Winter Raspberry Production in Greenhouses

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SUMMARY. Floricane-fruiting (summer-bearing) raspberries (*Rubus idaeus* L.) were grown outdoors in pots in upstate New York until mid-December when the chilling requirement was fulfilled. They were moved into a greenhouse and placed at a density that is three times higher than field planting. Bumble bees (*Bombus impatiens* Cresson) were introduced at flowering for pollination. Fruiting occurred from mid-February through mid-April, a time when the retail price for raspberries is between $3.00 and $6.00 for a half pint (180 g). Fruit quality was high, and individual 2-year-old plants averaged 11 half pints (2 kg) of marketable fruit. These yields and retail prices are equivalent to 19,000 lb and $142,000 per acre (21 t, $350,000 per ha). Raspberry production during winter allows growers to dramatically extend the harvest season and to produce a high-value crop at a time when greenhouses often are empty.

In North America, greenhouse production of edible products has been limited primarily to tomatoes, cucumbers, greens, and herbs, while food retailers have relied on imports to supply fruit during the off season. In many cases, the quality of this imported fruit is poor. We have been exploring the possibility of producing various fruit crops year-round for local markets to meet consumer demand for consistently flavorful fruit harvested when fully ripe.

Raspberries are uniquely suited for year-round production. The two growth habits allow for field production in the summer (floricane-fruiting types: bearing fruit only on second-year canes from late June through early August) and early fall (primocane-fruiting types: bearing fruit on first-year canes in late August and September). However, potted primocane-fruiting types fruit in late fall and early winter if plants are held in cold storage until early July, and floricane-fruiting types can produce during late winter and early spring if potted plants are brought into a greenhouse after their chilling requirement is fulfilled in early winter. This paper describes one method used successfully to produce raspberries during February through April in New York.

Raspberries are a high value crop that retail for $3.00 to $6.00 per half pint (180 g) during the winter and early spring throughout North America. No domestic sources of winter raspberries exist, except a few producers in a small region in southern California along the coast.

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Most winter raspberries are flown in from the southern hemisphere. Quality is often poor because raspberries have an extremely short postharvest life and bruise easily during shipping.

In the northeastern United States, many greenhouses are empty during the winter. These greenhouses could be used to grow high-quality raspberries with only moderate inputs, providing greenhouse owners with an opportunity to produce an extremely high-value crop during a time of the year when they are realizing no return on their capital investment. In our first attempt at growing greenhouse raspberries, we obtained the equivalent of $2,000 to $4,000 (660 half pints) of exceptionally high-quality fruit from 100 ft (30 m) of row (60 two-year-old plants of 'Chilliwack') in a 20 × 30-ft (6 × 9-m) house between mid-February and mid-April. This is >17,500 lb / acre (20 $t \cdot ha^{-1}$), about four times more than what growers obtain from field production in the northeastern United States. In addition, by holding dormant raspberry plants in cold storage during the winter and bringing them into the greenhouse at staggered intervals, they can be made to ripen for several months before and up to the normal raspberry season, dramatically extending the season of availability.

Raspberries appear to be uniquely suited to winter greenhouse production. Raspberry plants can produce a crop under low light, and the maximum photosynthetic rate occurs at relatively cool temperatures (Fernandez and Pritts, 1994). Off-season raspberry production has been attempted in mild growing areas of Europe where primocane-fruiting types are mowed in spring to delay fruiting into autumn (Oliveira et al., 1996), and Europeans are beginning to explore winter production of floricane-fruiting types in greenhouses (Dijkstra and Scholtens, 1993). However, commercial enterprises are only now beginning to develop.

Raspberry flowers require pollination to set fruit, so a successful greenhouse production system must ensure adequate pollination. Bumble bee hives are now commercially available, and bumble bees appear to be superior pollinators to honey bees in the greenhouse. In addition, biological control agents have been developed recently to manage greenhouse pests, making pesticide sprays unnecessary and allowing the bumble bee pollinators to thrive. Several factors are now in place that can make winter raspberry production successful: high prices for fruit, empty greenhouses throughout the continent during winter, domesticated bumble bees, and effective biological control. In addition, with deregulation of electric power, costs for heating and lighting should decrease while the cost of fuel for transportation is likely to rise. These changing economic conditions are favorable for local off-season and year-round fruit and vegetable production.

Procedure

We planted several cultivars of summer-bearing (floricane-fruiting) tissue-cultured raspberry plugs into 1-gal (3.8-L) pots filled with equal parts sand, peat, perlite, and vermiculite in May, allowed them to grow outdoors on a gravel bed with irrigation until late December, then brought them into the greenhouse. While outdoors, plants were fertilized weekly with a mixture of a soluble fertilizer (Peter's Hydrosol, 5–11–26), ammonium nitrate and calcium nitrate to obtain 100 ppm N, and pest outbreaks were managed using conventional practices. Once in the greenhouse, canes were trellised and watered with the same fertilizer solution. Household fans were used to circulate air down the rows to reduce pockets of high humidity and the subsequent risk of fungal infection. Temperatures were maintained between 55 to 65 °F (13 to 18 °C). Supplemental light was provided to first-year plants during off-peak hours [2200 to 0600 HR, 150 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of photosynthetically active radiation (PAR)].

Six to eight weeks after plants were moved into the greenhouse, they flowered. Bumble bees were used to pollinate the flowers, and fruiting began in late February, ≈10 weeks after moving the plants indoors. Primocanes were removed at regular intervals during the fruiting period.

With the 1-year-old plants, we used double rows [with row centers 5 ft (1.5 m) apart] and a pot-to-pot spacing so that 70 plants were contained in each 26 ft (8 m) length of row. Each plant produced ≈1 pint (350 g) of fruit.

We removed all of the canes after harvest, and transplanted into 7-gal (26.5-L) pots for the second year. Plants were placed outside for the growing season after harvest in April, and they were returned to the greenhouse in mid-December after the chilling requirement had been fulfilled. Rapidly satisfying the chilling requirement is one advantage that northern growers have over more southern producers. Outdoors, plants were watered regularly and fertilized once a week with a soluble fertilizer solution (100 ppm N). Canes were held upright with trellises as they grew and were exposed to full sun.

In the second year in the greenhouse, we spaced plants 22 inches (55 cm) apart in the row (single rows), with 5.5 ft (1.7 m) between rows. This density is three times that of standard field plantings. During 1997, we examined the performance of several varieties and evaluated two trellis configurations (an I and V trellis) and three light levels (ambient PAR ranging from 1 to 10, a constant 7.5 and a constant 15 $mol \cdot m^{-2} \cdot d^{-1}$) in the 2-year-old plants. Light levels were measured 6.5 ft (2 m) above the floor, and supplemental light was provided when required to meet the predetermined level of 7.5 or 15 $mol \cdot m^{-2} \cdot d^{-1}$. (On a cloudy January day, PAR can be <1 $mol \cdot m^{-2} \cdot d^{-1}$; on a sunny day in July, PAR can be >30 $mol \cdot m^{-2} \cdot d^{-1}$). Bumble bees were again used for pollination.

Cultivar performance

We fruited a number of cultivars over the 2-year period. Furthermore, we invited chefs and produce buyers to a blind tasting, where our fruit was compared with 'Heritage' purchased from two local supermarkets. The cultivar with the most desirable flavor was 'Tulameen', followed by 'Canby', 'Encore', and 'Chilliwack'. Other cultivars with acceptable flavor included 'Malahat', 'Qualicum', and 'Lauren'. 'Titan' also produced flavorful and extremely large fruit. Early in the season, 'Titan' fruit size averaged 6 g (some berries were 12 g) and fell to 3 g over the 8-week harvest period. 'Chilliwack' produced an average of 11 half-pints (2 kg) of fruit per plant between 18 Feb. and 18 Apr. Fruit flavor was very good, although the size was smaller than with some of the other cultivars, and the color was darker. Of all the red raspberry cultivars that we evaluated, 'Tulameen' was rated as having the highest quality, while the supermarket entries ranked lowest.

'Jewel' black raspberry also produced excellent large fruit, but yields were ≈70% lower than those of the red raspberries because the harvest season was much shorter (6 vs. 9 weeks).

Compared to field production, the greenhouse-produced berries were larger, firmer, and much less prone to fruit rot. Only 6% of the greenhouse berries were crumbly or otherwise unmarketable, whereas the percentage of field-grown berries that are unmarketable is usually much higher. Fruit tended to be slightly less sweet and more acid in the greenhouse, but well within the limits of acceptability. Only 'Royalty' purple raspberry and 'Autumn Bliss' and 'Heritage' red raspberry (floricane crop) did not produce fruit of acceptable flavor.

We suspect that 'Titan' has a longer chilling requirement than 'Tulameen' or 'Chilliwack', because only the top third of the canes produced flowering laterals. 'Titan' likely needs to be chilled beyond mid-December in our climate. If plants are to be kept outdoors later than mid-December in New York, then the pots must be protected from the cold weather. Otherwise, plants can be brought into a cooler in early December and the rest of their chilling requirement can be fulfilled there.

Primocane management

After harvest, we removed all canes and set the plants outside in late April. However, certain varieties failed to regrow primocanes until very late in summer, including 'Tulameen', 'Chilliwack', and 'Encore'—our most productive varieties. We believe this may have been due to the large amount of crop that we produced in conjunction with primocane removal to facilitate harvest, depleting the carbohydrate reserves. Fernandez and Pritts (1993, 1994) have shown that primocanes are the primary source for root carbohydrate, so it is not surprising that continual primocane removal will deplete reserves. In the future, we will retain some of the primocanes during the fruiting season so they can replenish root reserves. If we do this, plants will have to be kept in the greenhouse until the danger of heavy frost is over in spring so primocanes are not injured.

Light levels

Supplemental lighting had no effect on either fruit size or number of 'Titan' or 'Jewel' under our specific conditions. Plants grown under ambient light produced the same yields as plants grown under 15 $mol \cdot m^{-2} \cdot d^{-1}$, although fruiting under the ambient light level was delayed for 2 to 3 weeks. Fruiting laterals under low light conditions also tended to be quite long and would frequently break under the heavy fruit loads. However, quality (determined by flavor ratings and soluble solids measurements) was not different among light levels. The ability of raspberry plants to rely on stored carbohydrates to produce a crop under low light was documented in a previous study (Fernandez and Pritts, 1996).

Trellis configuration (I vs. V) also had little effect on yield, although it was more difficult to harvest V-trellised plants, as they required a greater amount of space. Therefore, we will use a standard I configuration in future studies.

Pests

We regularly released *Amblyseius cucumeris* Oudemans to control thrips, lacewing larvae and *Aphidoletes aphidimyza* Rondani midge for aphids, and *Phytoseiulus persimilis* Athias-Henriot for mites. Our major pest problem was two-spotted spider mites (*Tetranychus urticae* Koch), which occurred in one house during the last 2 weeks of harvest. We hypothesize that a lower night temperature will reduce mite pressure.

Economics

At our orchard store, we sold raspberries for $3.00 per half pint without consumer resistance, and the gross return per area [about $2.80 to $3.70 / ft^2 ($30.00 to $40.00 / m^2) for the 4-month period] was similar to the return that local growers typically receive from bedding plants. One bedding plant grower in the area is now producing raspberries to coincide with bedding plant season to increase customer purchases during April and May.

Raspberries are well suited to greenhouse production, and the economics appear to be favorable. We will learn much over the next few years as growers and researchers begin to experiment with this novel production system.

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