40 tons per acre are not uncommon. Sweet potato production is now undergoing similar renovation. Chrysanthemum has become the leading florist crop through the development and commercialization of cultured disease-free cuttings, soil fumigation, daylength manipulation, scheduled year-round production, and developed public acceptance of mums every month of the year. Forty years ago some nurserymen thought disease was a good thing because it insured replacement sales. Unfortunately, it is still extremly difficult to obtain pathogen-free nursery stock to plant in the home yard. It should be self-evident that there is money to be made by growing the healthiest and best possible plants.

2. **Nursery culture is simplified, and plant-growth potential increased:** Verticillium wilt of chrysantheumum was sometimes minimized by skillful watering and by use of tolerant cultivars. Use of soil treatment and healthy cuttings made possible a wider selection of cultivars without the necessity of resistance, and has made "preventive watering" a lost art. Phytophthora root rot of heather can also be reduced by minimal watering, but this retards plant growth and is difficult to achieve.

3. **Improved timing and scheduling:** Plant diseases are unpredictable, even capricious, in occurrence and severity. Freedom from disease makes possible consistent timing, essential in today's marketplace.

4. **Increased environmental tolerance:** Bedding plants in southern California in the 1940s sustained losses from damping-off caused by *Pythium*, *Rhizoctonia*, and salinity. Soil moisture could not be adjusted to control this complex. By eliminating the pathogens through soil treatment, and salinity by improving the soil mixes, the useful range of soil moisture was greatly expanded.

5. **Improved evaluation of cultural practices:** A diseased plant cannot grow as well as its environment should permit, and hence gives no indication of the growth potential of a healthy plant. A deficient root system may restrict water and mineral absorption, and a plant so impaired will not respond to fertilizer application. Only the young white root tips need be injured by "root nibblers" to severely decrease plant growth. The only true indicator of the value of a cultural practice is provided by a healthy plant with a sound root system.

6. **The better the plant culture, the greater the benefit from elimination of disease:** The use of clean plants and soil treatment obviously give greater benefit to an excellent than to a careless grower.

7. **It is cheaper and more effective to prevent plant disease than to control it once started:** In this day of mechanization, standardization of product, packaging, and scheduled production, there is no place for plants of uncertain performance, variable size, capricious flowering, and slow growth. Beside lowering cost of production, healthy plants do not introduce a destructive persistent pathogen into the customer's yard, decreasing future successful plantings and sales.

Abundant grower experience indicates that the use of clean stock, clean soil, and sanitation will produce more uniform, healthier, and larger plants at lower cost, more reliably, and faster than before. This is profitable for the grower and makes friends of the customers.

PLANT STANDARDIZATION

The trend to mass marketing of nursery stock requires increasing standardization, and many agencies have rushed to get on the bandwagon of establishing standards. Published standards have in common prescription size specifications for plants, without considering how the stock was produced. The underlying fallacious assumption on which such specifications are based is that, if a root disease is present it will be evident and that the plant will soon die. By inversion, this is frequently taken to mean that if plants do not die they must be free of root pathogens, or at least those plants which survived must be healthy. Neither of these assumptions is true. Experience shows that nursery stock infected with *Phytophthora* often grows well enough in the nursery to be sold and planted. The pathogen may not kill the tree until years later during a wet winter, after the plant's value has increased many-fold. However, growth in the interim will be below par and the soil will be permanently infested. Growers are often surprised by the growth potential of a really healthy plant. Most plants will grow tolerably well under a wide range of soil conditions, and unless there is a well-grown plant to compare it with, will appear satisfactory.

Growers generally recognize that two plants, apparently similar, may have vastly different growth potentials when planted. A well-grown plant produced without check under consistently favorable conditions and free of root-rot pathogens, is certainly a much better buy than a larger specimen slowly grown under intermittently unfavorable conditions, or one infected with root-rot fungi but not yet showing symptoms. Many of the state and nursery association standards ignore this rudimentary fact. One even frankly states that "Nursery stock when sold shall not be dead or in dying or seriously damaged condition." To accurately standardize plants it is necessary to assess their growth potential as well as to measure their size (2,4). It is not enough to specify, as one state does, that a certain grade requires "an exceptionally healthy and vigorous plant." A moment's reflection will show that plants must be grown for such standardization, not merely sized and standardized *after* they are randomly produced. Similarly, the quality of an automobile is determined more by quality control of materials on the assembly line than by measuring the overall length, quantity of chrome, or paint thickness of the finished product. In both cases, actual performance is the best criterion of quality. Growing procedure is the key to true standardization, not a series of photos of different plant shapes and sizes for each species. This does not necessarily mean that every grower must use the same method for producing a plant, but that those plants grown under the most favorable conditions will receive the best rating.

A means of describing the physical specifications of nursery stock is a necessary form of business shorthand, and as such should be continued and improved. To supplement these standards, a voluntary certification scheme for evaluating growth potential was suggested in 1959 (2). Official periodic inspections could provide information on the age of the plant in relation to its size, the time it has been in the container, the number of times it has been transplanted, and whether it has a root-bound condition. An estimate of root condition can be provided by examination of the root ball or by washing out a few representative samples. Information could also be collected on uniformity of plant growth rate, whether the soil was treated, whether the lining-out stock was pathogen-free, whether any plants had died and from what, whether specific sanitary precautions had been followed, whether any means of retarding or suppressing disease development had been practiced to conceal the presence of pathogens, and whether plants had been extensively forced to attain a certain size. There are precedents for such a program in the existing state certification schemes for seed potatoes, seeds, and for plants of strawberry, grape, avocado, peach, citrus, cherry, and sweet potato. It would be relatively easy to apply such a scheme to lining-out stock, and this would be a suitable place to begin. Grower participation should be voluntary, not legally required.

Under such a program a plant would always have a descriptive grade, and could have an additional certification. A buyer could then decide whether a certified No. 2 plant was a better economic risk for orchard planting than a cheaper No. 1 plant. Such a dual system appears to be the only feasible means of truly standardizing nursery stock.

SANITATION

> Sanitation is a way of life. It is the quality of living that is expressed in the clean home, the clean farm, the clean business and community. Being a way of life it must come from within the people; it is nourished by knowledge and grows as an obligation and an ideal in human relations.
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> — National Sanitation Foundation

In the last analysis, the ultimate sources of plant pathogens are previously infected plants and the soil, including its water and nonliving organic matter. Thus, disease control in the nursery basically comes down to using treated or pathogen-free soil, pathogen-free planting stock, and routine sanitation to keep them both clean. Soil treatment methods are discussed in the IPPS Proceedings (5,7), methods of obtaining and maintaining pathogen-free propagules are discussed elsewhere (3,6,7). Sanitation (1,4) procedures prevent contamination of the soil, plant, or both, by pathogens during growth of the crop.

The primary propagator must practice hospital-level cleanliness because so many other growers are dependent on him and connot undo the results of any defects in his technique. This does not mean that other types of growers can be careless or sloppy, but that they should practice at least the level of sanitation that they expect in their homes. For example: dishes are carefully washed in hot water in the home, and plant containers should be disinfested unless they are new; one doesn't use another's toothbrush or towel, and nursery tools should be treated before re-use; wives don't condone tramping mud into the kitchen, and growers should not walk on flats or beds of treated soil; one sneezes or coughs into a handkerchief to reduce spreading colds, and a grower should avoid scattering infested soil in watering or handling operations; one doesn't visit friends while suffering from mumps or chicken pox, and a grower shouldn't place plants of uncertain health in a block of healthy stock; polluted water is boiled before being drunk, and contaminated water should be chlorinated before use on plants; man has found it perilous to use human excrement for fertilizer, and it is dangerous to dump diseased or dead plants in a compost pile which is not treated before use; clean sheets are demanded on beds in hotels, and benches should be disinfested before re-use. Such social customs were unknown to primitive people, ignored in early civilizations, scorned as fussy in the Middle Ages, only grudgingly adopted in the nineteenth century. In many areas today, people look down on those who do not conform to such minimal standards. To which developmental stage does your concept of nursery cleanliness belong?

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