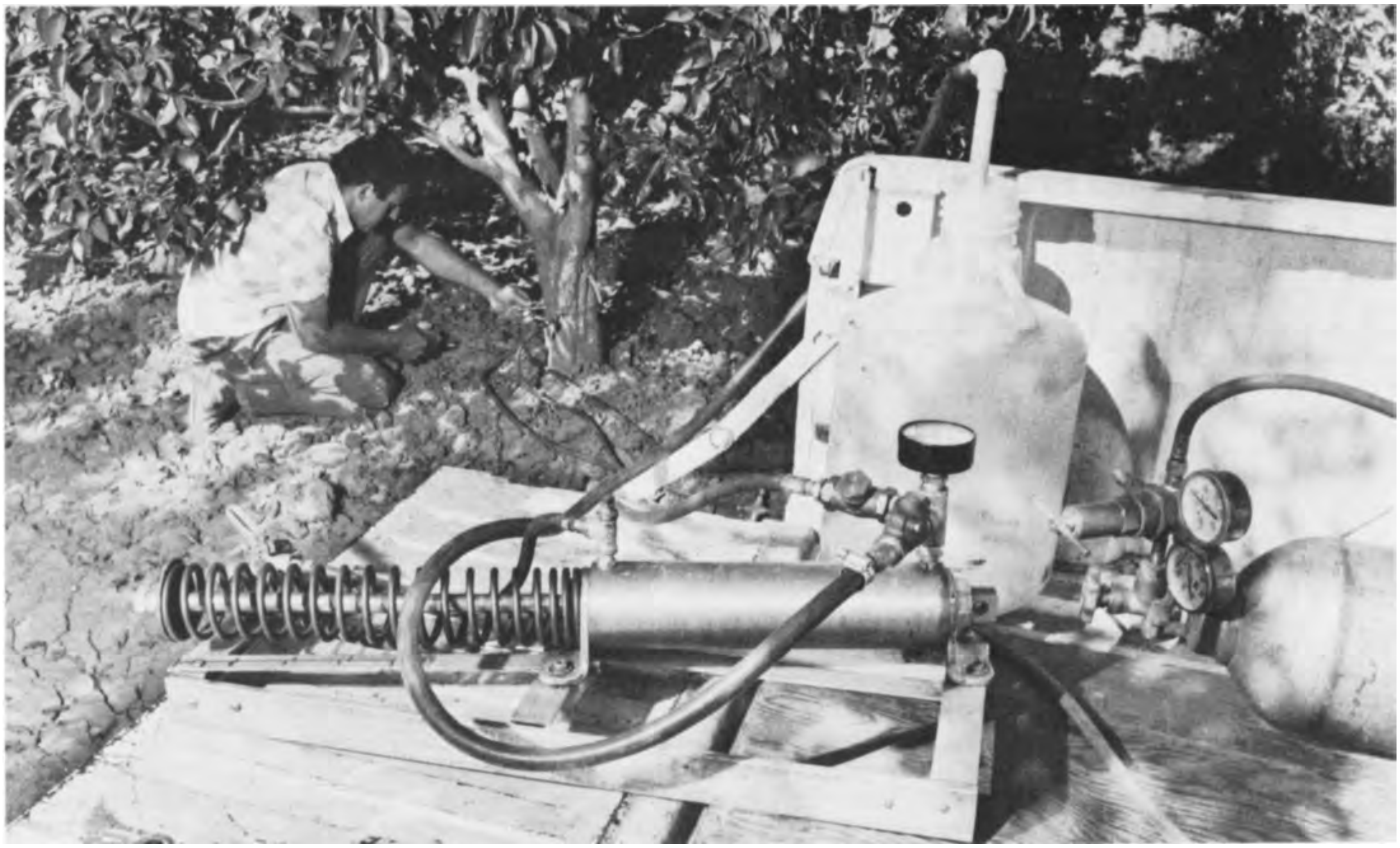


A close-up of the pressure-injection machine.

Pressure-injecting chemicals into trees

Wilbur O. Reil

Equipment to inject pesticides or nutrients into trees under high pressures has been developed and used in the last five years. Because of such recent development, limited knowledge is available on techniques, procedures, and uses of injection. Recently, injection studies have been conducted by several University of California researchers on many different trees, and approximately 250,000 pear trees are also being commercially treated in California for pear decline.

Observations from these trials and the experiences of researchers and farmers are summarized here to improve injection techniques. Before attempting to inject many trees, an applicator should: have some practical knowledge about procedures; check restrictions on chemical labels; confer with farm advisors and county agricultural commissioners; and/or inject only a few trees to observe results.

Drilling injection holes in trees

Proper drilling of holes for pressure-injection can determine distribution of the injected liquid as well as the time required for uptake. On trees with a single trunk dividing into three scaffolds, 2 or more feet above soil surface, injection holes should be placed directly under the scaffolds and approximately 6 to 12 inches above ground. More injection points are advisable on trees having multiple scaffolds or several limbs starting near the ground. On trees with over 16-inch trunk diameters, injection holes should be spaced approximately every 6 inches around the trunk.

Drill 1/4-inch holes on the thickest areas of the trunk (ridges). These areas are in active growth and will take up liquid rapidly. Holes should be drilled approximately 3/4 to 1 1/2 inches deep, but do not force or overload the bit. The drill bit should be repeatedly moved in and out so that sawdust is cleaned from the hole. Sharp bits are essential for smooth cuts. Dull bits tear the wood and seal the tissues, causing poor movement of liquids into the water-conducting (xylem) tissues.

High-speed (1200 to 1700 rpm) electric drills have generally been the most satisfactory. Slow-speed electric drills can also be used, but the holes they make require frequent cleaning while drilling and a very sharp bit is essential. With all electric drills a standard metal-type bit is best. (A hand-powered brace and bit can be used if the bit is sharp.) Small, battery-pack drills will generally only drill 20 to 40 holes during one charge and are the least satisfactory.

Setting injection screws

Once the holes have been properly drilled, the next important step is placing the injection screw. Liquids move more rapidly in the recently formed xylem directly underneath the bark and transfusion rate decreases with depth. The screw, therefore, needs to be set as shallowly as possible. Usually, the injection screw should go through the bark with only 2 to 3 turns into the wood tissue to seal the hole and hold the screw so it will not blow out or leak; do not continue to twist the screw deeper. Experience will soon determine the depth necessary to properly set the screws.

Injection screws should not be removed until the liquid has moved into the tree. The time for this movement (shown by pressure decrease) depends on the tree and time of year, and may vary from about 30 seconds to 5 minutes. While waiting, the equipment operator can inject one or two other trees.

The exposed hole should be left open with no sealant applied after the screw is removed. Holes left untreated have had less decay problems under California conditions and have healed faster than did holes treated with sealant.

Time required for application

The time required and the amount of material which can be forced into a tree varies for several reasons. Materials inject most readily when the tree is vegetatively active; therefore late spring, summer, and early fall are the best times for maximum uptake. Uptake rates decrease in late autumn, when leaves start falling, and are lowest in winter when no leaves are present. Moderate stress on leaves will increase the rate of uptake from pressure injection; therefore, midmorning to evening is ideal. A mild wind will also increase the uptake rate.

Some species of trees can be injected during dormancy, but movement of solutions in dormant deciduous trees seems to be much slower than in the same trees when actively growing. Injection rates in the spring vary, depending on tree species. Walnuts cannot be injected in the spring because of internal pressure within the xylem. Pears, apples, and *Prunus* spp. can be injected slowly. More phytotoxicity is caused by winter and spring applications than by summer or fall treatments.

If the tree is not extremely dry, injection uptake will be faster before an irrigation than afterward. Healthy trees inject faster than sick trees, and the more leaves on a tree the faster the injection rate.

Injection rate and species of tree

Many species of fruit trees, including pistachio, pears, apples, peaches, plums, prunes, almonds, and cherries, have been successfully injected. Apricot trees can be injected, but pressure must be below 100 psi, because higher pressures can cause severe gumming. Walnuts, pecans, olives, and avocados require several minutes for injection of 1 quart of material. In grapes and lemons uptake of injection fluid is very slow, with less than 1/2 pint entering in 10 minutes.

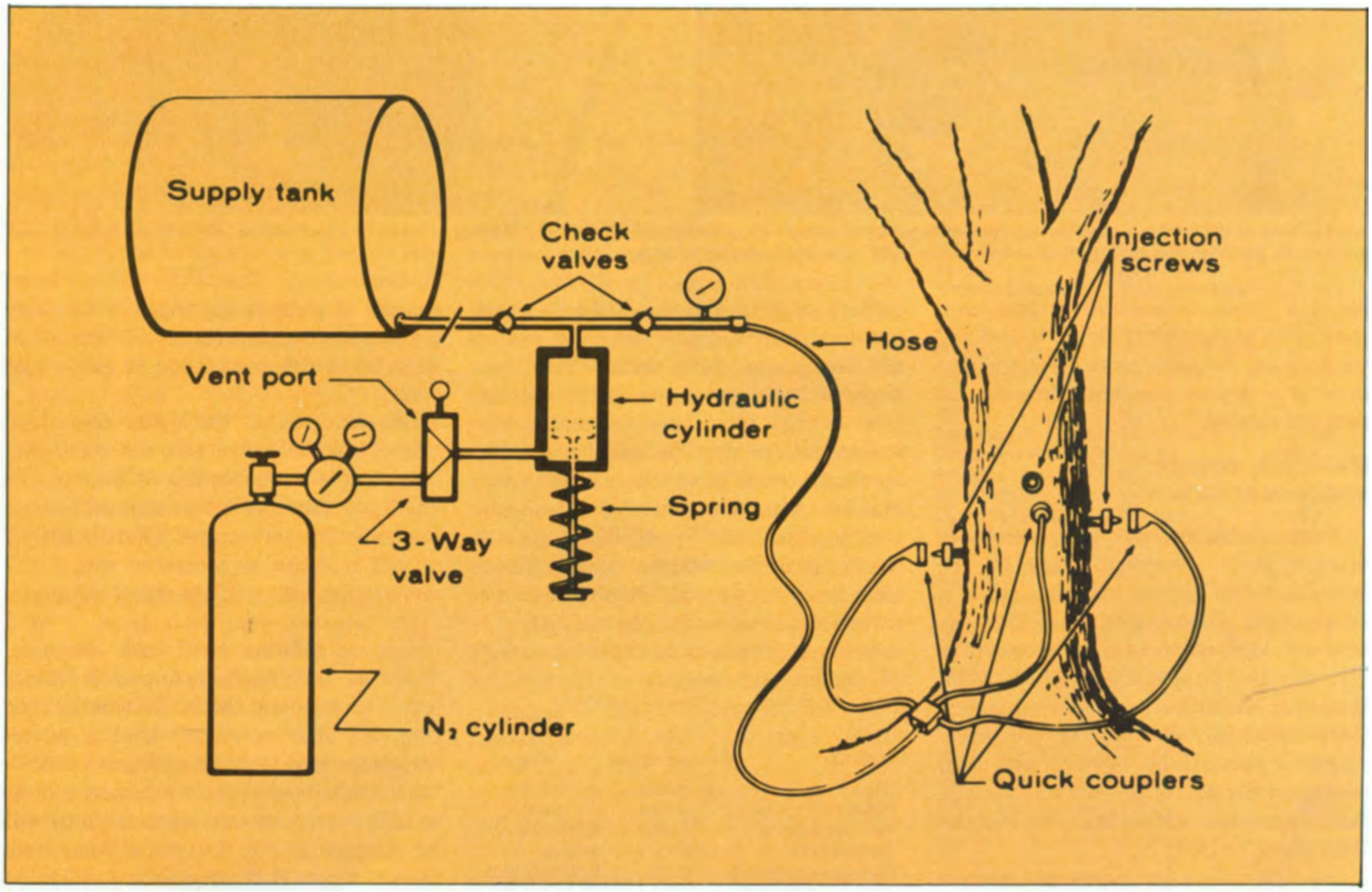
Ornamental trees which have been successfully injected include Modesto and Morain ash, palms, sycamore, camphor, elm, eucalyptus, tulip tree, acacia, pin oak, liquidamber, live oak, and zelkova. Maple, fir, and pine trees accepted injection very slowly in some tests, and in one test the conifers would not take up material.

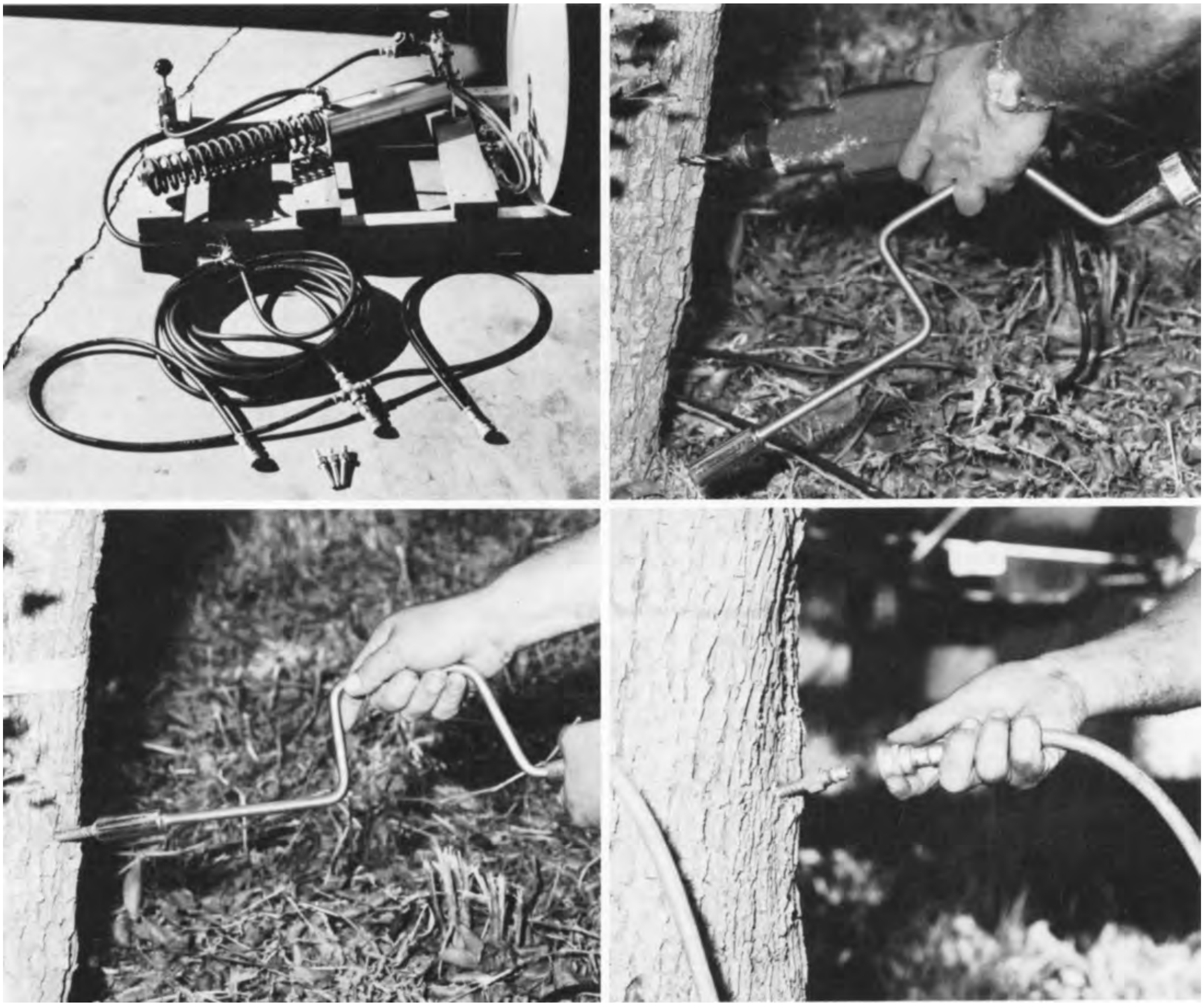
Injection pressure

The ideal injection pressure is that amount that will provide the maximum movement of solution into the tree without physically damaging it; pressures may vary from 100 to 200 psi, depending on tree species. Pressures higher than 200 psi do not decrease injection time appreciably, and they increase the chance of tissue damage and tip blowout or leakage.

Apricots, as stated earlier, should be injected with less than 100 psi pressure. Low pressures should also be used on trees with damaged bark or dead areas on the trunk. However, distribution or phytotoxicity problems have been noticed at pressures below 100 psi. Materials injected at low pressures are more likely to concentrate in some branches of a tree and not in others, causing phytotoxicity in some areas and no treatment in others. Oxytetracycline and ferrous sulfate caused extreme damage when applied by gravity flow and 15 psi,

Pictured here are the essential parts of the pressure-injection machine. The fittings necessary to connect the parts are not shown, mainly because fittings can vary depending on the brand or size of the components.





Another view of the pressure-injection equipment required is seen in upper left photo. Upper right, drilling of holes in a tree begins, while in lower left is seen the shallow placement of an injection screw. Lower right, injection of material begins.

but the same concentration and rate showed no phytotoxicity at 125 to 200 psi. No data are available to indicate whether there is a critical minimum thresold for each tree species.

Materials, dosage, and concentration

Water-soluble materials can generally be injected easily, although many of the larger-molecule organic materials go in at progressively slower rates. Pesticides successfully injected include oxytetracycline (Terramycin), carbendazin (Arborol), thiabendazole (Arbotect), oxydemeton-methyl (Meta-Systox-R), and acephate (Orthene). Nutrients successfully injected are urea, potassium nitrate, ferrous sulfate, zinc sulfate, magnesium sulfate and iron chelates (Fe 330 and Fe 138).

Label directions for dosage and concentrations of pesticides should be followed. Nutrient concentrations vary with materials and species. Iron chelates have produced severe phytotoxicity and defoliation, even though trees have responded with normal foliage after the initial shock. Accordingly, use of iron chelates is not recommended. The rates indicated below have been used successfully on several varieties or species of trees. Before injecting many trees, however, a limited number should be treated and observed for phytotoxicity.

The concentrations listed are the amount of material (by weight) mixed with the amount of water (water weighs 8.4 pounds per gallon): 1 percent solution is 1 pound of material in 100 pounds (or 12 gallons) of water.

Material	Concentration	Pounds Per Gallon Water
Urea	5 to 10%	0.4 to 0.8 lb
Potassium nitrate	5 to 10%	0.4 to 0.8 lb
Ferrous sulfate	1 to 2%	0.008 to 0.17 lb
Zinc sulfate	1%	0.08 lb
Magnesium sulfate	1 to 2%	0.08 to 0.17 lb

On some species the higher concentration of material moves into the tree slower than does a less-concentrated solution. In one trial, 1 quart of a 5 percent solution of potassium nitrate required approximately 1 minute to inject as compared with 1 1/2 minutes for 1 quart of 10 percent solution.

On standard-sized fruit trees, 1 to 2 quarts of solution have been adequate. There is not much information about length of time that correction will last, but iron and zinc treatments have given response on pear trees for two years following a single treatment. If injection is done in early to midsummer, some response will be observed in 1 to 2 months. Some trees showed a new flush of growth and limited bloom after injection at high concentrations, but these mostly were trees that had suffered severe symptoms prior to treatment. Abnormal growth after injection has not been detrimental to the trees the following year.

Tank mixing and water quality

Certain types of water have increased injection time considerably, presumably because of impurities. Usually, these waters have been from surface sources and changing to other sources corrected the problem.

Oxytetracycline in water will darken when exposed to air and light. This has not reduced the chemical effectiveness if it is used within 24 hours, but sunlight will break down the oxytetracycline in a few days. Therefore, limiting the amount of light on the mixed tank solution will increase the solution's life. Material left in the tank for extended times should be disposed of, not used. If oxytetracycline is aerated, oxidation occurs and the material precipitates; therefore, agitation or return bypass flow machines should not be used. Some stirring or mixing is desirable for other materials.

In re: equipment

No commercial company is manufacturing pressure injection equipment for application of liquids at 200 psi. Equipment described in the December 1976 issue of *California Agriculture* can be made with a minimum amount of tools and parts available from hardware, plumbing, and industrial suppliers. The cost of the equipment will vary depending on quality and supply, but should cost approximately $400 to $500 (1979 prices). Additional plans, directions, or help may be obtained from the author, Wilbur O. Reil, Pomology, Cooperative Extension, c/o Wickson Hall, University of California, Davis, CA. 95616.

Wilbur O. Reil is Staff Research Associate, Cooperative Extension, U.C., Davis.

Reaction of cauliflower cultivars to downy mildew in Imperial Valley

Demetrios G. Kontaxis ☐ Keith S. Mayberry ☐ Vincent E. Rubatzky

Cauliflower, *Brassica oleracea* L. Var. *botrytis* L., is a minor crop in Imperial Valley; about 200 acres are grown there annually. It is extensively cultivated, however, in several coastal counties including Monterey, Santa Barbara, Ventura, and Alameda.

Cauliflower, like cabbage, broccoli, and other members of the cruciferae family, is susceptible to downy mildew caused by the fungus *Peronospora parasitica.* The disease is prevalent in coastal and cooler parts of California, but in an arid area like the Imperial Valley it is normally sporadic and of minor economic significance.

The first recorded downy mildew epiphytotic on crucifers in Imperial Valley occurred during November and December 1976. During that year it became epiphytotic and attacked all local broccoli, cabbage, and cauliflower fields. Since then it has become endemic, infecting local crucifers every year.

Materials, Methods, Results

Several cauliflower cultivars were planted during August 1978 at the University of California Agricultural Experiment Station near Holtville. The objective of the test was to study the possible adaptation of some of these cultivars to the desert environment and to obtain yields, quality, maturity, and other information under the same climate.

The plots, 40 inch wide by 60 feet long, were randomized and replicated four times. There were two plant rows per plot (bed), and the plants were thinned to about 12 inches apart.

Downy mildew appeared on commercial crucifer fields during November 1978. The experimental cauliflower plots were also infected, thus presenting an excellent opportunity to assess their reaction to downy mildew.

Fifteen mature leaves were taken at random from each plot on January 15, 1979 and the incidence and severity of downy mildew were recorded (table 1). The severity of the disease on each leaf was based on the extent of necrotic tissue on a scale 0 to 10 (0 = no necrosis, 10 = 100 percent of the leaf necrotic).

Table 1 shows that there was some variability in the reaction of the cultivars to downy mildew infection. Visually, the cultivars Igloo (Keystone), Snowball Y (Ferry Morse), Dok Elgon, and RS-355 (Royal Sluis) appeared to be resistant to the disease (less leaf necrosis), whereas MSU 817 (Homna), White Contess #10 (Sakata), and T-3 (Dessert) were susceptible to downy mildew. The cultivars Igloo and Snowball Y are commonly grown in the Imperial Valley.

The information presented may guide growers in selecting for planting a cauliflower cultivar, particularly in areas with severe downy mildew history. The same information may also be of value to breeders of cauliflower.

TABLE 1. Reaction of Cauliflower Cultivars to Downy Mildew in the Imperial Valley (1978-1979).

Cultivar	Supplier	Disease Index*
MSU 817	Homna	5.70 U
White Contessa #10	Sakata	4.36 V
T-3	Dessert	3.76 VW
T-2	Dessert	2.95 WX
Self Blanche	Harris	2.49 WXY
Suprimax	Royal Sluis	1.91 XYZ
MSU 812	Homna	1.69 XYZ
Meru	Royal Sluis	1.64 XYZ
Snowball Opal	Sluis and Groot	1.59 XYZ
Imperial 10-6	Harris	1.53 XYZ
T-4	Dessert	1.52 XYZ
Snowball Masters	Sluis and Groot	1.45 YZ
Nevada-RZ	Rijk Zwaan	1.33 YZ
Exp. Hyb. 6353	Keystone	1.12 YZ
165-RZ	Rijk Zwaan	1.10 YZ
Snowball 42	Ferry Morse	1.05 YZ
Christmas White	Sakata	0.94 Z
Snowball 76	Ferry Morse	0.84 Z
Strong Osena	Keystone	0.83 Z
Alpha Hormade	Rijk Zwaan	0.66 Z
RS-355	Royal Sluis	0.63 Z
Dok Elgon	Royal Sluis	0.62 Z
Snowball Y	Ferry Morse	0.51 Z
Igloo	Keystone	0.43 Z

*Disease index (average of four replications) 1 = 10 percent of foliage necrotic due to downy mildew; 10 = 100 percent of foliage necrotic. Means with different letters are significantly different at the 1 percent level on Duncan's Multiple Range Test. Means with the same letter are not significantly different.

Demetrios G. Kontaxis is Farm Advisor (Plant Science-Pest Management), Contra Costa County, and Keith Mayberry is Farm Advisor (Vegetable Crops), Imperial County. Vincent Rubatzky is Vegetable Specialist, U.C., Davis.