

# Greenhouse Raspberry Production Guide



**For winter or year around production**

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## About this Guide

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## Photo Credits

The photographs used in this publication are gathered from various Cornell University faculty, staff and students, the American Phytopathological Society's *Compendium of Raspberry and Blackberry Diseases and Insects*, and the *Fruit Growers News*. Sincere appreciation is expressed for the use of the photographs.

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## Introduction

At Cornell University in Ithaca, New York, researchers have been working on a production system for producing high quality, premium raspberries for the off-season market. In the Northeast, greenhouse growers often have crops that will take them from the late spring season with bedding plants, all the way through the early winter months with poinsettias. After the greenhouses are emptied in December, these greenhouses may sit empty until spring when bedding plants are once again started. With winter raspberry production, a grower is able to keep their greenhouse in production, thus capitalizing on a time when fresh raspberry fruit is lacking locally, and also providing further profit for themselves and their families during a period that otherwise would be a downtime for the greenhouses. With the use of fall bearing raspberries, different cultivars, and storage



coolers, year around production of raspberries is possible in the greenhouse as well. Over the past several years, many growers in locations all across the country have started a greenhouse raspberry operation.

Field production of raspberries has certain considerations for management of plants and pests that differ from winter production, but many aspects of the production methods are similar. Both production approaches will be discussed in this production guide.

Fresh, high quality raspberries are not readily available in the United States in winter because no significant domestic production system has been developed. Rasp-berries available in

grocery stores during the winter months are mostly grown in Mexico, Central and Southern



America. The raspberries that finally arrive are very expensive and often of poor quality due to very delicate fruit that is shipped long distances. Fruit quality begins to degrade quickly after harvest and is often damaged in the shipping process. The fruit available in the grocery stores are often well into the process of decomposition and may be moldy. The fruit industry has tried to avoid this problem by harvesting the raspberries before they are completely ripe. Even though this will help to preserve the physical appearance of the fruit for display, the fruit is often lacking in flavor and the sugar content is extremely low because the ripening process is brought to a halt when the fruit is picked. The flavor quality of the fruit will not improve once the fruit has been picked.

## Characteristics of greenhouse production of raspberries:

- The grower is able to provide the consumer with a high quality fruit year around that will both look good and offer excellent flavor.
- Compared to field production, greenhouse-produced berries are larger, firmer and much less prone to fruit rot.
- The grower is able to achieve a high level of quality because the fruit never becomes wet from rain or irrigation and thus greatly reduces the instance of fruit rotting infections, and the fruit can be harvested at the peak of ripeness for optimum flavor.
- The storage and shelf life of greenhouse

raspberries under refrigeration is greatly increased because the fruit has been kept dry, and therefore, fruit rotting infections are much reduced.

- Fruit tends to be slightly less sweet and more acid in the greenhouse, but well within the limits of acceptability.
- Varieties differ in performance and flavor; varieties that do well in the field will not necessarily perform well in the greenhouse.
- Consumers are willing to pay between \$3.00 and \$6.00 per half-pint for fresh fruit of superior quality, and restaurant chefs seem willing to pay even more.

This production guide is intended as a comprehensive resource for both the novice and experienced grower to attain a successful and profitable enterprise of growing fresh, high quality raspberries for the off-season market. Included is information on greenhouse preparation, plant selection, planting, insect and disease control, nutrient and moisture management, harvest, economics, and marketing. A glossary, a list of supplementary materials, and general references are located at the end of the book.

## Biology of the Cultivated Raspberry

Cultivated raspberries are of two basic types: primocane and floricanes fruiting. The primocane fruiting types produce fruit on the cane tips on the first year's growth, and a smaller crop lower down the cane in the second year. After the second year's crop, the canes will die and can be removed, as new canes will continue to grow from the perennial root system. Floricanes fruiting types produce fruit on the lateral branches that emerge from axillary buds on a second year cane. The cane will grow the first season (primocane), go through a winter dormancy period, and after the dormancy requirement has been fulfilled, the lateral buds will break and produce flowers that when pollinated will produce fruit. Similar to the primocane fruiting types, after the floricanes fruiting types have produced their crop, the canes will die and can be removed to make

room for the new canes arising from the root system.

The canes typically exhibit an S-shaped growth curve, but this can be modified by the environment. First year canes grow rapidly after dormancy, but during hot conditions extension growth slows. If adequate moisture is supplied, elongation can increase. Nodes on first-year canes form at a constant rate over time, and the variation in the growth rate of the cane leads to variation in internode length along the cane. The cane typically has short internodes at the base and tip, with long internodes in its mid-region.

Flower-bud initiation usually occurs under short days and cool temperatures, but with some varieties, initiation will occur once the cane reaches a certain height regardless of day length. If initiation occurs before the first year canes stop growing, the primocane fruiting trait occurs.

Fruiting lateral branches (laterals) elongate rapidly after bud break, and continue to extend until the terminal fruits begin to form. The flower buds on the laterals may or may not develop into fruit depending on cane vigor and weather conditions in the fall during flower bud initiation. A vigorous cane and a mild fall results in more flowers per bud (node) and more nodes with flowers. Thirty or more flowers may be produced on a single flowering lateral. Most buds that reach a diameter of 2 mm continue to develop, set and mature fruit. Insect pollination is essential for good fruit set. In the absence of pollinators, 80% lower drupelet set can occur. Raspberry flowers produce copious quantities of nectar which attract pollinators. The stigmas in the flower buds remain receptive for only about six days, so it is important to have the pollinators available in time to set the fruit.

The structure of the fully developed fruiting lateral varies depending on its position on the cane. On untipped fruiting canes (canes that have not been pinched or trimmed back to a given height), the laterals at the tip are

short, have few nodes and bear a low yield of small fruits. They become progressively more vigorous with higher yields over the middle two-thirds of the cane, although yield of the bottom laterals on the cane is decreased. Yields may be greatest in the mid-section or in the top section of a tipped cane, depending on the cane height. Short canes with many nodes tend to have high yields on the laterals in the mid-region, whereas tall canes with few laterals and long internodes tend to produce high yields at the top of the cane. Increased cane diameter has been associated with increased yield. However, fruit numbers differ only slightly between thin and thick canes after they have been tipped. Thicker canes generally have more berries per lateral but fewer laterals per cane than thinner canes. Thicker canes tend to be taller, and tend to take longer to break dormancy than thinner canes.

Fruits take between 30 and 45 days to develop from flowering, depending on the cultivar and the environment. Most of the increase in fresh weight takes place in the last 7-10 days of development. When the fruit becomes over-ripe, some of the weight is lost. The yield of fruit increases rapidly during the first few harvests to a peak, and then declines fairly slowly although the size of the peak and rate of decline varies with cultivar. Individual fruit weight remains fairly constant through the major part of the season and then drops towards the end.

## Choosing a Production Type of Raspberry

There are advantages and disadvantages for both primocane and floricane raspberries in the greenhouse. Some producers use a mixture of both types.

### **Primocane-fruiting**

#### *Advantages*

- long harvest season from the same plant
- less movement into and out of the greenhouse
- shorter time from transplanting to first full

harvest

- simple trellis is required

#### *Disadvantages*

- mites and other pests build up during the long harvest season
- yield per plant is low
- bees must be active for months at a time

### **Floricane-fruiting**

#### *Advantages*

- short harvest season with high yields
- easy to schedule production cycles
- pests easier to control
- only one bee hive required per harvest
- superior flavor and size

#### *Disadvantages*

- requires extensive manipulation of plants and canes
- may be two years before full harvest is realized
- significant chilling is required to break dormancy
- plants require trellising
- larger plants take up more space

## Preparing the Greenhouse Environment

A greenhouse with a heat source will be required for maintaining warm temperatures of up to 70°F (20°C) inside while the weather is cold outside. Coolers and venting may be necessary for late spring production. Other materials needed include a clean water source with low salinity, a fertilizer injector, an irrigation system, growing media and 3 gal (13 L) containers. Other supplies that are optional include growing lights, a weed barrier for the greenhouse floor to suppress weeds and keep the plant containers from directly contacting the earth, and temperature and humidity gauges. Humidity levels will vary when the greenhouse floor is gravel vs. when the floor is concrete. Concrete floors tend to absorb moisture much more and therefore may need to be sprayed with water during the day in order to maintain sufficient humidity. The target range for the relative humidity is between 65-75%. To

maximize light levels, reflective white plastic sheeting can be laid on the ground.

The greenhouse can be an excellent environment for pests and disease organisms to thrive. The greenhouse must be thoroughly cleaned before any raspberries are moved in. Remove any plant debris. In the summer, temperatures greater than 104°F (40°C) and less than 50% RH (relative humidity) for 3-4 days in a greenhouse that is completely void of plants (weeds, “pet” plants, unsold plants, stock plants, etc.) will eradicate many insects.

## Plant Container Spacing

Measure the available greenhouse space to determine how many 3 gal (13 L) containers can fit pot-to-pot in rows with a minimum of 5.5 to 6 ft (1.6 to 1.8 m) between rows. Remember to leave about 3 ft (1 m) to access both sides of the outside rows so the fruit can be harvested. Estimate how many containers will be needed, and decide how many extras are desired for replacements in case a few plants in the rows do not survive.

## Plant Selection

Obtaining high quality, virus-indexed planting stock is an important step in developing a successful bramble



A typical Tulameen raspberry fruit

operation; poor plant material guarantees a poor planting. Plants should be ordered from a reputable source, preferably a nursery that sells plants from “certified” virus-free stock. Virus-free plants have the best growth and productivity and will generally live longer. Field-grown nursery stock has a greater chance of being infected with disease, such as crown gall or *Verticillium* wilt, than greenhouse stock straight from tissue culture.

For reasons not yet understood, cultivars that are proven to be reliable producers of high quality fruit in the field do not necessarily

perform similarly in the greenhouse. Some varieties that have performed well include:

‘Autumn Bliss’, ‘Autumn Britten’, ‘Cascade Delight’, ‘Chilliwack’, ‘Encore’, ‘Titan’ and ‘Tulameen’. In side by side tests, ‘Tulameen’ has proven to be an



outstanding variety that consistently produces a high quality raspberry in the greenhouse and also has fewer insect and pathogen pests.

## Plant Types: Tissue Culture Plants

Tissue culture plugs provide the grower with a consistent stand of plants as well as certified virus-free plant material. Tissue culture plugs are grown under very strict propagation conditions of sanitation. The tissue culture plugs are grown under protocol of aseptic conditions so as to be able to offer virus-free material free of insect pests and soil borne pests and pathogens. The plantlets are all identical clones



A tissue culture plug

of the same mother plant. Therefore, all plantlets will be nearly identical in performance and will fruit at approximately the same time. Tissue culture plants are grown for one season and fruit in the second season, with the largest

crop in the third season. This means there will be no fruit to harvest and sell until the second year of production. Tissue culture plugs should be ordered only from a certified plant propagation nursery to ensure the quality of plant materials. To ensure an order is available to be shipped in full, contact the certified nursery six months to a year in advance of when planting is expected to begin.

Growth of tissue-cultured plugs is more uniform and vigorous than traditional plant material. When planting, the top of the root ball should be covered with soil media to a depth of  $\frac{3}{4}$  in (1.9 cm). Media should be pressed to ensure good contact with the root ball. Tissue-cultured plants have never been exposed to the outdoors, and have shallow root systems that are sensitive to drought. They are also susceptible to frost damage. The containers should be irrigated immediately after transplanting. The containers can be placed outdoors for the plants to grow during the first season if danger of frost is past.

## Nursery Mature or Dormant Short Canes/Bare Root

Dormant short canes are rooted canes or “handles” with one season of growth that were dug after becoming dormant in the fall. The canes are tipped, or cut, leaving 12 to 18 inches (30.5 to 46 cm) of cane above the roots. The resulting shape looks like a “handle” and gives rise to the term used. The dormant cuttings are stored until spring shipping. This is the conventional transplant type for raspberries.

The use of dormant short canes may require the use of a larger growing container as the attached root mass may be too large to fit into a 3 gal (13 L) container without becoming damaged. All of the plant’s energy is stored in the roots, so it is best to retain as much of the root mass as possible and minimize damage. An advantage of the dormant short canes is that they are not sensitive to frost in the spring, so they can be potted up and set outside with no worries. It is imperative that

the roots are not allowed to dry out prior to transplanting. Soaking the roots in a bucket of water just before and during planting will assist in rehydrating the roots, and give the roots a little head start in moisture absorption. The canes will break bud and grow when outdoor temperatures are typically past the time frame of spring frosts, and any new growth that may be subjected to a spring frost will be hardy to the cold temperatures. A disadvantage of using dormant short canes is that the canes have spent a season in field conditions that may or may not have introduced insect and/or disease pests to the plant. It is impossible to guarantee that the dormant short canes will be 100% pest free, so close observation of the plants should occur to monitor for any indications of pest problems.

## Dormant Long Canes

An alternative to using tissue culture plugs is field-grown, dormant, dug long canes. These plants have already grown their first year in the field, and since their chilling requirement has been fulfilled, will be ready to fruit after transplanting. One advantage of dormant long canes is that there will be fruit to harvest in the current season when transplanting, which allows the grower to have limited production in the first season. The long cane will be putting energy into replacing the roots that were lost when it was dug and removed from the growing bed at the nursery. This energy requirement for root replacement will take away some energy resources that would otherwise be available for fruit production. In the second fruiting season, the amount of energy available for fruit production will return to normal and yields will be larger.

It is crucial to slowly warm the greenhouse after transplanting dormant long canes. When they were dug from the field, the dormant long canes lost a great deal of their root system that supports water and nutrient intake, as well as serving as the cane’s energy storage tissue. The cane will need time to re-grow some of the root system to sufficiently support the growth

and eventual fruiting that will take place. If the greenhouse is warmed too rapidly, the buds will break and the growth that occurs will be too demanding for the amount of root system present. It is likely that there will be death of the new tissue and if the canes did fruit, the root system may not be able to continue to support the demands put upon them and cause premature death. To avoid this scenario, bring the dormant long canes in to the greenhouse and maintain the temperature at 50°F (10°C) both day and night for 3-4 days. Afterwards, gradually warm the greenhouse a couple of degrees every 3-4 days so it will be a couple of weeks before maintaining the temperature at night at 55°F (13°C) and 72°F (21°C) during the day. This gradual warming of the greenhouse will be less shocking to the cane's system and allow its root system to re-grow enough to support the new growth and fruiting.

When using dug canes, it is possible to bring into the greenhouse insects and pathogens that are already in or on the canes or their roots. No matter how clean the plants and roots are, it is impossible to guarantee 100% pest free plants. This possibility of pest introduction requires extra vigilance by the grower to observe the plants for any signs of pest problems. Some growers may choose to apply a soil drench of an approved insecticide or fungicide for preventative measures. With field dug canes, a consistent stand of plants may not be as likely as with tissue culture plants. Field dug canes can vary in their growth rate, in when they fulfill and break dormancy, and the time of harvest. Depending on the

distance from the nursery from which the dug canes are purchased, the shipping costs for sending a box of dug canes can be a large expense.

## Establishing Container Raspberry Plants

When establishing a new planting of container-grown raspberry plants, it is important to use a well-drained potting media rich in organic matter and with sufficient soil pH and nutrients. Raspberries grow best in media with a pH between 5.5 and 6.5. Most raspberries will not



An example of 1, 3, 5, and 7 gallon containers

grow well in media with a pH below 5.5, and iron deficiency may occur in soils with a pH above 7.0. Raspberries must receive adequate moisture during the first few weeks after planting. The containerized plants can be grown outdoors during the first growing season, so it is important to have an available water source near the plants so they will not dry out at any time.

• **Container and Potting Medium Selection**  
Many options are available for growing potted plants. Some growers use 3, 5 or 7 gallon (13,

22 or 31 L) containers, while some growers may use grow bags and insert the raspberry plants directly into a slit in a bag of peat. A three gallon container is recommended as it provides sufficient room for root and primocane growth, and it will also be easier for the grower to move in and out of the greenhouse as the container and its contents will weigh less than the larger containers and contents.

As with other greenhouse crops, the growing media chosen will depend on personal choice as well as research recommendations. What works for one grower, may not be the media of choice for another grower. One recipe that Cornell used was a soil-less mix containing 2 bu (70.5 L) peat, 2 bu (70.5 L) vermiculite, and 1 bu (35.25 L) sand. The sand was included to add weight to keep the containers from tipping over too easily. For the total 4 bu (141 L) media mixture, micronutrients were added including: 411 g of lime, 82 g of triple super phosphate, 82 g of calcium nitrate, and 124 g of Micromax trace elements. All the previously mentioned ingredients are thoroughly mixed and used as the growing medium for the tissue culture plugs. Other commercially available, premixed media such as Metromix and ProMix also have been used successfully. Out of one batch of the media mixture, 15-20 3 gal (13 L) containers should be able to be filled 2/3 full.

## First Season Care and Management

### • Location and Spacing

The plants can be potted up and placed outside to grow the first season. Pest management is usually easier to apply outdoors in comparison to a greenhouse. Place the plants in full sun, out of the wind and on a growing bed with a weed barrier and automated drip irrigation. A north-south orientation is preferred for better light interception. If possible, locate the growing bed in a location near the greenhouse to minimize

the distance for handling the containers when it comes time to move the plants into the greenhouse. This will minimize damage to the plants as well as the stress on the handler's back. The growing bed should be located away from sources of insect and disease populations as on nearby apple trees, hedgerows, Taxus shrubs and areas containing many weeds that may disperse weed seeds into the containers.

Sufficient spacing between the rows of at least 8 to 10 ft (2.5 to 3.0 m) should be allowed for maximum sun exposure on the lower portions of the canes. If the plants are too close together, the lower buds will not produce fruiting laterals once they are moved into the greenhouse. As the primocanes grow during that first season outdoors, support stakes will be necessary to keep the canes upright in the wind. This upright stability can be achieved through relatively simple measures such as using strategically located bamboo stakes and a series of twine support lines run between the support stakes.

### • Pest Control

During the first growing season outdoors, insects and diseases should be minimal, but weekly scouting should occur, especially to monitor for Japanese beetles and for raspberry sawfly larvae. Other pests to watch for include spider mites, aphids, cane borers, tree crickets and root weevils. These and other pests are



Containers on a gravel bed during the summer

described in more detail in the insect and disease pest section. Detailed life cycles of insect pests can be found in the *Bramble Production Guide* (Pritts & Handley, 1988). Conventional pest control measures can be utilized.

Monitor the containers on a weekly basis and remove any weeds that may have started to grow in the containers. Weeds growing in the containers will be a source of competition for nutrients and moisture with the raspberry plants, as well as a possible attractant for insects and disease. Keep the containers away from, or completely remove all *Taxus* (yew) shrubs, as they are a source of food and breeding for the black vine weevil, a pest that will come into the greenhouse inside the containers.

• **Moisture and Fertilization Requirements**

The containers should be carefully monitored so they do not completely dry out in the sunny, warm months of summer. Newly potted or transplanted raspberry plants are very sensitive to drying out. During hot, sunny, and/or windy days, the containers may need to be watered more than once a day. The plants should be fertilized with a complete soluble fertilizer solution containing 100 ppm N, either in the irrigation water or at least once a week, while the plants are growing outdoors. This fertilizer solution can be applied via an injector system hooked up to the drip irrigation system or a siphon attachment available through most nursery suppliers.

**Late Season Care**

As autumn begins, cut back on watering and fertilizing the plants to reduce succulent growth that will be more likely damaged



Moving containers in and out of the greenhouse is physically strenuous



Straw bales insulating containers from cold autumn temperatures

by cold weather. Do not allow the containers to completely dry out, but as the temperatures begin to decrease in the autumn, the containers will not require much watering. In October after leaf drop, move the pots closer together and surround them with bales of straw to protect from cold temperatures. Root systems are more sensitive to cold temperatures than canes, and temperatures below 20°F (-6°C) for an extended period of time will kill roots, and then some canes, in pots that are setting on top of the ground. In late December, move all of the containers into the greenhouse. Plants may have to be moved earlier if temperatures are forecast to fall below 20°F (-6°C) for several consecutive hours. In this case, move plants into an unheated greenhouse or building until

the end of December to allow the plants to fulfill their chilling requirement.

• **Chilling Requirements**

Tulameen plants require a chilling period of about 800 hours of temperatures between 28°F and 45°F (-2°C and 5°C) in order to break dormancy. If this dormancy requirement is not met, the plants will not break bud and grow to produce fruit, or only the top few laterals will grow and produce fruit. To ensure that a sufficient number of chilling hours has been achieved, plants can be moved into a cooler (that does **not** contain other fruit that can produce ethylene gas) for 8 weeks prior to moving them into a warm greenhouse. If natural chilling is relied upon and autumn temperatures are mild, then chilling may not occur until later than desired. Buds on thicker canes and buds lower on the cane also have a longer chilling requirement (1000 hours) than buds on thin canes or near the top of canes.



Newly moved in dormant plants

If the greenhouse is vacant, the containers can be moved directly into the greenhouse prior to receiving sufficient chilling as long as it is possible to maintain temperatures in the greenhouse below 45°F (5°C). Even on

cool sunny days in autumn, the temperatures in a greenhouse can quickly rise well above the

45°F (5°C) mark, and this will be detrimental to the mandatory chilling period for the canes. It may be necessary to closely monitor the temperatures inside the greenhouse at this time and open vents, doors or and use fans to ensure the temperature does not rise above 45°F (5°C) for too long on sunny autumn days.

Alternatively, plants can be moved into a cooler after mid-summer to complete their chilling requirement and begin their fruiting cycle earlier than nature would allow. The plants can be moved into the coolers with their leaves intact as early as August, and after the chilling requirement has been fulfilled, moved into the greenhouse where the plants will break bud, grow their laterals, flower and fruit. Moving potted plants into the coolers and greenhouse is an extremely labor-intensive operation. Consider how this might be accomplished most efficiently.

## Greenhouse Growing Conditions

After the chilling period has been satisfied, usually by mid to late December in the Northeast, the plants can be moved into the greenhouse. Initial temperatures in the greenhouse should be maintained at 50°F (10°C) at night and about 65°F (18°C) during the day. Supplemental lighting is not necessary for successful greenhouse raspberry production, but if lights are already installed in the greenhouse, they will accelerate harvest by a couple of weeks and may increase yield by 20-30%. Supplemental lighting is an added expense to the system, and the added expense might exceed income from higher yields. The benefit and cost of supplemental lighting will depend on climate conditions such as percent of sunshine and average temperatures. It is probably not economical to install lights only for the production of raspberries. Raspberries are a crop that tolerates lower light levels than most greenhouse crops. They also thrive at cooler temperatures than most other greenhouse crops, as the optimal temperature for raspberry photosynthesis is approximately 72°F (22°C).

Once in the greenhouse, canes are spaced pot-to-pot with 5.5 to 6.0 ft (1.7 to 1.8 m) between rows, trellised, and watered with a 100 ppm N complete fertilizer solution. Short or broken canes are removed. Three to four canes per container are left to produce fruit. Canes should be supported by an I-trellis or held upright by some other creative means. Rather than staking and tying each individual cane in the container, one grower chose to secure the canes in the upright position by attaching string to the cane, wrapping the string around and up the cane (not too snugly) and tying the other end of the string to an overhead support. Here lies another opportunity for individual expression of ingenuity as to how a grower chooses to manage the canes. Spreading canes into a V-trellis is not an efficient use of greenhouse space although it works well in the field where space is less valuable.



Dormant buds beginning to break

After the canes have been in the greenhouse for one week, an application of a fine horticultural oil before bud break can reduce early outbreaks of spider mites. The use of inexpensive box fans on the greenhouse floor will keep good air circulation around the plants to help reduce pockets of high humidity that

encourages disease infections. The relative humidity (RH) should be maintained between 65-75%. Relative humidity below 65% will encourage mite infestations as well as poor pollination, and RH greater than 90% will encourage fruit mold and poor pollination. As the plants fully leaf out, the temperatures can be maintained as low as 55°F (13°C) during the evening and 70°F (21°C) during the day. Injection of CO<sub>2</sub> gas (1000 ppm) may increase yields up to 10%, but it may be difficult to contain the gas in the greenhouse as most

greenhouses are not airtight and the gas tends to leak out. The additional yield may not justify the cost of the gas and the measures necessary to maintain an airtight greenhouse.

## Trellising and Cane Management

A trellis support system is absolutely required, as the fruiting laterals will become heavily weighed down with the production of the fruit. Pruning and trellising affect plant growth rate, fruit quality, quantity and size, soluble solids (sugars), disease susceptibility, ease of harvest, and spraying efficiency. Brambles respond significantly to pruning and trellising, but these practices are an expensive and time-consuming part of an operation. Growers must use care when choosing pruning and trellising strategies. The actual trellis support system decided upon is an individual choice; several options exist.



Fruiting laterals weighed down with an abundance of ripe and unripe fruit

### Option #1:

Monofilament plastic wire is the preferred material for trellis construction. It is as strong as metal wire, but much lighter and easier to handle. Inexpensive devices hold the monofilament taut at the anchoring posts and can rejoin lines that have accidentally been cut. Trellis posts and anchors should be made from readily available materials. The I-trellis consists of I-shaped wooden or metal posts, approximately 7 ft (2.1 m) long, with 3 ft (1 m) cross arms. The ends of the cross arms have a screw eye or other hardware to hold a length of plastic wire or twine. The wire is strung from pole to pole and pulled tight to keep the canes upright.



This is one example of a trellis support system with support wires and drip irrigation installed. The white buckets are filled with sand to add weight for stabilizing the trellis frame that will need to support a heavy fruit load during the harvest season

## Option #2:

Some growers use a strong string to gently wrap around the cane and tie to an overhead support beam or post to keep the plants securely upright. This method reduces the need to use bamboo posts to secure each individual cane in the upright position. Otherwise, an individual bamboo post or similar product is inserted into the pot for each cane and the cane is secured to the post in order to maintain upright stability. The use of the individual strings removes the need for the individual bamboo posts needing to be inserted and then again removed when the plants are brought in and out of the greenhouse.



Lateral bud break after cane tip has been pinched off

## Primocane Management

New emerging primocanes will be growing from the root systems during harvest. These primocanes can put on growth as much as 15 ft (4.5 m) in the first season, and must be pinched back so they do not both become a major source of competition with the fruiting floricanes as well as get in the way of harvesting the fruit. Most primocanes should be removed at the soil level leaving only four healthy primocanes for next year's crop. The smallest and the largest primocanes should be removed, leaving the primocanes about 0.5 in (1.25 cm) in diameter. The smallest canes will be too weak, and the largest, thickest canes will take too long to fulfill and break their dormancy. The four remaining primocanes should be pinched back at their tips when the canes reach a height of approximately 3 ft (1 m). This will temporarily halt the primocane's growth long enough to harvest the fruit without the primocanes being in the way. The primocanes will break a bud below the pinched area and once again continue to grow later in the season.



A commercial bumble bee hive in action

## Pollinator Management

The plants will break bud in 3-4 weeks, produce blossoms in approximately 5-8 weeks, and harvesting of fruit should occur in about 10-12 weeks after being moved into the greenhouse. Bumble bees are used for pollination as they tend to function better at cooler temperatures and cloudy skies than honey bees. Proper pollination is essential for optimal fruit set and production, and if proper pollination does not occur at the time of flowering, the berries will become very crumbly and, therefore, be unmarketable. Bumble bees are relatively docile and will not sting unless provoked. Even though bumble bees are available year round, vendors should be contacted early enough in the season so hives can arrive in time. Careful scheduling should be followed so the bumble bees are ordered at least one week before they are needed (i.e. 5 - 8 weeks into the season). The vendor can offer a recommendation on which type and how many hives are required for optimum pollination, depending on the size of the greenhouse.

Bumble bee hives are short-lived, 6-8 weeks, so they have to be replaced if a staggered cropping sequence is being implemented. Bumble bees can be obtained from numerous vendors who import them from Holland or Canada. They are flown to a nearby airport for

pick-up. (A list of vendors for biological controls and bumble bees is provided at the end of this guide in the suggested readings and suppliers section.)

## Water Management

In most areas, water quality should be good enough for irrigation purposes. However, water quality should be evaluated prior to using it for irrigation. Water quality includes its physical, chemical, and biological constituents.

Physical constituents refer to sand, silt, or other suspended materials in water. While physical constituents are generally not damaging to fruit crops, they can create wear on an irrigation system. High sand content, for example, damages pumps and can clog drip systems.

Chemical constituents such as the amount of dissolved material, the proportions of dissolved ions, and any organic-based compounds such as oil, should be low in irrigation water. Water with a high concentration of total dissolved solids may affect salt-sensitive fruit crops, such as raspberries, by causing leaf burn and general growth inhibition. Chloride, sodium, and boron are some constituents to which many fruit crops are sensitive. A water quality test should be taken at your facility to take into account the pH of the water as well as minerals present in the water. The pH and EC (electrical conductivity, or soluble salts in the water) will vary for the water source from one region to another and ultimately will vary depending upon the fertilizer mixture that is used. Some commercial fertilizers will indicate on their packaging the EC levels of the fertilizer mixture according to the ppm and rate. The optimal pH and EC range will vary from crop to crop, with raspberries in the range of 6.0-6.5 for pH and  $>3$  mS/cm for EC levels. For more detailed explanations on water and nutrient aspects of greenhouse operations, please consult the *Water and Nutrient Management for Greenhouses* publication available from NRAES (Natural Resource, Agriculture, and Engineering Service) listed in the resources section at the end of this publication.

Biological constituents, such as bacteria and algae, are more often present in surface water sources. These constituents are not harmful to fruit crops themselves, but they can affect drip and/or trickle irrigation systems. Biological constituents should not be much of a problem if well or municipal water sources are being used.



Drip irrigation tubes installed for efficient delivery of moisture and nutrients

## Irrigation System

In drip or trickle irrigation systems, emitters are grouped into two categories: (1) line-source and (2) point-source. Line-source emitters are an integral part of a lateral. Point-source emitters can have single or multiple outlets and are generally classified as drippers, bubblers, or misters

(foggers), depending on the method of final water application. Compared to sprinkler nozzles, emitters have very small openings, usually pin hole size. Different emitters have different internal flow characteristics that determine how sensitive they are to pressure changes and particles in the water. Because of the small openings in emitters, water filtration using a 30-200 mesh screen is normally required. However, some emitters are self-cleaning or can be taken apart and cleaned.

Low-pressure emitters normally operate at pressures of 2-4 psi, with flow rates of 0.5-1.5 gallons (1.9-5.7 L) per hour. Since the pressure and discharge requirements of emitters are much less than those of sprinklers, drip laterals and mainlines are smaller and the annual operating costs of these systems tend to be lower. A publication entitled *Trickle Irrigation in the Eastern United States* (NRAES-4) provides

detailed information, including consideration of small fruit crops and many design aspects, on this method of irrigation. Irrigation is adequate when there are no dry spots in the container root zone and water has moved through the entire container. If irrigation continues after water has begun draining from containers, fertilizers will be leached and runoff water will have elevated levels of nutrients.

## Nutrient Management

Fertigation, or applying fertilizer through the irrigation system, is a practical method of delivering nitrogen and other major nutrients to greenhouse-grown raspberries. The fertilizer solution when applied to the plants should contain approx. 100 ppm N and all of the essential macro and micronutrients. Commercial soluble fertilizers are available that contain a complete set of nutrients. Most of these formulations were developed for flower and foliage crops. In our experience, raspberries grow best with a higher proportion of N relative to the P and K found in commercial formulations. Therefore, it may be necessary to use two stock solutions to obtain the right balance between N and the other nutrients.

A commonly-used soluble fertilizer for greenhouse operations is Peter's Hydrosol (5-11-26). A solution of 100 ppm N from Hydrosol contains too much P and K for raspberries, so two stock solutions can be used to obtain a better balance. Following is an example of how to prepare two stock solutions of 10 gal (38L) each, using a commonly available proportioner to obtain a 100 ppm N solution with lower P and K than would be made with the commercial formulation alone.

Two stock solutions are used: Stock #1 is prepared by dissolving 615g calcium nitrate and 130 g ammonium nitrate in 10 gal (38 L) of water. Stock #2 is prepared by dissolving 1230 g of a soluble, commercial 5-11-26 fertilizer (Hydrosol) in 10 gal (38 L) of water. The fertilizer delivery system contains a proportioner that adds both stock solutions in

equal proportions, diluting each to a ratio of 1 part fertilizer to 50 parts water prior to delivery to the plants. Under these conditions, the output from the proportioner contains a solution of 100 ppm nitrogen. A conductivity bridge can be used to determine the electrical conductivity (EC) of this fertilizer solution at 100 ppm nitrogen, and then this EC reading can be used as a standard for maintaining the fertilizer concentration of the irrigation water. The EC of the fertilizer solution should be a maximum of 1.5 mS/cm.

Once the solution is made, use phosphoric acid (if too alkaline) or potassium hydroxide (if too acidic) to maintain the solution pH at 6.5. This application rate of 100 ppm N should be maintained while plants are vegetative; once flowering begins, reduce the overall rate to 50 ppm (change the proportioner to 1:100) to avoid excessively lush canopy growth and soft fruit. When iron deficiency is indicated by leaf analysis, it can be alleviated by the application of an iron chelate fertilizer through the irrigation system - independent of the standard solution to prevent precipitation.

To ensure proper fertilization, leaf samples should be taken and sent in to the nearest testing lab for accurate assessment of nutrient levels and adjustments made to encourage optimum plant health and productivity. Leaf analysis is a useful tool for assessing the nutritional status of the plants because the analysis determines actual nutrient levels in the plants. One of the greatest advantages of a leaf analysis is that deficiencies can be anticipated before they reduce plant growth. Contact your local County Cooperative Extension office for the location of the nearest lab testing facility.

## Considerations for Pest Management

While the plants are in the greenhouse, scouting for insect and disease should occur weekly and records kept as to what is found, when it is found, where it is found in the greenhouse and what measures are taken. These records will be helpful in following years as indication as to when to expect possible

problems and how the problems were or were not successfully managed. It is possible to manage most insect pest populations with the use of cultural and biological controls and careful monitoring, so with proper care, no chemical pesticides may be required.

United States Environmental Protection Agency (USEPA) policy currently states that a pesticide can be used in a greenhouse as long as the target crop and organism are listed on the pesticide label, unless the label specifically restricts us in greenhouses. Pesticides cannot be used in the greenhouse if there is a specific greenhouse prohibition on the label. Biological and cultural controls often provide adequate pest control, but the use of a pesticide may be required for sudden and/or extreme pest outbreaks in which biological controls may not be effective quickly enough.

The predominant arthropod (includes insects and mites) pest problem is two-spotted spider mites. This pest can be managed by the use of certain predatory mites that are available from various biological pest control suppliers. Two-spotted spider mite populations can very quickly get out of control, and biological controls can take a while to bring pest populations under control, so careful, weekly scouting is essential. Predatory mite releases should begin in the greenhouse shortly after the leaves emerge from the buds, which will break bud 3-4 weeks after being brought into the greenhouse. Becoming educated in identifying both the insect pests and the beneficial, predatory insects is necessary to be able to differentiate between the “good bugs” and the “bad bugs”. Encouraging good air circulation, removing excess primocane growth, monitoring nutrient levels, and maintaining proper humidity and temperatures can significantly reduce pest pressure and create conditions favorable for biological control. (See section on individual pests.)



## Harvesting, Handling, and Transporting Fresh Fruit

Raspberries are a very perishable commodity, but steps can be taken to give them sufficient shelf life for marketing and consumption. By using proper management practices, many problems can be avoided that can lead to unmarketable fruit. Providing proper trellising and pruning will allow air and light movement through the canopy, which will discourage decay and disease organisms. The use of drip irrigation keeps the fruit from becoming wet, which greatly reduces the amount of infection to the fruit. Proper fertilization will keep plants

from becoming stressed, and fruit from stressed plants will have a shorter life than fruit from healthy plants. Keeping insect pests to low levels will also be less stressful to the plants and will keep insect feeding on the fruit to a minimum. Just as important is the careful handling of the plants when moving them in and out of the greenhouse. Handle the plants as little as possible to minimize any damage to the canes. Even small wounds can become sites for fungal infection or cause damage to the vascular system that may not become apparent until the canes leaf out and are not able to be supported by the damaged vascular system.

During the harvesting season, the fruit will ripen in stages, slowly at first, with a peak season in the middle, and then tapering off towards the end of the season. Ripe fruit should be picked at the peak of ripeness and harvested directly into half-pint containers. The ripe fruit is very delicate and prone to damage if handled too much or too roughly. The fruit is generally ripe when the fruit releases from the core when very gently tugged. The fruit should not be picked if it takes too much effort to pull it off the core. If the fruit is to be transported a long distance or stored on display for a long period, the fruit can be harvested slightly unripe to avoid soft, mushy berries, but flavor will be sacrificed as the berries will not continue to ripen after they have been picked. Raspberries grown outdoors and shipped long distances tend to have very short shelf life and begin to decay very quickly, whereas greenhouse grown raspberries have been held in cold storage for as long as three weeks without showing any sign of fungal decay (although they will shrivel). The flavor intensity will decrease after less than a week, but since greenhouse grown raspberry fruit never become wet, the occurrence of fungal decay is much reduced in comparison with raspberries grown outdoors.

Since the fruit is so delicate and flavor quality decreases rather quickly, it is best to harvest and sell the fruit as quickly as possible. If access to a cold storage facility is available, harvesting the fruit and placing each filled flat

of harvested fruit immediately into the cooler will help maintain the high quality of fruit until delivery to a seller or market is possible. During the peak harvest season, it may be necessary to harvest on a daily basis, as the fruit load can be quite heavy. In the first year of fruiting, each plant can produce about two half-pints (350g) of fruit. In following years, a harvest of up to as much as 20 half-pints per plant can be obtained in a two-month harvest window.

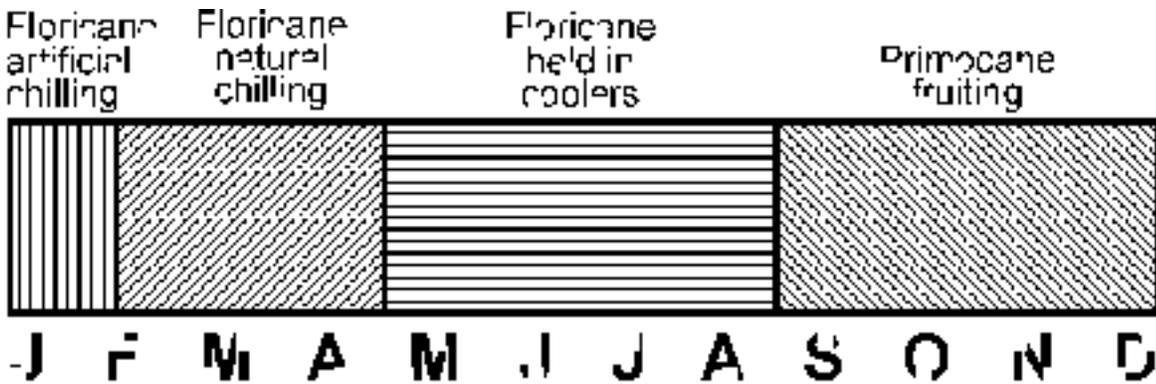
## Post-Harvest Plant Care

After the harvest season has ended, the fruiting canes can be completely cut off at the soil level and discarded, or in the case of primocane fruiting types, cut below the fruiting zone to promote additional bud break. After the risk of killing frosts has passed, the containers with the newly growing primocanes can be moved outdoors to grow for the summer, thus beginning the cycle all over again. These new primocanes may need to be cut back to a height of 6 ft (1.8 m) in order to remain manageable. ‘Tulameen’ is a very vigorous variety that can grow as much as 15 ft (4.5 m) per year, so pruning back the primocanes may be necessary. This also keeps the fruit harvested the next season within reach.

### • Staggered Production

If a two-month production period is too short, production can be lengthened using a variety of techniques. For floricane-fruiting varieties, several options exist.

- 1) Hold plants in a cooler and bring them into the greenhouse 10 – 12 weeks before fruiting is desired. By staggering the time plants are brought into the greenhouse, production can be staggered as well. Plants can be held in a cooler from winter through summer, bringing them into a warm greenhouse as late as August or September. These plants will flower very quickly and fruit by late November. Yields tend to be lower, however, since canes would have been held a long period at cold temperatures.
- 2) Plants can be artificially chilled by moving them into 34°F (1°C) coolers as early as mid-August, with the leaves intact. After 8 weeks in coolers and 8 weeks in the greenhouse, plants will produce flowers by December and fruit by late January. In experiments at Cornell, defoliation of plants prior to chilling had no effect. It is unknown if a lighted cooler would be advantageous.
- 3) With a cooler, one can move plants into and out of the cooler during appropriate times to provide chilling to primocanes, essentially



## Season Extension

By utilizing some of the following suggestions, it is possible to produce high quality raspberries during different times of the year as an alternative to relying on the brief, set time frame of the standard outdoor production system.

mimicking winter and summer. A combination of cooler and greenhouses can be managed to eliminate outdoor growing, and establish a year around production season.

Dormant raspberry canes can be stored successfully for several months in a humid

cooler maintained at about 34°F (1°C). Inside the cooler, plants should be watered when needed to maintain soil moisture. The longer plants are stored in the cooler, the shorter will be the time between bud break and fruiting because plants respond to warmer temperatures faster with more accumulated chilling.

These techniques open the possibility of significantly lengthening the fruiting season of floricane-fruiting greenhouse raspberries.

Starting production earlier than February would have several advantages for growers who use the greenhouse for spring crops, such as bedding plants.

### • Primocane-fruiting

Primocane-fruiting raspberries are most useful for producing fruit in late fall and early winter. Primocane-fruiting varieties will continue fruiting in the fall in a greenhouse, well past the time that production would normally cease outdoors due to cold weather, if they are moved inside the greenhouse by early September. Pinching primocanes when they are about 3 ft (1 m) tall will delay flowering and fruiting, shifting the crop to late in the fall. This practice has been successful under high plastic tunnels, as well as in greenhouses. Bumble bees are used for pollination, and the fertility program is similar with 100 – 150 ppm N until fruiting, then 50 ppm N after flowering in a complete fertilizer formula. Varieties that have performed well in the fall include Autumn Britten, Heritage and Caroline.

With a small amount of chilling, most primocane-fruiting varieties will produce a sequence of new canes that will fruit about 3 months after emergence. Once fruiting occurs, primocanes can be tipped several nodes below the fruited portion to stimulate new lateral production. This will allow raspberry fruit to be



A high tunnel structure with the sides rolled down and the ends closed

produced for a very long period of time. With the primocane-fruiting varieties, the yield may be less than with floricane-fruiting varieties, but the extended fruiting season for the primocane-fruiting varieties may equal out for overall total yields. The extended fruiting season also means labor and maintenance costs will be higher, but having fresh raspberries available during the autumn when they are normally not available, will also allow a grower to charge a higher, premium price for the fruit.

### • High Tunnels

A high tunnel is a simple inexpensive structure similar to a greenhouse that provides a great deal of season extension versatility. High tunnels offer the opportunity for the grower



A high tunnel structure with the sides rolled up  
Photo courtesy of the Fruit Growers News

to get a crop started early in the season, to stay in production later in the season, and, possibly to produce a crop such as greens through the winter. High tunnels also provide protection from rain and hail and can reduce disease and pest pressure. With good planning, variety selection, and close management, this low cost system can add another dimension to a raspberry operation. Under high tunnel systems, some primocane fruiting varieties have begun fruiting as early as the end of May, with the fall crop beginning in early July. Depending on the weather conditions for the autumn season, it may be possible to extend the fall-fruiting crop into November, or even December in some climates. Tipping the primocanes of primocane-fruiting types prior to flowering will delay harvest into late autumn.

In a high tunnel system, raspberries are planted directly into the soil. The tunnel is large enough for the grower to plant, monitor and harvest the crop from inside the structure. The standard tunnel is 14 ft (4.25 m) wide, 96 ft (29.25 m) long, and 7.5 ft (2.3 m) tall at the center. Tunnels should be no wider than 30 ft (9 m), for good cross ventilation and reduction of snow accumulation on the roof in the winter. The Quonset frame consists of metal bows made by bending steel pipe or tubing and potential stresses caused by the weight of snow or heavy wind must be considered.

Metal pipes are driven into the ground approximately 2 ft (0.6 m) deep and set every 4 ft (1.2 m) of the high tunnel length, providing support for the Quonset frame. The bows fit into the ground pipes and are attached by bolts. The ends of the structure can be plastic or wood on a wood stud frame, but should be removable to allow access for tillage equipment and to increase ventilation in the summer. The structure is typically covered with a single layer of 6-mil polyethylene with provisions for rolling up the sidewalls. The poly is secured onto a batten board on each side of the high tunnel about 3.5 ft (1 m) above the soil line. A vertical sidewall helps to keep rain out of the tunnel and when rolled up, provides ventilation. A pipe is

then attached to the loose bottom end of the plastic along the length of the structure. A “T” handle on the end of the pipe is used to roll the plastic onto the pipe to open the sides. Cross ventilation is assisted by wind and has proven to be very efficient. See the suggested readings section at the end of this guide for links to more detailed information.

The key to successful use of the high tunnel is to spend the time laying out and preparing the site for construction. The better the tunnel is constructed, the easier the roll-up sides will work and the easier it will be to ventilate. During periods of cold weather the sides are lowered in the afternoon to hold heat and then raised in the morning to vent before temperatures inside get too high. The floor of the structure is covered with a layer of 6-mil black plastic. This helps to raise the temperature inside the house, control weeds, and prevent evaporation of soil moisture. Excess moisture will raise humidity in the tunnel and may lead to disease problems. Humidity of the air will increase at night as the air cools down. Venting in the morning will allow drying of any condensed water.

High tunnels can actually reduce the incidence of some diseases, particularly if trickle-irrigation tubing is used underneath black plastic mulch. No water (rain or irrigation) gets onto the foliage to transport spores or otherwise encourage disease development.

The use of high tunnels does require an increase in both the level and the amount of management required to grow the crop. The sides must be raised and lowered to regulate temperature and humidity. Plants must be irrigated regularly and fertigated as needed. Plants can be grown on raised beds covered with plastic or landscape fabric with the rows in between bare soil or the entire floor can be covered with landscape fabric. Unless supplemental heat is provided the tunnel may not be able to provide adequate protection to the plants after the November/ December time frame depending on the year. Disease problems may occur in the protected environment;

management of the environment is critical. Ventilation to avoid high temperatures or high humidity is very important. Unpredictable weather in spring and fall will make management intensive. Powdery mildew is one disease that may be favored by the high tunnel climate and should be monitored for closely.

Insects will find the microclimate created for the plants to be favorable to their growth also. Without a doubt, scouting must begin when the plants are set out. The use of beneficials may be the most practical way to deal with some insect and mite problems. However, season extenders can actually be used as physical barriers to keep insects off the plants. For example, screening the sides to exclude insects, and the use of floating row covers that have the edges secured will prevent many insects from reaching the crop.

Bumble bees may be required to maximize production in the early and late part of the season when the sides are rolled up infrequently. The bees flying in and out will stop off on the various flowers on their way in and out each day, which should provide adequate pollination. (Information provided by: <<http://plasticulture.cas.psu.edu/>>)

## Arthropod Pests

### Twospotted Spider

**Mites:** *Tetranychus urticae*

### Pest Biology

Two-spotted spider mites are the most common species of free-living mites to cause damage to plants and are also probably the most significant pest for greenhouse raspberries.

Two-spotted spider mites cause damage to raspberry plants in such a way that they weaken the plant by feeding on the undersides of the leaves. The spider mites use their



The twospotted spider mite

piercing and sucking mouthparts to drain the nutritious fluids out of the tissue cells in the leaves. This act of feeding by the mites leads to one of the diagnostic symptoms of mite feeding, the yellow mottling that appears on the upper side of the leaves. A second diagnostic symptom of mite infestation is very



The leaf on the left shows severe damage from mite feeding

fine webbing present on the underside of the leaves. In areas of major infestation, the webbing can also be seen bridging the space between leaves adjacent to each other. This webbing on the leaves protects the mites from enemies as well as chemical sprays. Round mite eggs, immatures, adults, cast skins and empty egg shells may be seen with a hand lens. If left unchecked, mite infestations can lead to extremely chlorotic leaves that are no longer functional to the plant and may abscise prematurely. Infestations will most often begin in the lower canopy of the plants and move upwards. Under extreme conditions this can lead to defoliation, stunting of plants and much reduced yields.

The adult female mite has eight legs, is about 0.5 mm (1/50th of an inch) long, and the color ranges from yellow/green to brown or becoming orange/red towards autumn before it overwinters. The male is much smaller, 0.3 mm (1/80th of an inch), and has a narrow body with a pointed abdomen. The signature two dark spots on the sides of the body are actually food contents visible through the insect's semi-transparent body. The body is oval with sparse spines. Immature mites may have only six legs, but otherwise resemble the adults, just smaller



Webbing from the twospotted spider mites between severely damaged leaves

in size. The adult female can lay eggs at the rate of 2 to 12 a day, thus able to produce over 100 eggs in less than a month's time.

Spider mites overwinter as adults in soil under leaf debris, on raspberry canes or surrounding weeds. These mites are capable of producing numerous (10+) generations in a single growing season. Outdoors, female mites emerge late in the spring and begin laying eggs usually along midribs of younger leaves. If male populations are low and mating does not occur, the females will lay eggs that will produce only male offspring. Mites will generally survive for about 30 days under favorable conditions. Optimum mite development occurs around 30°C (86°F) and new generations occur every 8 days. New generations occur every 6 weeks under minimum development temperatures of 12°C (54°F). Egg-to-adult development time can range from 5 to 19 days depending on the temperature - longer for cool temperatures around 12°C (54°F) and less for temperatures of 24°C (75°F) or higher. In greenhouses the mites do not require a cold-induced hibernation period and new generations are produced continuously if left unchecked.

When the containers of raspberries have been placed near apple trees during the summer months, the following growing and fruiting season inside the greenhouse has shown infestations of European red mite, *Panonychus ulmi*. The European red mite looks quite



A female and male European mite

different from the twospotted spider mite, and should not be a problem on greenhouse raspberries unless the containers have spent the summer outdoors near apple trees. There are biological controls available for European red mites if infestations do occur.

• **Cultural Control**

For raspberries grown outdoors, the two spotted spider mites become most active in the spring of the year and into early summer. In

greenhouses spider mites are always a problem and need to be contended with at all times. For outdoor raspberries the mites can be controlled with heavy irrigation or spraying the leaves with a heavy force of sprayed water, thus “washing” the mites off the leaves.

The two spotted spider mites tend to thrive in the warm and dry conditions often encountered in a greenhouse during the winter. Reducing the temperature at night to 12°C (55°F) and maintaining high humidity discourages mite outbreaks. Low humidity encourages mite feeding and at the same time is more distressing to affected plants. Maintaining humidity in the greenhouse above 70% but less than 90% will discourage mite feeding and also aid in hatching predator eggs. Removing leaves with “hot spots” of mite infestations will also help to reduce the mite populations. Use a hand lens to monitor for mites and release predators as soon as **any** mite-damaged leaves are found.

### • Chemical Control

The mites also can be controlled with an application of sulfur (80% WP) according to the label directions for powdery mildew. An application of a fine horticulture oil in the dormant season can be effective in managing populations by smothering the overwintering mites on the canes. Applications of horticulture oil during the hot, sunny part of the growing season is not recommended as the plant’s leaves are sensitive to the oil and may become damaged due to phytotoxicity.

In most cases for raspberries grown outdoors, two-spotted spider mites are not usually a serious threat. Very few chemical options exist for mites. An organophosphate may temporarily suppress mite populations, but natural predators will also be reduced and lead to a later explosion of mite populations as they will be allowed to develop uninhibited by natural predators. Miticides are available for control, but tend to only control specific life stages. Therefore, repeated sprays will be necessary to control the following generations

that hatch from the eggs left behind. Alternate the use of miticides with different modes of action so a build up of resistant populations are less likely to occur. Heavy infestations with webbing will require higher pressure to get the spray to go through the webbing and reach the mites. In all cases, adequate spray coverage on the bottom and upper surface is required. One currently registered ovicide/miticide available for use on raspberries is Savey® 50 DF (Hexythiazox). (Any and all brand-name products mentioned in this production guide are provided for informational purposes only, and is not an endorsement of the product and/or its parent company. Please contact your local County Cooperative Extension representative for your specific state regulations and recommendations.)

### • Biological Control

Natural predators including mites, lacewing larvae, lady beetle larvae (*Stethorus punctillum*), minute pirate bugs (*Orius* spp.), big-eyed bugs (*Geocoris* spp) and predatory thrips (*Scolothrips sexmaculatus*) will all attack mites. Numerous mite predators in the Phytoseiidae family are commercially available including *Galendromus occidentalis*, *Phytoseiulus persimilis* (excellent at quickly reducing a light infestation population), *Phytoseiulus longipes*, *Neoseiulus fallacis* (can be used as a preventative) and *Neoseiulus californicus* also can be used as a preventative. Organophosphate-resistant strains of *P. persimilis* are commercially available. Some of these commercially available predatory mites do not overwinter in cold climates so reintroduction each season will be necessary.

Successful use of predatory mites in the greenhouse requires familiarity with the predators themselves. The predatory mite *Phytoseiulus persimilis* thrives in 20-30°C (68-86°F), humid (60-90% RH), semi-shaded environments. Adults are pear shaped, orange (sometimes tan or brown), and have long front legs. This fast moving mite will feed on all stages of the two-spotted spider mites and is able to move forward and backwards, whereas

two-spotted spider mites only move forward. *P. persimilis* females lay approximately 50 eggs that are oval, slightly orange and twice as large as the eggs of the two-spotted spider mite. The eggs hatch three days later into six-legged non-feeding larvae. Within a couple of days the larvae will molt into eight-legged nymphs and begin their feeding. *P. persimilis* can multiply twice as fast as prey and has a voracious appetite, able to devour 30 eggs, 24 young or 7 adult mites per day. Once *P. persimilis* eat all their prey, they will starve. Therefore, reinoculation is necessary if mite populations flare up. Best results are obtained if predatory mites are introduced into the greenhouse as soon as any signs of a mite infestation are found with careful monitoring, before massive mite infestations occur. It can take up to three weeks to attain control. A common reason for failure to control a mite outbreak with predators is releasing too few predators too late. Weekly releases for at least 3 weeks are needed.

*Neoseiulus fallacis* is another predatory mite that has been found to be very successful in reducing populations of the two-spotted spider mite. *N. fallacis* can be utilized as an inoculant against outbreaks and is able to survive lower temperatures, low numbers of prey, some pesticide applications, and is able to quickly bring down a light population of mites. A close relative, *Neoseiulus californicus*, is another predator that is slower in controlling outbreaks, but it can survive for a much longer time in the absence of prey. *N. californicus* is also adapted to a much wider range of environmental conditions and is able to survive and be highly successful in variable greenhouse conditions. A mixture of *N. californicus* and *P. persimilis* can be used for mite control as the *P. persimilis* will quickly reduce mite populations until *N. californicus* is able to build up and maintain low levels of mites for the long term.

Predators are usually shipped in sawdust or vermiculite and are sprinkled onto moistened raspberry leaves. To avoid higher chances of powdery mildew, it is best to spot-mist hot spots and then sprinkle on the predators rather



than to wet down the entire canopy. Apply the predators in the mite infested hot spots so they will be able to quickly find their prey.

**Black Vine Weevil: *Otiorhynchus sulcatus***

The black vine weevil is a dark snout beetle 8 to 11 millimeters long (0.25 to 0.4 inches), that will more likely been seen in the second year of production

after bringing the plants into the greenhouse from outdoors. The adult weevils are nocturnal and will only be active at night. Feeding by the adults will first be seen as “notching” on the edge of leaves closest to the soil. The adults will feed



on leaves of the newly developing lateral branches, and during harvest will feed on the ripening fruit making it unmarketable. The adults must feed on plant material for 21 to 45 days before the are ready to lay eggs. After the preoviposition period has passed, the females place several eggs each day into the soil or leaf litter. Adults may live 90 - 100 days and usually lay 200 eggs during this time. The eggs hatch in 2 - 3 weeks and the small, C-shaped, legless larvae feed on the plant rootlets. Root feeding may not kill the plants, but the feeding will interfere with nutrient and water uptake, thus negatively



Weevil feeding on fruit

affecting the overall health and performance of the plants. The larvae grow slowly, molting 5-6 times. By late fall outdoors, the larvae have matured and are about 5/8 inch long. The mature larvae enter a quiescent

prepupal stage in an earthen cell and pupate the following spring. A single generation occurs each year. In the warmth of a greenhouse, the larvae may pupate in January or February and the adults emerge in March or April. Control of the black vine weevil can be attained by various measures including a soil drench of entomopathogenic nematodes, *Steinernema* and *Heterorhabditis* spp., that will kill the larva, but the timing of the soil drench must coincide with the presence of the larva in the soil. In the warmth of a greenhouse, the larvae may pupate in January or February and the adults will emerge in March or April. The soil

drench is ineffective on adult weevils. A manual method for managing adult weevils is by placing a tarp on the floor and gently shaking the plants in the evening to dislodge the adults from the plant canopy and discarding them. The black vine weevil has a single generation per year.



Weevil feeding on edges of leaves

Avoid growing potted plants near weevil food sources, such as crabapples, yews, and other ornamental plants.

**Raspberry Cane Borer, Renecked Cane Borer and Crown Borer:**

*Oberea bimaculata*, *Agilus ruficollis* and *Pennisetia marginata* (respectively)  
 Borer problems are occasional and will more likely occur in the second year of production after plants have been outdoors during the summer and then brought into the greenhouses during the winter. The presence of borers is evident by the wilting of the canes from the growing tips downward. Infestations occur during the summer when the plants are outside.



Cane borer larva feeding down the inside of a cane; indicative pair of girdle marks and entrance hole on cane; frass on leaves from feeding larva.



The adults burrow holes in canes towards the tip, and then lay an egg inside. Cane borers produce a double ring of girdling marks approximately 2 cm (1 in) apart that go completely around the cane. The action of

girdling the cane causes the growing tip to wilt and die, often breaking off later in the season. The egg will hatch into a larva that will feed on the tissue inside the cane and eventually bore its way down the cane, causing extensive damage. The cane will suffer weakening, wilting and perhaps death.



Swelling in cane from feeding larva of the Crown Borer

The only effective way to control these boring pests is to cut off the infected canes just below



Crown borer larva feeding inside cane near the root base

the girdle marks if caught before the larva feeds down the cane. These boring pests tend to cycle in severity from year to year, so one year they may be in

abundance and in other years they may almost completely absent. The best control measure is for the grower to keep a watchful eye for wilting symptoms of the plants, and check for girdle marks, swellings, and remove the infected portions as soon as possible.

**Aphids:** *Amphorophora agathonica* and *Aphis rubicola*

Aphids tend not to be a significant problem in the greenhouse for red raspberries, but they do occur and can build numbers quickly if left unchecked, particularly with black raspberries. Aphids occur on the new, succulent growth. The aphids feed on the major vein on the underside of leaves and may cause leaf curling. Aphids are the primary vectors of most bramble viruses. They can be effectively controlled with biological controls, such as lady bugs, lace wing larvae, and certain parasitic wasps. An application of a fine Horticulture oil will also reduce the numbers of aphids.



**Leaf Rollers** (Orange tortrix: *Argyrotaenia citrana*; Oblique-banded: *Choristoneura rosaceana*) and **Raspberry Sawflies** *Monophadnoides geniculatus*

Both leaf rollers and sawflies may be found in plants that have been brought into the greenhouse from outside. Leaf rollers have not been as much of a problem on greenhouse

raspberries as sawflies. Sawfly larvae cause



Leaf roller larva exposed after unrolling leaf (above, left): sawfly larva and feeding damage on leaves

skeletonized leaves and leaf roller larvae roll up leaves which harbor the developing larvae. Sawflies can be abundant in certain years and quickly skeletonize many leaves in a very brief amount of time. The loss of many leaves will reduce the plant's ability to photosynthesize and sustain fruit production. If feeding is severe, fruit production and quality of fruit will be much reduced if not halted entirely, and there is the possibility of premature cane death. A couple of control options for sawflies is to prune out severely infested leaves with the hope that you will also remove the larvae, or simply pick off the larvae when found and destroy them.

Some other possible pests that are less likely, yet possible, to be found on greenhouse raspberries includes: tree crickets, thrips, and tarnished plant bug (*Lygus lineolaris*). These pests and their damage should be minimal, but photos are provided to assist in identifying each. Additional information regarding these pests can be found in the *Bramble Production Guide*.



Tree crickets (below), signs of their damage on the cane and their eggs inside the cane (left.)

The "bronzing" effect due to the damage caused by the feeding of thrips



The adult tarnished plant bug

# Disease Scouting and Management

## Diseases

The first step in minimizing disease problems is to start with disease-free plants from certified nursery stock. Tissue culture plants are one option since the plants are grown under sterile conditions. Dug canes are also used for faster fruit production, but the risk of introducing of pest problems increases since insects and diseases may be attached to the canes and/or small soil particles on the roots.

### Botrytis Fruit Rot (Gray Mold): *Botrytis cinerea*

Botrytis fruit rot is a fungal pathogen that can affect not only the fruit, but also other parts of the plant including the flowers, laterals and the canes themselves. Botrytis can be identified by the appearance of fuzzy, gray mycelial growth on the fruit. The fungal infection tends to occur under conditions of high humidity and shaded conditions, and any physical damage to the fruit and/or plants will increase the risk of infection. Therefore, care should be taken when harvesting the fruit and moving plants in and out of the greenhouse to minimize physical damage to the canes. Botrytis is especially damaging to harvested fruit that will be shipped or stored.



Harvest fruit before it becomes overripe, store the fruit as soon as possible in a cooler around 2°C (34°F), and sell the fruit as quickly as possible.

Botrytis can be controlled by various management practices such as cleaning plant

debris from the greenhouse, removing any infected fruit, and maintaining an open canopy for good light penetration and air circulation.



The use of drip irrigation minimizes the wetting of fruit and plant parts. If hand watering is practiced, water the containerized plants early in the day so the plants will have time to dry off before evening.

### Powdery Mildew: *Sphaerotheca macularis*

Powdery mildew is a fungal pathogen that can infect raspberry plant leaves, fruit and shoot tips. Infected leaves have light green mottling or speckles on the upper surface, and white mycelial growth on the underside. Control of this pathogen is most effective with partially resistant cultivars such as Tulameen. Infected shoot tips can be covered by white mycelial growth and the shoots can become elongated, spindly and have smaller than normal leaves. Infected fruit will also be covered by the white



mycelial growth. Infection can occur under warm and dry conditions, so keeping the greenhouse temperatures below 24°C (75°F) and the humidity above 60% will be helpful. Keep the area clean of plant debris and maintain an open canopy for

good air circulation. The use of inexpensive box fans on the greenhouse floor can aid in better air circulation. A sodium bicarbonate (baking soda) mixture has been shown to be somewhat effective in the control of small, isolated outbreaks of powdery mildew. An effective, commercially available product based on bicarbonates is Armicarb. Certain greenhouse growers use a sulfur vapor to manage powdery mildew. Elemental sulfur is placed in a small foil pie pan on a heating element over night to release the sulfur into the air as a vapor. When powdery mildew is a problem in greenhouses, a weekly application of sulfur vapor tends to keep the problem to a manageable level.

**Phytophthora Root Rot:** *Phytophthora fragariae* var. *rubi*

Phytophthora root rot is a disease that is more likely if using dug canes instead of tissue culture plants, as the pathogen may travel from the field into the greenhouse on infected root systems or soil particles. Symptoms are sudden shriveling of healthy plants, followed by cane death. No practice is completely effective, so if the disease is encountered, discard all infected plants and sterilize all infected containers before reusing. The symptoms of Phytophthora are similar to other cane blights, except that lesions at the soil level can be found on cane blights, but no visible lesions exist with Phytophthora infection.

**Crown and Cane Gall:** *Agrobacterium tumefaciens* and *A. rubi*

Crown and cane galls are caused by a bacterium that causes galling in the crown of the plant's root system just below the soil surface or on the lower canes. This disease will only occur on dug canes where the disease was present in the field from where the plants originated. Severely galled plants are weakened, stunted, and unproductive. The abnormal proliferation of plant tissues that results in gall formation disrupts water and nutrient uptake and transport in the plant. No effective control measure for this disease exists, other than to discard the infected plants. Begin with disease-free tissue cultured plants grown

in sterile, soil-less growing media and sterilized growing containers.

**Fire Blight:** *Erwinia amylovora*

Fire blight on raspberries is rare in the field, but it has been observed in the greenhouse.

Fire blight is caused by a bacterium that infects many plants in the *Rosaceae* family, including raspberries. The common symptom of fire blight is a dark, scorched shepherd's crook at shoot tip. Fire blight is unlikely to be a serious threat to greenhouse production of raspberries,



but the grower should watch for symptoms and remove infected cane tips. Sterilize pruners with a chlorine or alcohol solution after every cut as it is possible to transmit the disease by infected pruners. Fire blight has the potential to spread rapidly under warm, moist conditions.

## Physiological Anomalies

There are certain physiological problems that may be encountered with growing any particular crop, either inside or outside of a greenhouse. As mentioned earlier in this production guide, some varieties respond better than others inside a greenhouse setting than others, and physiological anomalies may or may not occur, or they may occur one year and not the next. It is not fully understood why these mystery anomalies occur, but damage from them if they do occur should be minimal. A couple of examples are provided with photos here for reference.

**Solar Damage:** solar damage can cause individual and/or groups of individual drupelets to turn white. Some varieties of raspberries are more susceptible to solar damage than others. This damage tends to occur under bright light and high temperature conditions.



**Leaf Chlorosis:** leaf chlorosis is often caused by a nutrient imbalance, but in some cases a few leaves may show symptoms of a unique coloration while the rest of the plant and surrounding plants remain healthy looking. It is not clearly understood



what the cause for this problem is, but the damage seems to be isolated and not cause significant damage to the plant and/or harvest. If the problem spreads to the rest of the plant or surrounding plants, a sample should be immediately sent in for analysis at the nearest diagnostic lab.

## Marketing Greenhouse Raspberries

Greenhouse grown raspberries can be extremely large yet flavorful. Consumers have been willing to pay between \$3.00 and \$6.00 per half-pint for these superb quality fruits, and restaurant chefs seem to be willing to pay an even higher price in order to offer their patrons such high quality, fresh raspberries. How a grower intends to market their fruit, where their potential niche market is located, and how it will be advertised and serviced should be taken into account and planned out well in advance. A Cooperative Extension agent may be a good source of helpful marketing strategies.

Some marketing options include:

- Sell directly to supermarkets or co-ops
- Sell directly to chefs
- Sell at farmer's markets
- Sell alongside spring annual/perennial plant materials

## Budget Assumptions:

The following budget scenario is based on an example of growing raspberries in a 24 X 96 ft (7.32 X 29.25 m) greenhouse. Three hundred tissue culture plants were purchased for \$1.20 each and planted in one each in a 3 gal (13 L) containers with a soil-less growing media. The containers were spaced pot-to-pot, 100 containers per row with 6 ft (1.8 m) between rows. The building materials for the trellis support system were purchased at a local hardware supplier, and the irrigation materials were ordered from a greenhouse supply company. A total of 41 hours of labor at \$8.00/hr were attributed to the start-up costs including planting the tissue culture plugs, setting up the containers, assembling the trellis system and irrigation system.

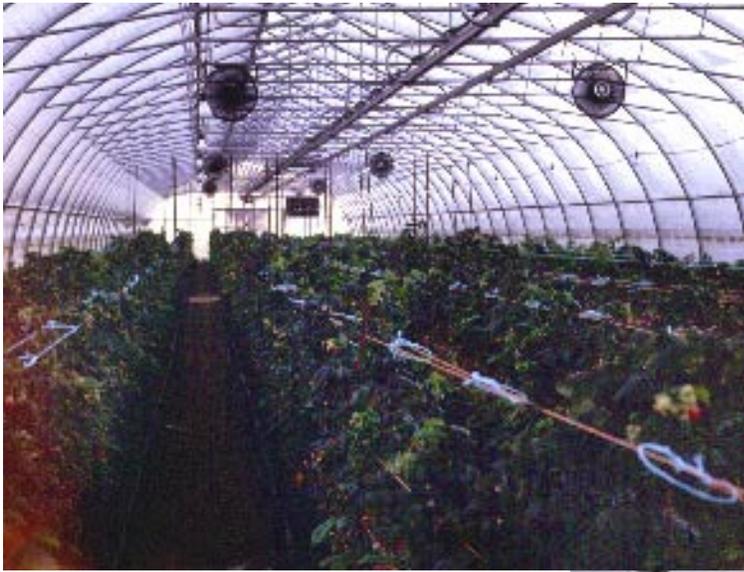
The production costs for the five month growing period in the greenhouse includes the total fertilization costs, the pest management supplies, two bumble bee hives for the pollination, and a greenhouse space charge of \$0.10/ft<sup>2</sup> per month for five months. Harvesting costs include paying the picker \$0.50 per half-pint piece work, and \$0.10 for the cost of each half-pint container.

The yields and profitability are listed for three years (a total of four years including the planting year) realizing no yield in the planting year, 2 half-pints per plant in the first fruiting year, and 16 half-pints per plant the following years. Each half-pint of fruit received a price of \$3.00.

## Greenhouse Raspberry Production Guide

Budget for Floricane-type raspberries  
Grown from plugs in an unlighted 24 X 96 ft. greenhouse

<b><i>I. Start-up costs</i></b>					
<b>Planting</b>					<b>\$1,260</b>
	300 plants	(\$1.20 per plant x 300 = \$360)			
	300 pots (3 gallon)	(\$1.50 per pot x 300 = \$450)			
	Pro-Mix	(\$1.50 per pot x 300 = \$450)			
<b>Trellis</b>					<b>\$1,200</b>
	Wood, screws, wires, ties				
<b>Irrigation</b>					<b>\$850</b>
	Tubes, clamps, connectors				
<b>Labor</b>					<b>\$320</b>
	Build trellises, planting (40 hrs)				
<b>TOTAL</b>					<b>\$3,630</b>
<b><i>II. Annual production costs (mid December - mid May)</i></b>			<b>Year 1</b>	<b>Year 2+</b>	
Start-up costs			\$3,630		
Fertilizer per pot			\$400	\$400	
Pest management (predators, stylet oil, sticky cards)			\$1200	\$1200	
Bee hives (2 @ \$125 each)			\$250	\$250	
Greenhouse costs \$0.10 per sq. ft. per month, 5 months			\$1150	\$1150	
Labor			\$896	\$1056	
<b>TOTAL</b>			<b>\$7, 526</b>	<b>\$4,056</b>	
<b>Labor breakdown</b>			<b>Year 1</b>	<b>Year 2</b>	
Set-up outdoors			12 hrs	16 hrs	
Move plants into house			8 hrs	8 hrs	
Trellising		(8 hrs. twice)	16 hrs	16 hrs	
Irrigation set-up		(8 hrs. twice)	16 hrs	16 hrs	
Scout/Biocontrol		(2 hrs/wk)	40 hrs	40 hrs	
Primocane management			8 hrs	24 hrs	
Move plants outside			8 hrs	8 hrs	
Remove trellis and irrigation			4 hrs	4 hrs	
<b>TOTAL</b>			<b>112 hrs</b>	<b>132 hrs</b>	
<b><i>III. Harvest costs</i></b>					
\$0.50 per half-pint piece work \$0.10 per half-pint for containers					
<b><i>IV. Yields and profitability</i></b>					
(Yields per plant: 2 half-pints {Year 1}, 16 half-pints {Year 2}; Price received: \$3.00/half-pint)					
Year	Yield	Income	Expenses		
			Harvesting	Production	Total Profit
Planting year	0	0	0	\$7, 526	(\$7,526)
Year 1	600	\$1,800	\$360	\$7,526	(\$2,616)
Year 2	4,800	\$14,400	\$2,880	\$4,056	\$7,464
Year 3	4,800	\$14,400	\$2,880	\$4,056	\$7,464
<b>TOTAL</b>	<b>10,200</b>	<b>\$30,600</b>	<b>\$6,120</b>	<b>\$19,694</b>	<b>\$4,786</b>



A few examples of independent growers growing greenhouse raspberries

This is what it's all about - smiles and happy customers!



## Suggested Readings

- **Bramble Production Guide** NRAES-35  
(Pritts, M. P., Handley, D. 1989. (NRAES) Natural Resource, Agricultural & Engineering Service)  
Available for purchase at: <<http://www.nraes.org/publications/nraes35.html>>
- **Cornell Fruit Resources** <<http://www.fruit.cornell.edu/berry.html>>
- **Cornell Greenhouse Horticulture Resources**  
<<http://www.hort.cornell.edu/greenhouse/cropcult/culture.html>>
- **Compendium of Raspberry and Blackberry Diseases and Insects** (Ellis, M.A., Converse, R.H., Williams, R.N., and Williamson, B. 1991. The American Phytopathological Society)  
Available for purchase at <<http://www.apsnet.org/>>
- **High Tunnel Plasticulture Resources** from Penn State <<http://plasticulture.cas.psu.edu/>>
- **Water and Nutrient Management for Greenhouses** NRAES-56  
(Weiler, T. C., Sailus, M. 1996. (NRAES) Natural Resource, Agricultural & Engineering Service)  
Available for purchase at: <<http://www.nraes.org/publications/nraes56.html>>
- **Greenhouse Operation and Management**  
(Nelson, P. 2002. 6th edition. Prentice Hall College Div.)  
(Provides detailed instructions in layman's terms.) Available for purchase through your local and on-line book sellers.
- **The Ball Redbook**  
(Internet link for print resources for all aspects of greenhouse operations.)  
<<http://www.ballpublishing.com/commerce/>>

## Sources for Biological Controls and Bumble Bees

- Biotactics Inc., 20780 Warren Road, Perris, California 92570.  
Phone: (909) 943-2819, FAX: (909) 943-8080, E-mail: [sales@benemite.com](mailto:sales@benemite.com)  
<<http://www.benemite.com>>
- Crop King, 5050 Greenwich Road, Seville, OH 44273-9413  
Phone: (330) 769-2002, Fax: (330) 769-2616  
<<http://www.cropking.com>>
- GB Systems, P.O. Box 19497, Boulder, CO 80308 or P.O. Box 39063,  
N. Avon Belden Rd., North Ridgeville, OH 44039 (216) 353-9437
- The Green Spot, 93 Priest Rd., Nottingham, NH 03290 (603) 942-8925  
<<http://www.greenmethods.com>>
- Hydrogardens, P.O. Box 25845, Colorado Springs, CO 80936-5845  
Phone: (888) 693-0578, FAX (800) 694-6362  
<<http://www.hydro-gardens.com>>
- IPM Laboratories, P.O. Box 300, Locke, NY 13092 (315) 497-2063  
<<http://www.ipmlabs.com>>
- Koppert Bio Systems, 28465 Beverly Rd, Romulus, MI 48174 (800) 928-8827  
<<http://www.koppert.nl/>>

An electronic database of suppliers of beneficial organisms with information on IPM may be accessed through the California Department of Pesticide Regulation homepage at  
<<http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm>>

Or request a written copy:  
California Department of Pesticide Regulation  
Environmental Monitoring and Pest Management Branch  
1020 N. Street, Room 161  
Sacramento, CA 95814-5604  
(916) 445-4300

For another comprehensive listing of biocontrol suppliers and information visit this website: <<http://www.anbp.org>>. This is the site of The Association of Natural Biocontrol Producers (ANBP), a professional association representing the biological pest management industry. ANBP membership includes producers, distributors, and in addition, users of natural enemies and researchers.

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- Demchak, K. *High Tunnel Production of Primocane-Bearing Raspberries*. Penn State University. 2003. Electronic access:<<http://www.fruit.cornell.edu/Berries/hightunnels.html>>.
- Pritts, M. P., *Raspberries in Winter: An Alternative Growing System for Northern States*. New York Fruit Quarterly, Vol. 6, No. 4. 2-4, 1999.
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- Pritts, M. P., W. Langhans, T. K. Whitlow, M. J. Kelly and A. Roberts. *Winter Raspberry Production in Greenhouses*. HortTechnology, Vol. 9 No. 1, 13-15, 1999.
- Thomas, C. Bug vs. Bug - *Sources for Biological Controls and Bumblebees*. Integrated Pest Management Program Pennsylvania Dept. of Agriculture. 200.3

## Glossary

**Adventitious bud** - A vegetative bud that develops along the root of a bramble plant and that will grow into a primocane.

**Aggregate fruit** – A type of fruit that develops from a single flower, but which consists of many smaller drupelets that fuse and ripen together.

**Annual** – A plant that completes its life cycle (vegetative growth, flower, and seed) in only one year.

**Anthesis** – The time at which a flower is at full bloom and the pollen is shed.

**Apical meristem** – A group of cells at the growing point of roots and shoots from which all vegetative or reproductive growth originates.

**Axillary bud** – A bud that develops in the axil of a leaf, the point where the leaf attaches to the shoot.

**Biennial** – A plant that requires two growing seasons to complete its life cycle; vegetative growth occurs the first year, reproductive growth the second year, and then the plant dies.

**Certified plant stock** – Plant from a nursery which have been visually inspected by a state representative and found to be free of virus and other disease symptoms.

**Chlorosis** – A yellow color that develops in a green leaf.

**Crown bud** – A vegetative bud originating from just below the base of a bramble plant and which will develop into a primocane.

**Cultivar** – A “cultivated variety”; an entity of commercial importance which is given a name to distinguish it from other genetically different plants.

**Cultural control** – The use of production practices typically used to improve plant growth and yield to also control pests.

**Cuticle** – The waxy layer on the surface of a leaf or fruit.

**Desiccation** – The process of drying or losing water.

**Differentiation** – The physiological and morphological changes that occur in cells, tissues, or organs during development and maturation.

**Drupelet** – The small sections of a raspberry or blackberry fruit, each containing a seed.

**Entomology** – The study of insects.

**Epidermis** – The outside covering or skin of a leaf or fruit.

**Evapotranspiration** – The total water lost through evaporation from the soil surface and from transpiration through the plant.

**Fall-fruiting** – A raspberry which forms fruit on the tops of first-year vegetative canes near the end of the growing season; the same as primocane-fruiting.

**Fertigation** – The delivery of nutrients using an irrigation system.

**Fibrous root** – A type of root system characterized by many branches of fine roots.

**Florican** – The second-year cane which overwintered and will fruit and die in the current year.

**Florican-fruiting** – A raspberry or blackberry which forms fruit only on second-year canes in late spring or summer; the same as summer-fruiting.

**Frass** – Plant residues or fecal material that remains after insect feeding.

**Hardiness** – The ability of a plant to withstand cold temperatures.

**Inflorescence** – A flower cluster.

**Instar** – A stage in the development of an insect between molts.

**Lateral roots** – Roots that originate from the primary roots.

**Leader bud** – Buds at the base of a cane, often underground, which have the capacity to grow into a primocane.

**Micronutrient** – An essential plant nutrient that is required only in small quantities.

**Necrosis** – The death of plant cells.

**Node** – The point of attachment of buds or laterals to the main cane.

**Ovary** – The enlarged lower part of the pistil, enclosing the ovules or young seeds.

**Oviposition** – The laying of an egg by an insect.

**Pathology** – The study of diseases and the organisms which cause them.

**Perennial** – A plant or plant part which lives for more than one year.

**Petiole** – The stalk of a leaf.

**pH** – A measure of the acidity or alkalinity of the soil ranging from 0 to 14; a low pH indicates acid, a pH of 7 is neutral, and a high pH indicates alkaline.

**Photosynthesis** – The process in a plant of making sugars for growth and respiration from the raw products of water, carbon dioxide, and sunlight.

**Phytotoxicity** – The ability of a chemical substance to cause harm to a plant, often used to characterize the effect of an herbicide on crops.

**Pistil** – The female reproductive organ of a flower.

**Pollination** – The act of placing pollen from the male reproductive organ onto the female reproductive organ of a flower; often is carried out by bees or wind.

**Primocane** – The first-year cane of a raspberry or blackberry.

**Primocane-fruiting** – A type of raspberry which forms fruit on the tops of first-year canes near the end of the growing season; the same as fall-fruiting.

**Receptacle** – The portion of the flower to which the flower parts attach.

**Respiration** – The process of converting sugars into carbon dioxide, water, and energy. Often, the energy is in the form of heat.

**Setae** – Bristle-like parts or organs of an insect.

**Shoot bud** – A bud on the aboveground portion of a plant.

**Stamen** – The male part of a flower; it produces pollen.

**Stigma** – The female portion of a flower upon which the pollen germinates.

**Stomata** – Pores on the bottom of a leaf through which carbon dioxide enters the plant and water vapor exits.

**Sucker shoot** – A young, vegetative cane originating from an adventitious bud on the root.

**Summer-fruiting** – A raspberry or blackberry which forms fruit only on second-year canes in late spring or summer; the same as florican-fruiting.

**Threshold** – A predetermined level below which no response occurs.

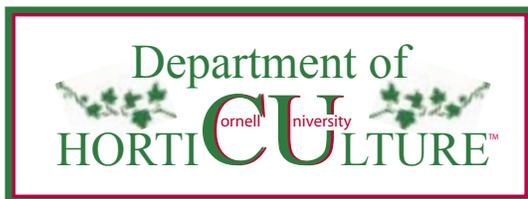
**Tipping** – The process of removing the tops of primocanes for the purpose of stimulating lateral branching; sometimes called pinching.

**Tissue culture** – A method of propagation in which whole plants are obtained from meristematic tissue in indoor facilities.

**Topping** – The removal of the top portion of cane after it has overwintered.

**Torus** – The center of a fruit to which the drupelets attach, also called the receptacle.

**Transpiration** – The process of water exiting the plant through the stomata.



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