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PRODUCTION OF HIGH TUNNEL SPECIALTY CROPS IN PENNYSLVANIA

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Abstract: Edible ginger (*Zingiber officinale* Roscoe) and taro (*Colocasia esculenta*) are tropical crops that were grown in an unheated Pennsylvania high tunnel. Crops were harvested after a killing frost on October 29, 2007. A single edible ginger seed piece (50 grams) was planted per pot on May 14 and pots were placed in a sub-irrigated tank on July 2. Ginger produced an average of 19 shoots and 1056 grams of air dried rhizomes per pot. In another trial which was planted on June 14, only 11 shoots and 407 grams of air-dried rhizomes were produced per seed piece in a 25 cm deep peat-perlite bed. Ginger normally requires a growing season of 10 months. Taro was planted on June 26 and produced an average of 476 grams per plant of edible leaves (blades + petioles) from mother and daughter plants, 229 grams of edible corm and 7 daughter plants per mother plant. Taro normally requires a growing season of 6 to 10 months. These experiments demonstrate that ginger and taro can produce a salable crop in a temperate location high tunnel, but it may not be possible to obtain ginger and taro yields equivalent to a tropical region. There remains potential that ginger and taro can be profitable niche market crops, especially if the growing season can be extended by several months in high tunnels.

Introduction

Edible ginger (*Zingiber officinale* Roscoe) is a tropical crop that optimally requires a 10 month growing season in Hawaii to produce mature ginger rhizomes (7). A shorter growing season results in reduced yields and rhizome size. *Baby ginger* or *young ginger* results from early harvesting and is a gourmet quality product with a tender, low-fiber texture and is mostly used for pickling. Although ginger is typically grown in field culture, other growing methods include a clean seed production method in containers of sterile medium (5), various hydroponic methods (6, 9) and aeroponic cultivation (4). Both raw and cooked fresh ginger are prized in Indian and Asian culinary. Examples of processed food products include ginger ale, ginger beer, gingerbread and ginger snaps. Both fresh and prepared ginger have medicinal uses. Ginger is sold as a dietary supplement, because it is not FDA approved as a medicine. However, mixed claims have been made for effectiveness on nausea, motion sickness, a cold remedy, for settling an upset stomach and for inflammation. Doctors warn against possible blood thinning properties, because ginger may interact with other medicinal blood thinners.

Taro (*Colocasia esculenta*) is an important staple food crop for inhabitants of the Pacific region. Taro produces edible leaves which may be boiled or steamed and a starchy corm (11) which may be boiled, steamed, baked, or made into poi, flour or chips. Taro corms and leaves have an acrid irritation property caused by a protease associated with calcium oxalate crystals. This protease is a protein which can be deactivated by heat. Before eating, corms must be boiled or steamed for 1 to 3 hours and leaves with petioles must be boiled or steamed for 4 to 5 hours, depending on the variety. The Chinese taro variety 'Bun Long' is known for its low acridity. Taro normally requires 6 to 10 months to mature (12), but leaves may be harvested at any time (3) and lower corm yields may be expected with a shorter growing season. Leaves are rich in vitamins (particularly A and C) and minerals (12). Taro starch grains are only about one-tenth as large as that of potato and are easy to assimilate. Taro may be consumed by people with digestive problems. Taro flour is used for infant formulae and is useful to persons allergic to cereals and may be consumed by children sensitive to milk (11). Taro is commonly grown as 'wet' taro under frequently or constantly flooded conditions or as 'upland taro' which is grown in a rain-fed or irrigated field (8).

The frost-free growing season (90% probability) in central Pennsylvania's temperate climate is about 120 days and typically extends from May 15 through September 15 (10). High tunnels typically increase both minimum and maximum temperatures by 3 to 4 ^{o}C over ambient temperatures (2), particularly when side coverings are lowered. This enables a high tunnel to extend the frost-free growing season by 30 to 60 days (10). Daylight duration for State College, PA (N 41^{o} latitude) exceeds that of Hilo, HI (N 20^{o} latitude) by 176 hours during a typical high tunnel growing season of May 1 through October 15 (1).

Experiments were conducted on edible ginger and taro to determine if the combination of longer daylight hours plus a longer frost-free growing season and higher air temperatures would make it possible to produce these tropical crops in unheated Pennsylvania high tunnels.

Methods and Materials

Sub-irrigated trials were conducted in a high tunnel at the Rock Springs Horticultural Farm near State College, Pennsylvania. Black plastic pots (11-liters) containing peat-perlite growing medium rested on 2.5-cm high soft nursery trays which were supported by a polyethylene-lined tank floor. A constant 5 cm level of water was maintained with a float valve such that the pots were watered by sub-irrigation. The nutrient solution was checked weekly with an electrical conductivity meter and replenished with equal amounts of 2 stock nutrient solutions to maintain an electrical conductivity level of 1.5 to 2.0 mS. One nutrient stock solution consisted of 120 grams of soluble greenhouse grade calcium nitrate per liter of water, and the other stock solution consisted of a mixture of 72 grams of magnesium sulfate and 120 grams of Chem-Gro 8-15-36 Lettuce Formula (Hydro-Gardens, Colorado) per liter of water. The Chem-Gro formulation also contained micronutrients. Large batches of stock solutions (95 liters) were stored in 2 opaque plastic trash containers and mixed prior to use. The growing tanks were covered with very reflective aluminized plastic mulch which maintained a cool surface such that leaves did not burn when they contacted the mulch. Data were analyzed and standard error and coefficient of variability values were computed.

Edible ginger.

Ginger rhizome (50 grams) 'seed pieces' were sent from Hawaii. They were planted in pots on May 14, 2007 and top watered on a greenhouse bench until July 2 when the pots were placed in a 3 x 1.2 m tank such that there were 2 rows with a 30 cm spacing between pot centers within rows. Ginger was harvested on October 29, 2007 by removing the foliage at a 5 cm height above the surface of the growing medium and emptying the pots in a large plastic tray. The rhizomes were washed, and then moved into a greenhouse to air dry by placing a single layer of rhizomes on screened racks which were covered with a polypropylene row cover. After 4 days they were ready for market or storage as seed for next year's crop. Data collection included shoot number, height of the tallest shoots, shoot fresh weight and rhizome fresh weight immediately after harvesting and after air drying for 4 days. There were 8 fertilizer applications such that 128 grams of nitrogen plus the accompanying nutrients were applied.

In a second experiment, 14 ginger rhizomes were planted on June 14 in a 3 x 1.2 m peat-perlite bed which was 25 cm deep. The growing medium was trenched to a 10-cm depth and seed pieces were planted 2.5 to 5 cm deep. The growing medium was hilled to promote vertical, rather than horizontal growth of the rhizomes. Harvesting conditions were similar to the previous experiment. There were 10 fertilizer applications of a 20-10-20 fertilizer such that 120 grams of nitrogen plus the accompanying nutrients were applied.

Taro

Dr. S.C. Miyasaka of the University of Hawaii provided 19 vegetative propagules of 'Bun Long' Chinese taro. Each one is called a *huli* and consists of a sucker with about a 6 mm section of a corm and 15 to 30 cm of petiole. Propagules were planted in pots on June 26 and remained in a building until July 2 when they were planted in a 6 x 1.2 m tank such that there were 2 rows with 60 cm spacing between plants within the rows. All of the plants were growing by July 10. Harvesting of the leaves began after the plants were about 60 cm tall and the modified arrow or heart-shaped leaves became 25-40 cm long. Then, starting with the fourth fully emerged leaf, every other leaf was harvested. The entire plants were harvested on October 31, 2007. The petiole of the mother plant was cut 3 cm above the corm-petiole intersection. Roots and any extraneous petiole tissue were removed from the corm. Data collected include plant height, number and fresh weight of frost damaged leaves, number and fresh weight of edible leaves and petioles from the mother plants and daughter plants (keiki plants), fresh weight of inedible foliage, fresh weight of corms, number and fresh weight of daughter plants. Edible leaves were defined as being at least 25 cm long and nearly blemish-free. There were 13 fertilizer applications such that 237 grams of nitrogen plus the accompanying nutrients were applied.

Results and Discussion

The harvest date decision was made by Mother Nature. On the early morning of October 29, 2007, the ambient temperature reached -5.5°C causing the unheated high tunnel temperature to plunge below -1°C. Visible frost damage was observed on the leaves of both ginger and taro, but no damage was evident to the root portions of the crops.

Edible ginger.

Harvest data from ginger grown in sub-irrigated 11 cm pots of growing medium are shown in Table 1.

Table 1. Shoot number, tallest shoot height, shoot fresh weight and rhizome fresh weight immediately after harvesting and after air drying for 4 days from edible ginger grown in sub-irrigated 11-cm pots of peat-perlite growing medium[z].

Parameter	Average[y]	Range	Standard Error	CV(%)[x]
Shoots				
Number	19	4-28	1.4	33.4
Tallest height (cm)	77	69-89	1.4	7.9
Fresh weight (g)	636	182-999	41.3	29.1
Rhizomes				

Harvest weight (g)	1401	318-2179	100.0	31.9
Air dry for 4 days (g)	1056	231-1625	79.9	32.1

[z] Planted – May 14; Transplanted – July 2; Harvested – October 29, 2007
[y] From 20 plants.
[x] Coefficient of variability

There was an average of 19 shoots from each pot which originated from a 50 gram seed piece. One plant had only 4 shoots and another plant had 9 shoots and these 2 plants also had the lowest fresh shoot and rhizome weights. This greatly increased the coefficient of variability (CV) for the experiment. The fresh harvest weight included a 5 cm height of shoots above the surface of the growing medium, because trimming the shoots stimulates a natural abscission zone between the rhizome and pseudostem (7). Cutting the shoot at the rhizome junction might have increased the entry of disease organisms into the rhizome. An abscission zone was developing after 4 days of air-drying. In a tropical environment, ginger would normally be harvested in December through February after the leaves turn yellow and dry down and the stems fall over (7). Since this ginger was harvested early, it was somewhat immature and the epidermis was still fragile requiring careful handling when harvesting and washing. Ginger which had air dried for 4 days averaged 1056 grams per pot. Both the interior flesh and the epidermis were lighter colored than the mother seed piece, but there was fiber development in the interior flesh. There was pungency with a distinctive ginger flavor and the rhizomes were marketable as fresh ginger. It was not clear if the ginger maturity stage and shelf life will allow good quality seed pieces for next year's crop.

Harvest data from ginger grown in a 25 cm deep bed of peat-perlite are shown in Table 2. This experiment was planted one month later than the previous experiment. The shorter growing season resulted in less shoots, shorter shoots and a lower harvest weight than ginger in the previous experiment. However, it is not possible to determine if crop performance was affected by the 2 different growing methods. This ginger had a low fiber texture and might be classified as baby ginger which may be used for pickling (7). Both the interior flesh and the epidermis were lighter colored than the mother seed piece, but there was a distinctive ginger flavor. The epidermis was more fragile than rhizomes from the previous experiment. It would not be recommended to save this ginger for next year's seed.

Table 2. Shoot number, tallest shoot length, shoot fresh weight and rhizome fresh weight immediately after harvesting and after air drying for 3 days from edible ginger grown in a 25 cm deep bed of peat-perlite growing medium[z].

Parameter	Average [y]	Range	Standard Error	CV(%)[x]
Shoots				
Number	11	5-18	1.2	39.4
Tallest height (cm)	48	38-58	3.8	29.8
Fresh weight (g)	256	91-409	26.3	38.5
Rhizomes				
Harvest weight (g)	564	272-863	54.8	36.4
Air dry for 3 days (g)	407	214-645	39.4	36.2

[z] Planted June 14 and harvested on October 30, 2007.
[y] From 14 plants.
[x] Coefficient of variability

These experiments demonstrate that ginger can produce a salable crop in a temperate location high tunnel, but the yields were much lower than those harvested in Hawaii (5, 6). It is being suggested that ginger should be planted in growing medium in a heated greenhouse at about April 1 and the sprouting plants be transferred to the tanks or beds in an unheated high tunnel about May 15 to May 30. This would add another 44 days of growing season to the conditions of the first experiment. Increasing the growing season should greatly increase the yield potential of ginger in Pennsylvania. Certainly, baby ginger is a candidate as a specialty crop for high tunnels. Although, it may not be possible to obtain equivalent mature ginger yields as from a tropical region, there remains potential for ginger to be a profitable niche market crop, especially if the growing season can be extended by several months in high tunnels.

Taro

Harvest data from taro grown in sub-irrigated 11-cm pots of growing medium are shown in Table 3.

Table 3. Plant height, number and fresh weight of frost damaged leaves, number and fresh weight of edible leaves and petioles from mother and daughter plants, fresh weight of inedible foliage from mother plants, fresh weight of corms, number and fresh weight of daughter plants of taro plants grown in sub-irrigated 11-liter pots with peat-perlite growing medium[z].

Parameter	Average[y]	Range	Standard Error	CV (%)[x]
Plant height (cm)	86.4	66-104	3.0	13.9
Frost damaged leaves				
Number/plant	5.4	1-13	0.9	63.0
Fresh wt/plant (g)	223.1	50-532	33.2	59.5
Edible leaves from mother plant				
Number/plant	4.6	4-6	0.2	19.1
Leaf blades/plant (g)	190.9	84-347	17.0	35.6
Petioles/plant (g)	117.0	37-243	12.9	44.2
Edible leaves from daughter plants				
Number/plant	6.3	0-13	1.2	75.6
Leaf blades/plant (g)	88.1	0-194	17.3	78.6
Petioles/plant (g)	80.3	0-194	16.2	80.8
Inedible foliage from mother plant (g)	978.6	499-1712	86.4	35.3
Corm trimmed weight/plant (g)	228.5	96-405	23.5	41.1
Daughter plants per mother plant				
Number[w]	7.4	5-9	0.4	17.9
Fresh weight (g)[wv]	1444.5	579-2257	140.0	34.9

[z] Planted June 26 and harvested on October 31, 2007.
[y] From 16 mother plants.
[x] Coefficient of variability.
[w] From 13 mother plants.
[v] Does not include fresh weight from edible leaves.

At about 2 months after planting, 3 plants appeared to have a bacterial infection and eventually died, but a total of 16 healthy daughter plants appeared unaffected from the 3 diseased mother plants. These plants were excluded from Table 3 data. At one point, taro was subjected to an aphid infestation, but this was corrected with an insecticide application. An active IPM program is recommended for taro production.

Plant height averaged 86.4 cm. An average of 5.4 leaves per plant suffered frost damage. These were mostly upper leaves which would have otherwise been edible. The total edible leaf production from mother and daughter plants was about 476 grams per plant. The frost damage loss represents about 32 per cent of the total edible leaf production which could have been saved by harvesting the day before the freezing temperatures. The trimmed weight of edible corms averaged 228.5 grams per mother plant. Taro normally requires a growing season of 6 to 10 months for optimum corm production and this crop was only about 4 months old at harvest time. Premature termination of the crop may have contributed to high CV values. Taro growers specializing in corm production would not harvest leaves, because this would depress corm yields and consumers indicate the starch content of the corm decreases. This experiment demonstrates that taro can produce a salable crop in a temperate location high tunnel, but the yields were much lower than are normally harvested in Hawaii (11). It is being suggested that taro should be planted at about May 1 in an unheated high tunnel. This would add another 57 days of growing season during long daylength hours and should greatly increase the yield potential of taro in Pennsylvania. There was an average of 7.4 daughter plants per mother plant which can serve as propagules for a future crop. Experiments will be conducted to determine how long these plants may be stored and remain viable.

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