Aeroponic Cultivation of Ginger (*Zingiber officinale)* Rhizomes

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Abstract

Ginger (*Zingiber officinale* Rosc.) rhizomes are popular as a spice and an herbal dietary supplement. The anti-inflammatory and anti-nausea qualities of ginger have applications in the pharmaceutical industry. Conventionally grown as a tropical field crop, ginger is plagued by soil-borne disease and nematode problems. Aeroponic cultivation of ginger can provide high-quality rhizomes that are free from pesticides and nematodes and can be produced in mild-winter greenhouses.

An experiment involving 34 ginger plants grown in aeroponics was performed in a temperature controlled greenhouse in Tucson, Arizona. The unique aeroponic growing units incorporated a "rhizome compartment" separated and elevated above an aeroponic spray chamber. Bottom heat was supplied to one half of the plants. Accelerated growth was observed in plants receiving bottom heat. One third of the plants were grown in units where the rhizome compartment was filled with perlite, one third in sphagnum moss, and one third without any aggregate medium. Those plants grown in perlite matured faster than the other treatments. The aeroponic units without aggregate medium provided an opportunity to photograph the growth habit of rhizomes over a three month period. Those images were incorporated into a 60-second digital movie that dramatically illustrates how underground rhizomes develop and grow.

INTRODUCTION

Ginger (*Zingiber officinale*, Rosc.) is a major spice crop, grown primarily in central Asia for export worldwide. The species is not found in the wild, it has been cultivated for so long in China and India that its exact origins are unclear (Indian Institute of Spices Research, 2004). Recent interest in ginger as a potential anti-nausea and anti-inflammatory constituent in pharmaceutical preparations has opened new markets for consistent, high-quality ginger rhizomes (Mustafa, et al. 1993).

The perennial rhizome of the ginger plant is a specialized segmented stem structure that grows horizontally just under the soil surface. Upright-growing shoots are produced from the tips of lateral rhizome branches. Adventitious roots and lateral growing points emerge from the nodes of the rhizome stem. In ginger, the roots emerge from the lower rhizome sections. For commercial purposes, ginger is grown as an annual crop, the rhizomes are harvested after seven to nine months (Wilson and Ovid, 1993).

Ginger is commercially propagated vegetatively from "seed pieces" of rhizomes, which limits the reproductive and harvest productivity of the crop while perpetuating many devastating crop diseases. In field culture, ginger is susceptible to a number of pathogens and soil-borne diseases, such as Cucumber Mosaic Virus, bacterial wilt (*Ralstonia solanacearum*), *Erwinia* soft rot, *Fusarium* yellows, and rootknot nematodes (Inden and Asahira, 1988; Stirling, 2002; Vilsoni, McClure and Butler, 1976). These disease problems cause producers in infested areas to acquire virgin land for their crops every year, or undergo long crop rotations with unaffected crops. In Hawaii, ginger fields are fumigated with methyl bromide prior to planting in an attempt to control nematodes, *Fusarium* yellows and weeds (Kratky, 1998).

Hydroponics can be an alternative horticultural system for crops susceptible to soil-borne diseases. The uniform growing environment in a controlled greenhouse may

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produce crops with more consistent levels of secondary metabolites, which is of concern to the phytopharmaceutical industry. Unfortunately, there are few hydroponic or aeroponic production systems suitable for rhizome crops. Most hydroponic systems are designed for crops that produce fruit or leaf products and have fibrous root systems and a predictable crown size at the soil line. Rhizome-producing crops have special requirements, in that the horizontal growth habit of the rhizome needs room to expand and produce vertical shoots and secondary roots as needed, uninhibited by physical barriers.

Most commercial hydroponic systems utilize an aggregate growing medium, such as perlite or rockwool, contained in a plastic wrap or bag and are drip irrigated with a fertilizer solution. These systems provide sufficient aeration for the roots while physically supporting the plants. Non-aggregate systems, such as Nutrient Film Technique (NFT), Deep Flow or Ebb-Flood systems, are also popular commercially, but tend to minimize root growth and are dependent on a rigid plastic structure to support the plant at the crown. Aeroponics is another type of non-aggregate hydroponics, where the roots of the plants are suspended in an enclosed chamber and sprayed periodically with a fertilizer solution by means of a timer and pumps. Aeroponics offers several advantages over other hydroponic systems, particularly for root crops. The roots are easily accessible for monitoring, sampling, and harvesting. Without the buffering capacity of a solid or aggregate growing medium, the air/liquid medium of aeroponics permits precise control of the nutrient solution mineral composition and temperature. Finally, the common use of A-frame growing structures in aeroponics permits twice the growing area surface in the same size greenhouse, potentially doubling the economic yield for a grower. However, all aeroponic systems previously described in the literature require a rigid structure at the crown of the plant to support the plants while their roots are suspended in the fertilizer spray (Massantini, 1985; Weathers, 1992; Leoni, et al., 1994). This rigid support would restrict the horizontal growth habit of the rhizome. A new aeroponic system was needed to accommodate the horizontal nature and growth habit of a rhizomatous crop.

The study presented here describes a new aeroponic design that has not been previously reported. In this system, the rhizomes can be grown in an aggregate medium supported above the spray chamber by a porous layer that protects the rhizomes from direct contact with the nutrient salt solution, while permitting the roots to grow downward into the aeroponic spray chamber. Alternatively, the rhizomes can be supported just above the porous layer, but without the aggregate medium, under a layer of slotted plastic to protect the rhizomes from sunlight. This unique design allowed the rhizomes to grow horizontally and send up shoots at will, permitted the feeder roots to grow in an aeroponic environment, and provided easy access to both roots and rhizomes for sampling and monitoring.

MATERIALS AND METHODS

Initial planting stock was obtained from three different sources. Sixteen rhizome pieces were obtained from greenhouse-grown stock from S.P. McLaughlin at the Southwest Center for Natural Products Research and Commercialization at the University of Arizona. Since this was a very limited amount of material, an additional 26 pieces were obtained from local grocery stores in Tucson, Arizona. It is unknown if any post-harvest storage treatments, other than chilling, were applied to the ginger purchased from the retail stores.

All rhizome pieces were prepared for planting by cleaning with soap and water to remove any visible soil particles, rinsing well in fresh tap water, followed by soaking in a 10% solution of “Ultra bleach” (final concentration 0.6% sodium hypochlorite) for five minutes. The pieces were then rinsed in distilled water and soaked in warm water (50°C) for 10 minutes to reduce nematodes (Trujillo, 1963). All rhizome pieces were transplanted into the aeroponic growing units between March 20 and April 20, 2002.

Six identical aeroponic units were constructed using slotted angle iron and 2.5cm expanded polystyrene insulation board for structural support (See Fig. 1). The units were

1.8 m tall, each with a 0.6 by 0.6 m footprint. A plastic-lined reservoir at the bottom held approximately 100 liters of hydroponic nutrient solution. The solution was recirculated by an external timer-controlled pump, which sprayed the roots for one minute with three minutes off at a rate of approximately 0.03 $L\ s^{-1}$. No spray was applied during the night. The solution was replaced weekly. The nutrient solution composition is listed in Table 1.

Above the spray chamber, a “rhizome compartment” (RC) was constructed. The bottom of the compartment was supported by PVC-coated hex (poultry netting) wire secured to the steel frame, with a 2.5 cm layer of porous material above the netting wire to protect the rhizomes from direct contact with the fertilizer salts while permitting the roots to penetrate the material and grow into the spray chamber below. The porous material used was a latex-coated hog hair furnace filter purchased from a local building supply store. The sides of the RC were constructed using the expanded polystyrene insulation material.

Two treatments were imposed on the experiment: (1) type of growing medium used in the RC, and (2) heat vs. no heat in the reservoir below the spray chamber. The growing medium in the RC consisted of either (a) perlite, (b) sphagnum moss, or (c) no aggregate medium (NAM). The perlite was pre-rinsed to remove all fine material. The sphagnum moss was a loose, uncut moss from a local garden center, which was not pre-treated in any way before using. The NAM treatment utilized slotted white-on-black co-extruded polyethylene film suspended above the rhizomes to protect them from direct sun and increase the humidity in the RC environment. Each growing medium treatment was tested in two units.

One half the aeroponic units contained heated nutrient solution using a 100 Watt glass aquarium heater with an internal thermostat set at 25 °C. This provided bottom heat under the plants, heating the roots in the spray chamber. Reservoirs without heat contained nutrient solution that remained at approximately the same temperature as the ambient air. Greenhouse environmental conditions were maintained at photoperiod/dark period of 23 °C and 17 °C respectively.

Rhizomes were harvested on November 21, 2002 (seven to eight months after planting) and fresh weights were determined.

This pilot experiment was designed with four to seven rhizome pieces in each aeroponic unit. Due to the limited number of rhizomes available from each source, and the limited number of aeroponic units available, all rhizomes in each treatment were grouped together for statistical analysis regardless of the original source of the material. Means and standard errors were calculated using Quattro Pro software.

RESULTS

Growing Media Treatments

Due to a disease problem in one of the sphagnum moss units, which was likely due to contaminated planting stock and not attributable to the medium, both moss treatments (heated and unheated) were removed from the study.

Of the two remaining treatments, perlite appeared to provide the superior growing conditions over the NAM. In both the heated and unheated units, average net yields were higher in the perlite medium (1181 ±standard error of 284g/plant n=5 and 749 ±117g/plant n=4, respectively) than in the units without any aggregate growing medium (525 ±62.7g/plant n=7 and 333 ± 67g/plant n=5, respectively).

Heated vs. Unheated Nutrient Solution Treatments

Those plants growing in units with heated nutrient solution in the reservoir below the roots matured faster and produced slightly higher fresh rhizome yields than plants in the same medium without bottom heat. The plants in the aeroponic unit with bottom heat and perlite in the RC produced the highest average net yield compared to any other treatment, and the plants matured noticeably faster, producing far greater number of flower stalks than any other treatment (twelve flowers from five plants on October 3, 2002). The only other unit that matured to produce any flowers at all was the NAM with bottom heat (two flowers from seven plants). Although flowering is not critical for rhizome growth, and may even reduce yields, it is an indicator of maturity and rate of growth.

DISCUSSION

It is common practice in greenhouse culture to supply bottom heat to vegetatively propagated crops; however heat is normally discontinued after plants are established, particularly in warm-climate regions during the summer months. Ambient air temperatures in the greenhouse averaged 22 ±3°C, with the temperature in the unheated reservoirs averaging 23 ±2°C and the temperatures in the heated reservoirs averaging 28 ±2°C. The rhizome temperatures were dependent on the type of medium in the rhizome compartments. Those growing in perlite experienced a greater insulating factor (and therefore stayed cooler) than the rhizomes growing without any aggregate medium around them. Consequently, the plants in the aeroponic unit containing perlite around the rhizomes, and bottom heat warming the roots, responded with the highest yields and fastest maturation rate. Further study is needed to determine if this temperature differential between the rhizomes and the roots is directly responsible for the increased growth.

The loss of plants from disease in one of the sphagnum moss treatments is troubling from a growers' perspective, and preliminary work was done to develop an aeroponic system appropriate for acclimating young tissue-cultured ginger plantlets that could be guaranteed to be free from disease and nematodes. The tissue culture methods utilizing excised rhizome buds were based on Sharma and Singh (1997). The rooted plantlets were transferred to covered tubs containing autoclaved perlite and watered with sterilized hydroponic nutrient solution. Using full-strength hydroponic nutrient solution eliminated the transplant shock seen in plantlets transferred to tubs containing perlite and half-strength Murashige Skoog culture solution. The plants were kept in a growth chamber for two weeks, and then moved to a shaded area in the greenhouse. Four weeks after transplanting into the perlite, many of the plantlets were developing small rhizomes. They were then transplanted into an aeroponic unit at a very high planting density and irrigated from below continuously with a heated nutrient solution spray. Roots quickly developed and grew downward into the spray chamber. This may be an acceptable method for mass-producing disease free planting stock for hydroponic rhizome crops.

CONCLUSION

Ginger rhizomes were successfully grown in a modified aeroponic system. Although production practices and environmental conditions were not optimized, the benefits of an aeroponic nutrient delivery system were demonstrated.

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Tables

Table 1. Nutrient solution composition.

Fertilizer Element	Concentration
Nitrate-nitrogen (NO_3-N)	119 mg/L
Phosphorus	83 mg/L
Potassium	163 mg/L
Calcium	193 mg/L
Magnesium	48 mg/L
Iron	6 mg/L
Manganese	0.9 mg/L
Boron	0.3 mg/L
Copper	0.06 mg/L
Zinc	0.08 mg/L
Molybdenum	0.04 mg/L
Electrical Conductivity (EC)	2.0 mS/cm
pH (adjusted using Nitric Acid)	5.7

Figures

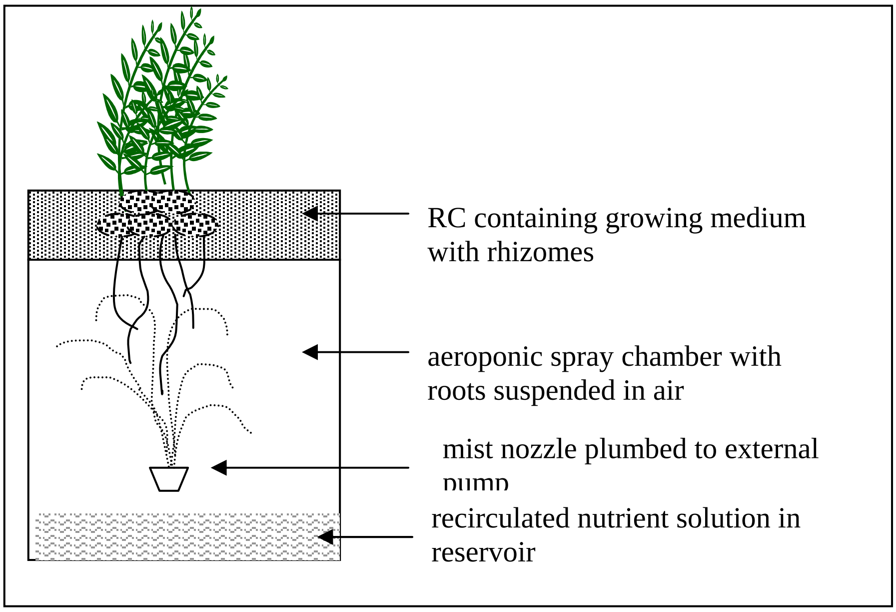

Fig. 1. Diagram showing aeroponic unit design with Rhizome Compartment (RC) above spray chamber containing roots.

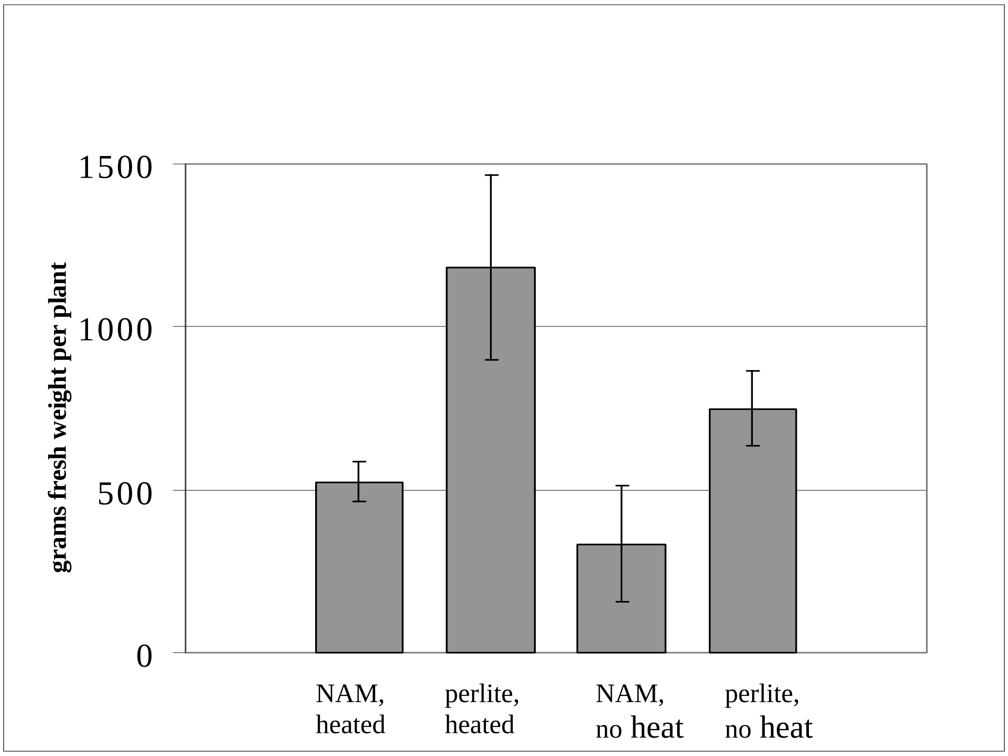

Fig. 2. Average net yield fresh weight (g/plant).