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Producing Bacterial Wilt–Free Ginger in Greenhouse Culture

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Ginger wilt, caused by a bacterium known as *Ralstonia solanacearum* (Smith) Yabuuchi, is the most limiting factor in the production of culinary ginger (*Zingiber officinale* Roscoe) in Hawaii. The disease was responsible for a 45 percent statewide production loss of the ginger crop in 1993. It is a complex and difficult disease to control, infecting the ginger crop through all phases of a production cycle. It is present systemically in seed rhizomes as both an active and latent infection that contaminates seed-pieces when they are cut and prepared for field planting.

In open-field production, even when disease-free starting materials are used in a clean field, it is difficult for a grower to prevent introduction of the disease from nearby diseased fields by means such as water runoff (as described by Trujillo, 1964) and human, equipment, and animal traffic. In fact, it is becoming more difficult for ginger farmers in the eastern part of the Island of Hawaii to find suitable planting areas that are not already contaminated by the ginger wilt bacteria. The availability of methyl bromide for use as a pre-planting soil fumigant against this pathogen is gradually being phased out by the U.S. Environmental Protection Agency. Alternative disease management approaches have to be sought for ginger production to remain viable in Hawaii.

The greenhouse production system we describe in this publication was inspired by a "noncirculating hydroponic method" (Kratky 1998). Tissue-cultured ginger plantlets produced at PBARC in Hilo provided clean, bacterial wilt–free starting materials. The greenhouse production and management system using rhizomes produced from tissue-cultured plants was developed, modified, and tested from 2000 to 2004 at PBARC.

Some advantages of greenhouse production

- A "clean start" is ensured by using clean seed rhizomes planted in a wilt-free greenhouse using a wilt-free commercial growing medium.
- Seed-pieces are of high quality because the rhizomes are selected from second-generation plants of tissue-

Figure 1. A 26-pound ginger rhizome, about 16 inches across, harvested from a single production bag.

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culture origin, which allows for elimination of the off-type rhizomes that may be produced from first-generation tissue-cultured plants.
- Control over growing conditions is assured when the growing area is secured and protected from weather throughout the growing season, reducing the potential for accidental introduction of the disease.
- Production is "unitized," in that each grow-bag is a production unit, allowing for quick removal from the area of a plant suspected of being contaminated.
- Materials and supplies are readily available.
- Wilt-free seed-pieces can be regenerated year after year.
- The facility and production system can be cleaned and disinfected for each growing season, eliminating the need to search for and prepare new land yearly.
- The value of investment in a greenhouse and benches can be depreciated through years of operation, and the yearly costs for heavy equipment for field preparation are eliminated.
- Grow-bags are topped with light-weight medium as the plants grow to simulate the hilling cultivation done in the field, eliminating the potential for root injury as an entry point for the disease.
- Use of light-weight planting medium provides for easy hilling, harvest, and cleaning; the medium is also readily removed and washed off, which is labor-saving and results in an excellent, clean appearance of the marketable rhizomes.
- Yields are high; our 2002 production average (9 lb per pot) was equivalent to 3.75 lb per square foot of bench space, while the 2003 season averaged 15 lb per pot, equivalent to 6.25 lb per square foot of bench space.
- The product is of high quality and free of bacterial wilt disease; in our tests almost all the rhizomes produced in 2003 were Grade A market quality and wilt-free.

Some requirements of the production system that may be considered disadvantages

- Initial capital investment can be high for greenhouse or shelter structures, plastic composite benches, an irrigation system, pots, and clean potting medium.
- A reliable source of clean water is needed, preferably a piped-in "county" water source.
- The availability of wilt-free starters is currently limited.
- Strict sanitation practices are needed to maintain greenhouse sanitation to prevent introduction of diseases.

Greenhouse or rain shelter

The greenhouse or rain shelter should be clean and disease-free, with a clean source of water, and located well away from any ginger processing activities. The floor

Figure 2. A simple plastic rain shelter with commercial plastic composite benches for bacterial wilt-free ginger production. Each bench can hold 10 15-gallon growth bags.

Figure 3. Selected ginger rhizomes ready for planting as seed-pieces.

should be covered with rock or gravel. The benches should be clean and at least 12 inches off the ground (the requirements for certified seed production may specify benches 3 ft from the floor). Clean 15-gallon plastic grow-bags (16 x 16 x 30 inches) are filled with 6 gallons of growing medium at planting time and placed on 3 x 8 ft benches, 10 bags per bench. The top of the grow-bag is rolled downed to 2 inches above the top of the planting medium. We use a commercial potting medium (Sunshine Mix 4 Aggregate Plus) for topping off the bag as the plants grow, which simulates hilling three times during the season. Our irrigation system consisted of three emitters (EFCO6 1-gal/hr) placed in each bag. Each plant was irrigated four times a day for 10 minutes per session to provide 2 gallons per bag per day.

Growing medium

To make 4 cubic feet (cu ft) of growing medium, we mix 2 cu ft of fine peat moss, 1 cu ft of perlite (Pahroc Giant size #3), and 1 cu ft of coarse vermiculite (Therm-o-Rock size #2), then add the following to each 4 cu ft of medium:

- Triple superphosphate, 100 ml (100 cc)
- Gypsum, 300 ml
- Granular fertilizer (Gaviota 10-5-40), 50 ml
- Scott's Micro-max Plus Amendment Mix (minor elements), 24 oz
- Maidenwell® All Purpose Hi-Silica Growing Medium (diatomaceous earth), 1 gallon

The growing medium and amendments should be mixed thoroughly and moistened, and 6 gallons of the mix is placed into each planting bag.

Slow-release fertilizer

We mix equal parts by volume of the following four slow-release fertilizers:

Nutricote®	13-13-13	240-day release
Nutricote	16-40-0	70-day release
Nutricote	1-0-38	240-day release
Nutricote	12-0-0	240-day release

We add 6 ounces of this mixture to the 6 gallons of growing medium in each bag at planting time. This provides most of the basic nutrient needs for the ginger plant during the growing season.

Ginger seed rhizome

Disease-free ginger hands were selected from rhizomes of plants that were two growing seasons removed from the original tissue-cultured ginger plant. Use only clean and well filled hands for seed-pieces. Cut the selected hands into 1–2 oz sections, sterilizing the knife after each cut; each seed-piece should have two to four well developed "eyes." Surface-sterilize the seed-pieces in a 10% solution of household bleach (1 part bleach in 9 parts water) for 10 minutes, then cure the seed-pieces in a clean, disease-free area for three days or more before planting.

Figure 4. Ginger plants 5–6 months old; the bags will be unrolled as the plants receive one or two more hillings.

Figure 5. Mature ginger planting with tops removed and rhizomes being cured for three weeks before harvest.

Planting

Ginger seed-pieces should be planted during March–April for best production. Plant a single seed-piece about 2 inches deep in each bag containing 6 gallons of growing medium. Roll the top of the planting bag down to 2 inches above the medium surface. Place the irrigation emitters on top of the medium and around the planted seed-piece. As the ginger plant grows, more medium is added (hilling), and the irrigation emitters are moved to the top of the medium. The top of the planting bag is unrolled upward to accommodate the added medium. Hilling, the periodic covering of the upward-expanding rhizomes, is an important process in ginger production to ensure development of rhizome size and mass.

Fertilizer additives at time of each hilling

The first hilling is done four months after planting (around mid-July), when the plant is about 2 ft tall. We then add gypsum, $CaSo_4 \cdot 2H_20$, at 1 pound (2 cups), and 2 oz (6 tablespoons) of 8-8-8 fertilizer (Complehumus Premium Fertilizer 8-8-8+1.8 Mg, Kyowa Hakko Kogyo Co. Ltd., Japan) to each bag, and then cover the base of the plant with a 6-inch layer of Sunshine Mix #4. Move the emitters to the top of the medium, and water thoroughly after hilling.

The second hilling is done about five months after planting (in mid-August), when we add 1 lb (2 cups) of gypsum, 4 oz (½ cup) of Dolomite AG65 Agricultural Liming Material, 4 oz (½ cup) of Light House Brand Kelp Meal, and 2 oz (¼ cup) of 8-8-8 Complehumus to each bag and then cover the fertilizer with a 6-inch layer of Sunshine Mix 4. Move the emitters to the top of the medium and water thoroughly.

The third hilling is done about 7 months after planting (in late October), when we add 1 oz (3 tablespoons) of gypsum and 2 tablespoons of calcium nitrate ($CaNO_3$) to the bag, then fill it with Sunshine Mix #4 and move the emitters to the top of the medium before watering thoroughly.

Supplemental nutrients and amendments to provide organic matter and micronutrients

Every two to three weeks after the first hilling in late July, one quart of “EM + Superthrive” solution is added to each bag. The solution is prepared by mixing 10 oz of EM1® Microbial Inoculant (EM Hawaii, Inc.) plus 1 tablespoon of SUPERthrive™ Vitamins-Hormones in 1 gallon of water.

Two weeks after the first hilling, add 2 tablespoons of the Nutricote fertilizer blend and 4 cups of E-Z Green Composted Chicken Manure (Mountain Springs Ranch Inc., Lyle Fohl, CA) to each bag.

One month after the second hilling (mid-September), add to each bag 5 oz of gypsum, 2 oz of Comple-

Figure 6. A single ginger rhizome cluster just harvested from a growth bag.

Figure 7. Washed and cleaned ginger rhizomes from a single growth bag.

Table 1. Comparison of bacterial wilt-free ginger rhizome production from different seed sources using the greenhouse production system.

Seed rhizome source	Average production per bag (lb)	Off-type rhizomes (%)
Tissue culture (2002)	7.7 ± 4.0	7.1–24.9
Selected rhizome, 1 oz (2002)[x]	9.0 ± 1.8	None
Off-type rhizome, 1 oz (2002)[x]	5.5 ± 2.6	75–100
Selected rhizome, 1 oz (2003)[y]	14.9 ± 7.1	None

[x]Rhizomes produced from tissue cultured ginger plantlets, 2000–2001.
[y]Rhizomes produced in 2001–2002, two cycles of grow-out removed from tissue cultured source.

humus, and 1 quart of a solution of TotalGro™ fertilizer and Metalosate® Calcium (Albion Laboratories). The stock solution of TotalGro 19-19-19 (Floral Crop Special) and Metalosate Calcium is prepared by adding 1 tablespoon of each product to 1 gallon of water.

In early October, we add 1 tablespoon of calcium nitrate per bag and water it in well.

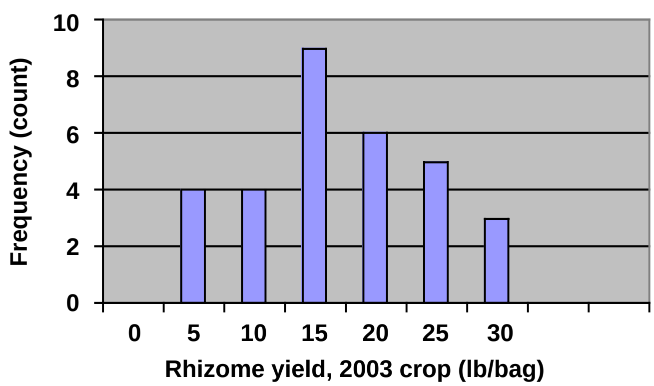
The supplemental calcium applications during hilling are important for rhizome quality and the healing of the stem scars at harvest.

The particular fertilizers and growth supplements detailed in this publication describe what was applied to our 2003 crop. Adjustments in amounts applied and application intervals may be necessary at other locations based on growth of the ginger plants. Commercial products mentioned are not recommended to the exclusion of other products that may also be suitable. Alternative plant nutrition programs may also provide satisfactory results.

Hardening and harvesting

Turn off the irrigation water in early January to dry out the matured plants. Three weeks later, cut off any wilted or wilting tops with a clean cutting tool. Then, cure the rhizomes for three more weeks by keeping the grow-bags dry. Remove the grow-bags to a sheltered area to cut them open. The loose medium can be easily removed. Large sections of each hand are broken off and set aside for washing. After washing, cure the rhizomes in a clean, dry area to protect them from contamination.

Frequency distribution of ginger rhizome yield per bag.



Production results (2003–2004)

Planting date	March 21, 2003
Harvesting date	Feb. 25, 2004
Total number of bags per bench	10
Total number of bags	31
Total rhizome yield	462 lb
Average yield per bag	14.9 lb
Range of yield per bag	3.2–27.4 lb

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