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# Outdoor Growing of Clean Edible Ginger Seed by a Pot-in-Pot-in-Pot Sub-Irrigation Method

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**Abstract.** Edible ginger (*Zingiber officinale* Roscoe) was grown outdoors in 9.5-liter pots (with drainage holes) filled with growing medium which nested in 10.3-liter pots with no drainage holes and were constantly sub-irrigated with 5 cm of nutrient solution. Vegetative rhizomes from a previous crop were cut into seed pieces (50 ± 10 g) for planting the next crop. Seeding material has been maintained free of root-knot nematode (*Meloidogyne incognita*) and bacterial wilt (*Ralstonia solanacearum*) throughout 3 growing seasons. Yields were higher when 3 or 4 seed pieces were planted per pot, but the increased yield per pot was not proportional to the initial seed piece. The 9.5-liter pot size was too small, and this resulted in competitive yield loss, burst pots and somewhat malformed rhizomes. A plastic gutter placed over a row of pots diverted 40 to 50% of the rainfall which otherwise would have diluted the nutrient solution. The use of gutters increased yields during 2 high rainfall years, but had no significant yield effect during a drier year. Upside-down, 3-liter pots placed in 9.5-liter growing pots reduced the growing medium requirement and also resulted in greater yields during 2 of 3 years. The highest absolute yields per pot occurred when an upside-down pot was placed in the growing pot and rainfall was diverted by a gutter from pots planted with 3 or 4 seed pieces.

## Introduction

In Hawaii, open field culture edible ginger (*Zingiber officinale* Roscoe) is commercially grown in deep, loose soil (6). Ginger is vegetatively propagated with 50 to 225 g rhizome seed pieces from a previous field-grown crop. Seed-borne and soil-borne diseases may cause significant losses for ginger growers (8). In past years, methyl bromide fumigation of the soil prior to planting, coupled with an excellent field sanitation program successfully controlled weeds, fusarium yellows (*Fusarium oxysporum f. zingiber*), root-knot nematodes (*Meloidogyne incognita*) (8) and bacterial wilt (*Ralstonia solanacearum*) (7) as long as clean seed was planted. Other disease control methods are needed, because methyl bromide fumigation of field soil faces an improbable future.

The first step in disease control is to plant clean seed. A clean ginger seed production method was developed by top-watering plastic bags (56-liter) in a greenhouse. The bags contained sterile growing medium and were planted with disease-free seed rhizomes that were two seasons removed from tissue-cultured plants (2). Ginger has successfully been grown under rainshelters in sub-irrigated pots (3,4,5) and trays (3) filled with sterile growing medium. Ginger has also been grown in a greenhouse by aeroponic cultivation (1).

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The purpose of this study was to develop a clean ginger seed production method by growing in sub-irrigated plastic pots of growing medium in outdoor conditions, thus saving the costs associated with greenhouses or rainshelters.

## Methods and Materials

Trials were conducted during 2006-2008 at The Waiakea Experiment Station located at a 165 m elevation near Hilo, HI 96720. In an outdoor location, 3.8 x 23 cm x 3 m long boards were supported by 2 concrete blocks, each at heights ranging from 15-25 cm above uneven rocky terrain covered with a plastic weed barrier fabric. Eight black plastic pots (22.5 cm bottom x 25 cm top x 22.9 cm height with a 10.3 liter capacity) with no holes rested on each board. Classic 1000 plastic pots (20.6 cm bottom x 25 cm top x 23.2 cm height with a 9.5 liter capacity) with 5 openings on the bottom nested in each of the previously described pots. Upside-down Classic 350 pots (15.8 cm bottom x 20 cm top x 12.7 cm height) rested in half of the treatments. All of the Classic 1000 pots were filled with a peat-perlite growing medium, but the half with upside-down Classic 350 pots required 3 liters less growing medium. Plastic rain gutters (10.8 cm wide) ran lengthwise along rows of 8 pots on half of the treatments and intercepted 40 to 50% of the potential rainfall entering the pots. Nutrient solution flowed by gravity from a storage tank to a plastic sump container with a float valve adjusted to maintain a 5-cm depth of nutrient solution which then flowed through a 1.3-cm polyethylene tube to each outer pot via 4.75-mm plastic tubes. Since the pots were at the same level as the sump container/float valve assembly, all pots were constantly sub-irrigated with 5 cm of nutrient solution. Water from rainfall was allowed to collect in the pots up to a drainage opening located 7.5 cm from the bottom of the pot. Thus, solution levels ranged from 5 to 7.5 cm depending upon rainfall. The nutrient solution (EC of 1.5 to 2.0 mS) was prepared from 2 stock solutions which were added in equal volumes to water in the storage tank. One stock solution consisted of 120 g/liter of a commercial (Hydro-Gardens, Colorado) hydroponic fertilizer (8% N, 6.6% P, 29.9% K, 0.20% B, 0.05% Cu, 0.4% Fe, 0.2% Mn, 0.01% Mo and 0.05% Zn) plus 72 g/liter of magnesium sulfate; the second stock solution consisted of 120 g/liter of soluble grade calcium nitrate. Each pot was planted with 1, 2, 3 or 4 clean seed pieces ($50 \pm 10$ g) which originated from tissue culture followed by multiple generations in hydroponic culture. Subsequent crops were planted with seed pieces cut from rhizomes grown in the previous crop. The plot was arranged as a thrice-replicated, randomized complete block factorial experiment with variables consisting of 4 seed piece numbers, with and without an upside-down pot and with and without a rain gutter. Data were also analyzed as a randomized complete block design with 16 treatments and 3 replications to directly compare individual treatments. Yield data consisted of ginger rhizome fresh weight.

## Results and Discussion

Incidences of bacterial wilt (*Ralstonia solanacearum*) and root-knot nematode (*Meloidogyne incognita*) were not detected in any of the treatments during the 3 ginger crops. The use of sterile growing medium, elevated pots and a plastic weed barrier fabric contributed to this successful outcome. Seed pieces for planting the 2006 crop were grown in sterile medium for several generations beyond tissue culture plants. Rhizomes from the 2006 crop were used to plant the 2007 crop which was subsequently used to plant the 2008 crop.

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An earlier planting date and lower rainfall from the June to October period (Table 1) contributed to higher yields from the 2008 crop (Tables 2 and 3). Yields from 2007 were lower than the other 2 crops due to a later planting date and a shorter growing season.

The lowest yields per pot occurred with one seed piece per pot in all 3 crops and the highest yields occurred with 4 seed pieces per pot in 2006 and 2007 and with 3 or 4 seed pieces in 2008 (Table 2). The yield increase for planting additional seed pieces was not proportional to the yield of the initial seed piece, and this indicates that additional seed pieces cause competitive effects. Total production from multiple seed pieces was likely limited by pot size. In fact, some pots burst from the pressure of the expanding rhizomes. Also, there was not adequate space for the rhizomes to freely expand, and the rhizome shape became somewhat malformed or rounded from hitting the sides of the pot. In fact, it was necessary to cut many of the pots open to remove the rhizomes. A larger growing container would be recommended when planting multiple seed pieces.

Rainfall entered the pots and diluted the nutrient solution. Drowning of the plants was prevented by an overflow opening at 7.5 cm from the bottom of the pot where excessive rain along with some nutrient solution could run-to-waste. Plastic rain gutters were placed over the pots to divert 40 to 50 percent of the rainfall and reduce dilution of the nutrient solution. The presence of a gutter increased yields in 2006 and 2007 when averaged over the other variables (Table 2). The 2008 rainfall for the period of greatest growth (June through October) was more than 50 cm lower than the 2 previous years (Table 1), so it was not surprising that a gutter did not contribute to a significant yield increase in 2008.

Upside-down 3-liter pots were placed in the 9.5-liter growing pots to reduce the growing medium requirement and possibly provide more air space. The soft, blow-molded pots crushed somewhat to accommodate rhizome expansion. Greater yields were observed in 2 of 3 years (2007 and 2008) when upside-down pots were employed (Table 2). In a best case scenario, 1 kg of rhizomes was produced with less than 2 liters of growing medium by using upside-down 3-liter pots in the growing pots. However, completely filling the 9.5-liter growing pots with medium always resulted in the requirement of more than 3 liters of growing media per kg of rhizomes produced.

Yields from individual treatment combinations are presented in Table 3. In 2006, the highest absolute yield (3.18 kg/pot) occurred in the treatment with 3 seed pieces plus an upside-down pot and a rain gutter, whereas the lowest yield (1.01 kg/pot) occurred with 1 seed piece and without an upside-down pot and gutter. The highest absolute yields in 2007 and 2008 were 2.61 and 3.53 kg/pot, respectively, from treatments with 4 seed pieces plus an upside-down pot and a gutter. The lowest yield occurred with 1 seed piece plus a gutter without an upside-down pot in 2007 (0.52kg/pot) and with an upside-down pot in 2008 (1.76 kg/pot).

Care must be taken to shade pots on peripheral sides which receive direct sunlight. Black pots become hot and this may cause root injury. Yields may become lower and the quantity of feeder roots may increase and this aggravates the rhizome cleaning process.

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An outdoor pot-in-pot-in-pot sub-irrigation growing method has maintained seeding material free of bacterial wilt and root-knot nematodes throughout 3 growing seasons. The highest absolute yields per pot occurred when upside-down pots were placed in the 9.5-liter growing pots and rainfall was diverted by a gutter from pots planted with 3 or 4 seed pieces. Additional research is needed to determine the optimum growing pot size, because the 9.5-liter pot size was too small and this resulted in competitive yield loss, burst pots and somewhat malformed rhizomes.

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Table 1. High/low temperature and rainfall data for 3 ginger crops during 2006-2008 at The Waiakea Experiment Station, Hilo, Hawaii.

| | Crop Period | | |
|---|---|---|---|
| | 4/28/06 to 1/18/07 | 6/05 to 11/05/07 | 4/02 to 12/01/08 |
| Av. High Temp ($^oC$) | 26.4 | 26.8 | 27.1 |
| Absolute High Temp ($^oC$) | 31.7 | 29.4 | 30.0 |
| Av. Low Temp ($^oC$) | 18.3 | 18.4 | 18.4 |
| Absolute Low Temp ($^oC$) | 13.3 | 15.0 | 12.8 |
| Total Rainfall (cm) | 329.4 | 143.7 | 141.1 |
| June to Oct. Rainfall (cm) | 139.7 | 132.0 | 81.3 |

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Table 2. Effects of the number of seed pieces per pot, rainfall diversion by a gutter and placing an upside-down 3-liter pot in the 9.5-liter growing pot on the yield of outside-grown edible ginger during 3 growing seasons.

| | 2006 | 2007 | 2008 |
|---|---|---|---|
| Seed pieces/pot | ---------------kg/pot | -------------- | |
| 1 | 1.40a[z] | 0.89a | 2.01a |
| 2 | 1.98b | 1.29b | 2.59b |
| 3 | 2.24b | 1.53b | 2.97c |
| 4 | 2.79c | 1.93c | 2.95c |
| | | | |
| Gutter | 2.27b[y] | 1.74b | 2.71ns |
| No gutter | 1.94a[y] | 1.08a | 2.55ns |
| | | | |
| Upside-down pot | 2.19ns | 1.66b | 2.77b |
| Control | 2.02ns | 1.16a | 2.50a |

[z]Means followed by the same letter within groups of either 2 or 4 variables in individual columns are not significantly different (P≤.05) by Duncan's Multiple Range Test when analyzed by a 4x2x2 factorial design.
[y]Means are significantly different (P≤.06) by Duncan's Multiple Range Test.

Table 3. Effects of individual combinations of number of seed pieces per pot, rainfall diversion by a gutter and placing an upside-down 3-liter pot in the 9.5-liter growing pot on the yield of outside-grown edible ginger during 3 growing seasons when analyzed as a randomized complete block with 16 treatments.

| | | 2006 | | 2007 | | 2008 | |
|---|---|---|---|---|---|---|---|
| Seed Pieces | Upside-Down Pot | Gutter | No gutter | Gutter | No gutter | Gutter | No gutter |
| | | --------------- | ---------------- | kg/pot | ---------------- | ---------------- | ------ |
| 1 | + | 1.63abc[z] | 1.69abc | 1.34bcde | 1.15 abcd | **1.76**[y]a | 2.02ab |
| 1 | - | 1.26ab | **1.01**a | **0.52**a | 0.55a | 2.14ab | 2.14ab |
| 2 | + | 1.96abcd | 1.47ab | 1.75cdef | 1.02abc | 3.19de | 2.49abcd |
| 2 | - | 2.32bcdef | 2.18bcdef | 1.56bcdef | 0.83ab | 2.26abc | 2.42abcd |
| 3 | + | **3.18**f | 1.67abc | 2.30fg | 1.16abcd | 3.01cde | 3.16de |
| 3 | - | 2.05abcde | 2.08abcde | 1.77cdefg | 0.88abc | 3.05cde | 2.67bcd |
| 4 | + | 3.08ef | 2.81def | **2.61**g | 1.95defg | **3.53**e | 2.98cde |
| 4 | - | 2.65cdef | 2.63cdef | 2.06efg | 1.08abcd | 2.74bcde | 2.56abcd |

[z]Means followed by the same letter within growing individual growing seasons (pairs of columns) are not significantly different (P≤.05) by Duncan's Multiple Range Test when analyzed as a randomized complete block with 16 treatments.
[y]Absolute lowest and highest yields per growing season are denoted in bold lettering.