High Tunnel Raspberries and Blackberries

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On line at: http://www.fruit.cornell.edu/berry.html

About this Guide

High Tunnel Raspberries and Blackberries is a work in progress composed of research results generated from ongoing bramble (raspberry and blackberry) high tunnel projects throughout the northeast region. Information in this guide comprises current thought on all aspects of bramble high tunnel production. New information and/or updated practices will be added as they become available.

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Additional Copies

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Introduction

Cornell and Pennsylvania State Universities are conducting research on high tunnel production to help northeastern berry growers capture a larger portion of the market for fresh berries through season extension methods. This publication, along with its counterpart, "Greenhouse Raspberries", (http://www.fruit.cornell.edu/Berries/bramblehtml/ghrasp.html) presents current data generated by this ongoing research.

Greenhouse production of raspberries and blackberries has helped to bridge one gap in establishing all season bramble production in the Northeast. However, using this method alone to cover bramble production during mid-winter months may not be cost effective for producers, especially in the face of rapidly rising energy costs. Conversely, the same rapidly rising energy costs also provide a unique opportunity for expanding local and regional market shares over those currently held by imports. Production of high quality, locally grown and shipped raspberries and blackberries could potentially shift the market supply from import to domestic along the Atlantic seaboard.

High tunnel bramble production offers the opportunity to bridge the remaining gaps in availability during late fall and late spring. Because tunnels offer a less expensive form of season extension than greenhouses, they appear to be an ideal production option when temperatures are not too cold.

Furthermore, high tunnels allow less hardy floricane-fruiting raspberries and blackberries to overwinter in climates where they would otherwise be killed. High tunnels allow primocane-fruiting blackberries to be produced where the growing season is too short otherwise to mature the crop.

These technologies, coupled with the continued development of new varieties and field production techniques, bring the goal of all season bramble production closer to fruition (no pun intended!) for northeastern small fruit growers.

What is a High Tunnel, Anyway?

High tunnels are simply large hoop houses covered in plastic (Figure 1), which allow the sides and end walls to be opened to regulate temperature. They provide an intermediate level of environmental protection and control between field production and greenhouse production.

High tunnels are usually not heated, though supplementary heat (such as portable space heaters) may be provided for protection on cold nights. Row covers used within high tunnels provide additional protection from cold temperatures. Most high tunnels typically have irrigation systems as their protective nature excludes rainfall.

Plants are generally established in ground in a high tunnel, rather than in containers with artificial media - although both types of production are possible.

In-ground high tunnel raspberry plantings are established at a relatively close spacing, frequently prior to tunnel construction.

Installing a tunnel over existing rows as an afterthought is difficult, and the row spacing cannot be changed. There is a possibility that diseases and weeds for berries grown in tunnels may gain a foothold in the planting prior to covering the tunnel, so close watch of conditions is necessary.

Figure 1. Raspberry high tunnel production in Scotland.

One difference between greenhouses and high tunnels is the plastic covering. Greenhouses are typically covered with double layers of polyethylene plastic that are replaced periodically as needed. High tunnel plastic is a single layer greenhouse grade plastic and may be applied and removed seasonally. With some types of high tunnels, seasonal plastic removal is a necessity.

Unlike their greenhouse counterparts, high tunnels typically do not have electric service or automated heating/ventilation systems. The sides of the high tunnel are constructed in such a way that they can be manually rolled up or opened for ventilation (Figure

2). They have no permanent foundation as poles are driven into the ground

Because of these structural differences, high tunnels are usually classified as temporary (removable) structures. This is an important distinction for taxation purposes in most areas; the non-permanent nature of high tunnels may allow them to fall outside certain tax, building, and zoning requirements.

Figure 2. Venting a raspberry high tunnel.

Greenhouses, on the other hand, are classified as permanent structures and as such are subject to various regulations and requirements. Check local zoning ordinances in your area for further details.

The Benefits of High Tunnel Production

Fresh local raspberries are typically available in the northeast from mid-June to early- October (Figure 3).

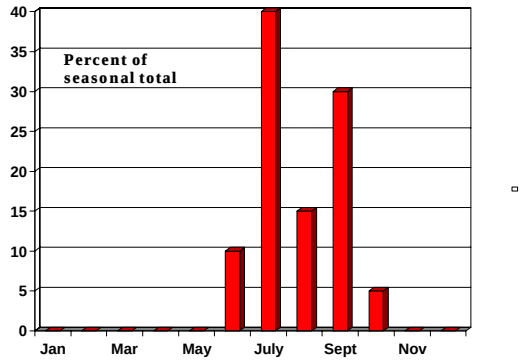


Figure 3. Current availability of fresh local raspberries in the Northeast. (Cornell University data)

Use of high tunnels in raspberry production can greatly extend the production season, beginning in May for some floricane-fruiting (summer fruiting) cultivars and extending through November for some primocane-fruiting (fall-fruiting) cultivars. This extended season can assist growers in capturing a larger market share, especially early and late season when premium prices are paid for raspberries (Figure 4).

Figure 4. Retail raspberry prices often range from $8.00 to $13.00/lb during early and late season periods.

For primocane-bearing raspberries, the yield increase under tunnels can be tremendous, partly due to lower incidence of gray mold disease. If managed only for a fall crop, at least double the yield per linear foot of row as compared to the field can be expected. If managed with a summer crop also, 2.5 to 3 times as much yield is reasonable, though the plants are likely to shift the majority of their yield to the summer without serious floricane thinning in the spring, down to 2-3 floricanes per foot.

The difference in yield and fruit size between field grown and tunnel grown black raspberries can be significant (Figures 5 and 6).

Figure 5. Tunnel grown 'Jewel' black raspberries.

Figure 6. Thornless blackberries (left) and black raspberries (right) under tunnel production.

For blackberries (Figures 6 and 7), tunnels can make the difference between no crop, and the equivalent of 25,000 lb per acre of marketable fruit. At this point, the yield increases appear to be attributed to two things: 1) a decrease in both stress and possible photosynthesis shutdown from wind and 2) adding 3-4 weeks of frost-free growing onto each end of the season, increasing growing time by 50%. There may also be other reasons as well.

Figure 7. Tunnel Grown Blackberries

High tunnel production also results in improved fruit quality and shelf life, and harvest of a more consistent crop. It also ensures continuous fruit production when conditions for field harvest are unfavorable.

Soil warming, wind, and rain protection are just some of the benefits of high tunnel production over field production. The need for disease, and insect, and wildlife management, compared to field production, is also reduced; this minimizes pesticide inputs. We have observed increased rodent activity in tunnels.

In addition, high tunnel production allows for diversification of farming operations, requires less capital expenditure than greenhouse production, and for relatively low investment, often yields high returns.

The above benefits not withstanding, good planning, cultivar selection, and detailed management are essential to successful high tunnel bramble production.

Site Selection

Plant Requirements

The same criteria for selection of bramble sites for field production apply for in ground raspberry and blackberry high tunnel production.

Soil quality is probably the most important of these factors. The top 20 inches of soil will contain about 90% of the raspberry root system. Brambles should be planted on deep, well-drained loamy soils. In addition, these soils should have good water-holding capacity and high organic matter content (>3%). Sandy loam soils may be acceptable but adequate irrigation must be provided. Clay and other heavy soils are not as desirable for raspberry production. Raspberries and blackberries do not tolerate "wet feet" well. Every effort needs to be made to provide adequate drainage. Heavier soils may be acceptable if drainage improvements are made prior to planting. Raised beds are generally of value.

Soils should be tested for nutrients and pH prior to site selection and planting. Brambles grow best at a pH between 5.5 and 6.5; pH values above 7.0 may result in iron deficiency. Values below 5.5 may result in poor establishment, growth, and yield.

Soil fertility may be improved by the addition of organic matter. Additional organic matter may take

several forms: dairy manure, compost, or 'green manure' cover crops. Dairy manure incorporated at the rate of 10-20 tons per acre provides N, P, K, and organic matter. It contains fewer weed seeds than horse manure, and is lower in nitrogen and phosphorus content than chicken manures while providing a similar amount of potassium.

A preplant cover crop seeded the year before planting is a second way to increase soil quality through the addition of organic matter. After a season of growth, the cover crop is incorporated into the soil where it decomposes. Legume cover crops provide more nitrogen than other cover crops, along with the added benefit of being turned down in early spring, a month or so before planting.

Other factors to consider in site selection include water quality and availability, previous cropping history, the possibility of significant herbicide carry over, and pest populations.

Water quality testing should be done prior to site selection in all instances

Brambles, particularly black raspberries, should not follow solanaceous crops (potatoes, tomatoes, or eggplant) or weeds (lambsquarters, pigweed, nightshade) or strawberries. These crops are highly susceptible to Verticillium wilt, which also affects raspberries.

Carry-over of triazine herbicides, such as atrazine used in corn production, may pose a potential danger to new bramble plantings.

Japanese beetle or chafer grubs may be present in soils formerly in sod for several years.

Soil tests are also needed to detect the presence of nematodes, microscopic soil "worms' which attack the roots of crops, causing crop damage and sometimes vectoring crop diseases.

For more information on these topics see "Site Selection and Preparation", Chapter 2 in the NRAES 'Raspberry and Blackberry Production Guide, 2nd Edition'

Structural Considerations and Orientation

After considering soil suitability, the next step is to examine the potential site in relationship to location of the high tunnel. On-farm placement is often one of the key factors to high tunnel success.

Gather information to help make an informed decision when selecting high tunnel sites:

- ❖What is the direction of the prevailing wind?
- ❖Water drainage on site?
- ❖Air drainage on site?
- ❖Potential snow and ice load?

The site selected should be relatively level and well-drained. Ideally, the tunnel should be perpendicular to prevailing winds to facilitate cross ventilation.

However, light interception also should be considered. During the standard growing season, plants in north-south rows receive the greatest and most even light interception. But very early or very late in the season, the south side of a tunnel will receive the most light. Therefore, it is preferable at high northern latitudes to orient the tunnel in an east-west direction to maximize light interception early and late in the season if the goal is season extension. If plant height differs from row to row due to a predictable factor such as cultivar, the shortest plants should be on the south side to minimize shading of other plants in adjacent rows.

Tunnels should be fully accessible without being in danger of damage from moving equipment. Proximity to other structures should also be reviewed in terms of blocking light exposure or equipment entrance and egress. The same would be true for environmental barriers or obstructions such as wind rows, ditches, bodies of water, large trees, embankments, etc. The distance between adjacent tunnels should be at least as far as the tunnels are tall.

Conversely, proximity to resources such as the water source, pump house, postharvest handling and equipment sheds may be beneficial in maximizing labor efficiency. The same environmental barriers or obstacles that may limit equipment accessibility could be beneficial for other reasons, such as serving as wind breaks.

Tunnel Selection

Types of High Tunnels

There are two main types of tunnels: single-bay and multi-bay. Single bay tunnels may have a peaked frame, or a Quonset-style frame. Multi-bay tunnels typically have a Quonset-style frame.

Peak-style frames are those whose supporting bows are bent at an angle forming a ridge or peak (Figure 8). This type of high tunnel construction better

supports snow load and facilitates snow shed than either Quonset (Figure 9) or multi-bay tunnels (Figure 10).

Figure 8. Peak-style high tunnel ribs (bows).

Quonset-style frames have smooth rounded bows, which are more susceptible to snow load damage than peaked tunnels

Figure 9. Quonset style high tunnel, Ontario, Canada.

Multi-bay style frames are those that are connected to cover larger acreages (Figure 7). It can be more difficult to regulate temperature in a multi-bay system. They, too, are not snow tolerant and plastic will need to be removed before winter. They are also more susceptible to high winds than single-bay tunnels due to less structure relative to the amount of area covered. In contrast to single bay tunnels, plastic should be opened and gathered for multi-bay tunnels under high wind conditions. Often they are used as rain shelters without temperature management. Use of a multi-bay system generates larger amounts of rainwater runoff and may necessitate a drainage system to carry water away from the structure.

Figure 10. Multi-bay style high tunnels, California.

Determining Tunnel Size

One factor to consider in selecting the proper size high tunnel for raspberry production includes having enough room to plant, monitor, maintain, and harvest the berries from inside the structure. In some instances, this may mean sufficient size to accommodate small tractors for cultivation and spraying.

Tunnel dimensions vary widely with manufacturer or construction plan. A typical size tunnel is 15 to 30 feet wide and 60-96 feet long. Wider tunnels have the advantage of being easier to manage; overall tunnel width, however, should not exceed 30 feet. Wider tunnels are usually taller.

Tunnels exceeding 96 feet in length pose some potential problems. Ventilation is limited in longer tunnels. Longer tunnels in use year round may be in jeopardy of collapse due to heavier snow loads. Longer tunnels may also pose psychological barriers for pickers. Peak height may range from 7 to 15 feet. A nine foot minimum peak for raspberry production is recommended. It is also advisable to install 4 to 5 foot side post extensions to increase air circulation, to reduce heat accumulation in the tunnel, and to accommodate the height of the raspberry plants.

Higher tunnels permit more stable temperatures at the level of the plants. Vents installed either in the roof or on the end walls below the peaks will allow hot air to escape and draw cool air into the structure. The higher the tunnel, the more air flow that can occur through the vents. With low tunnels without vents, temperatures inside the tunnel can damage plants on calm, summer days – even when the sides are rolled up.

Sources for Tunnels and Tunnel-related Materials

Regional High Tunnel Suppliers
Ledgewood Farm Greenhouse Frames
Rte 171
Moultonboro, NH 03254
Phone: (603) 476-8829
www.ledgewoodfarm.com

Rimol Greenhouse Systems Inc.
Northpoint Industrial Park
40 Londonderry Turnpike
Hooksett, NH 03106
Phone: 877-746-6544
http://www.rimol.com/

Greenhouse Supply Inc.
12 Acme Road, Suite 212
Brewer, ME 04412
Phone: 800-696-8511
www.harnois.com

Haygrove Multibay Tunnel Systems
Cramer's Posie Patch
116 Trail Road North
Elizabethtown, PA 17022
1-877-CRAMERS
www.haygrove.co.uk

Farm Tek
1440 Field of Dreams Way
Dyersville, IA 52040
1-800-327-6835
http://www.farmtek.com/farm/supplies/home

Grower who also makes tunnels:
Howard Hoover Family Farm
2849 Swartout Road
Penn Yan NY 14527
315-536-3192

Additional High Tunnel Suppliers

1. M. Leonard (Piqua, Ohio) www.amleo.com
2. Atlas Greenhouse Systems, Inc. (Alapaha, Georgia) www.AtlasGreenhouse.com
3. Conley's Greenhouse Mfg. (Montclair, California) www.conleys.com
4. CropKing, Inc. (Seville, Ohio) www.cropking.com
5. GothicArch Greenhouses (Mobile, Alabama) www.gothicarchgreenhouses.com
6. Grow-It Greenhouse (West Haven, Connecticut) www.growitgreenhouses.com
7. Hoop House Greenhouse Kits (Mashpee, Massachusetts) www.hoophouse.com
8. Hummert International (Earth City, Missouri) www.hummert.com
9. International Greenhouse Company (Georgetown, Illinois) www.igcusa.com
10. Jaderloon (Irmo, South Carolina) www.jaderloon.com
11. Keeler Glasgow (Hartford, Michigan) www.keeler-glasgow.com
12. Ludy Greenhouses (New Madison, Ohio) www.ludy.com
13. Poly-Tex Inc. (Castlerock, Minnesota) www.poly-tex.com
14. Speedling Inc. (Sun City, Florida) www.speedling.com
15. Stuppy Greenhouse Mfg (Kansas City, Missouri) www.stuppy.com
16. Turner Greenhouses (Goldsboro, North Carolina) www.turnergreenhouses.com
17. XS Smith (Eatontown, New Jersey) www.xssmith.com
18. Zimmerman's Welding (Versailles, Missouri) 573-378-4770

High Tunnel Construction Plans:
Penn State high tunnel plan:
http://plasticulture.cas.psu.edu/Design_construction.pdf

University of Kentucky high tunnel plan:
http://www.uky.edu/Ag/NewCrops/hightunnel.pdf

New Mexico high tunnel plan:
http://cahe.nmsu.edu/pubs/_circulars/CR-606.pdf

Additional High Tunnel Resources:
High Tunnels web site: http://www.hightunnels.org

Growing for Market web site
http://www.growingformarket.com/
Featuring: *The Hoophouse Handbook*, available in softcover, or as a downloadable e-book and *Growing for Market* newsletter.

Northeast Sustainable Agricultural Research and Education program (NESARE) website:
http://www.uvm.edu/~nesare/FGinfon.html.

Tunnel Construction

Erecting the Superstructure

A brief overview of tunnel construction is provided here by way of introduction. Follow the manufacturer's instructions provided or do-it-yourself design plans. Careful attention to construction details facilitates ventilation; the better the construction, the easier the sides roll up. *Note*: Tunnel construction is far easier on level ground. Most tunnel framing consists of steel pipe or tubing (or PVC tubing). These are bent into bows and form the 'ribs' of the high tunnel (Figure 8). It is important

to note peak-style tunnels shed snow loads better than the more gradual curves of Quonset-style tunnels (Figure 9).

After standard soil preparation, metal pipes are driven into the ground along the sides of the tunnel at set intervals, depending on the model of tunnel under construction. The pipes need to be set at approximately 2 feet in depth. The metal bows or ribs are then set into the ground pipes and fastened in place with bolts.

Figure 11. Peak-style high tunnel framing - side view showing close up of batten board fastening.

Batten boards are added to stabilize the structure and hold plastic in place (Figures 9 and 10).

Figure 12. Peak-style high tunnel framing - side view showing batten boards.

Tunnel ends may be plastic or wood, but should be hinged in some fashion to permit ventilation in the summer and entrance and egress of equipment. (Figures 13, 14, 15, and 16).

Figure 13. Peak-style high tunnel framing – front view shows end framing. Doors open outwards at both ends.

Figure 14. Peak-style high tunnel framing - close-up of end door.

Figure 15. End door construction (L to R) door stop, pulley system for door closure, door closure.

Applying the Plastic

High tunnels are typically covered with a 6-mil layer of polyethylene plastic. Plastic technology continues

to advance; consult a plastics specialist before purchasing a cover to get the best plastic available.

Figure 16. Hinged plastic covered tunnel doors.

Choose a time of day that is relatively calm with little or no wind (i.e. early morning) to apply the plastic. Several pairs of hands are useful in helping to unfold and secure plastic (Figure 17).

Unroll the plastic over the top of the tunnel. Allow several inches (< 8 inches) of overhang on the end so plastic may be adjusted later if need be and to help in rain runoff. Beginning there, fasten the plastic from the top down. After one end is secured, pull the plastic tight (not too tight; it will cut during fastening) and fasten the opposite end.

Fasten the plastic to the side batten boards approximately 5 feet above the soil line on each side of the tunnel. Wiggle wire works well for this purpose (Figure 18).

Figure 17. Applying the plastic over the high tunnel superstructure.

Figure 18. Fastening the plastic to batten boards with wiggle wire. The wire secures the plastic by pinching it in a channel.

Black straps made of batten webbing are then fastened to hook eyes in the batten board and tossed diagonally over the tunnel and fastened on the opposite side to help prevent the sides from flapping and chafing in the wind (Figure 19).

Figure 19. Webbing applied over plastic to keep it from blowing in the wind.

Vertical sidewalls below this point are attached to a metal pipe along the length of the structure. A crank or T-handle is then attached to the pipe and is used to roll or unroll the plastic (Figure 2) on the pipe in order to open and close the tunnel sides (Figure 20).

This provides protection from rain, ventilation in summer, and heat retention during colder periods.

Figure 20. Open vertical side wall.

Optional: Tunnel floors may be covered with a layer of black weed barrier. The purpose of this barrier is 4-fold; 1) it controls weeds, 2) it helps raise the temperature inside the house, 3) it prevents evaporation of soil moisture, and 4) it allows excess water to drain. This barrier should extend across the full length and width of the tunnel and extend slightly under the sides.

For more information on tunnel construction, see http://plasticulture.cas.psu.edu/Design_construction.pdf or see the "High Tunnel Production Manual, 2nd Edition". An assortment of publications using various other designs and techniques can be found at http://www.hightunnels.org.

Removing the Plastic

Plastic removal is done in reverse order of plastic application. Replacement is length and wear dependent but should occur on approximately a 3 year interval for tunnels in year round use. Plastic on tunnels used for end of season extension only may be usable for longer periods. Most wear and tear of plastic is caused by fasteners, in some cases reducing plastic life.

Multi-bay tunnel covers are rolled when not in use, and rest in the valleys where bays connect to keep them off of the ground. These should be covered with black plastic when rolled to protect from sun exposure and degradation.

Tunnel Maintenance

Tunnel structures remain relatively maintenance free. Plastic should be inspected regularly for wear and tear; rips should be repaired immediately with clear tape.

If the plastic remains on the tunnel for the winter, periodic removal of snow load may be needed to avoid structural weakening or collapse. This is best done with a non-pointed object such as a long-handled floor broom head or squeegee before a stiff crust or ice forms.

Drip irrigation systems should be inspected for leaks each year before use; drip tapes are particularly attractive to rodents.

Plant Selection

Local raspberry production in the Northeast is split for the most part between floricane raspberries in the early and mid-seasons, and their primocane counterparts mid-to late season (Figure 21).

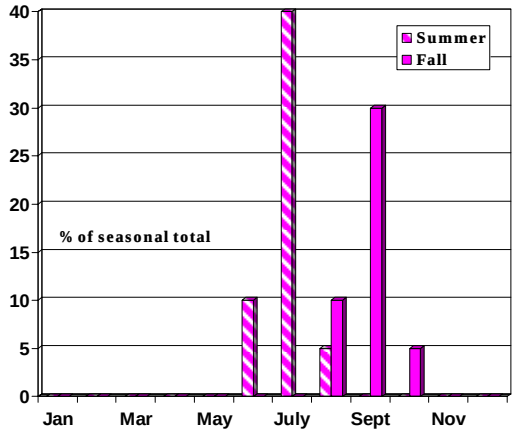


Figure 21. Current availability of fresh local raspberries. (Cornell University data)

First Season Management

Planting

Two types of bramble production are possible in high tunnels: in ground or containerized production. In ground production means the tunnel must be dedicated to that purpose alone, unless the tunnel itself is portable. Containerized production offers the advantage of having multiple crops grown in the same tunnel at different points during the growing season when raspberries are not in the bloom to harvest period.

Planting should be done much in the same manner as for field establishment, with the exception of plant spacing (See sections on containerized and in-ground planting for details). First year in-ground plantings may be given a light mulch, such as straw, to help

with establishment. Containerized plantings may be mulched with compost.

Monitor soil moisture carefully. Plants should not be subject to moisture particularly during the first few months of growth. No additional nutrients should be required during the establishment year for in-ground plantings beyond that applied pre-plant according to soil test recommendations. Containerized raspberries, of course, will require fertigation. This topic is discussed in more detail in the sections that follow.

Containerized Raspberries and Blackberries

Containerized bramble high tunnel production (figure 22) allows use of the high tunnel during non-bramble production periods for other crops. It does, however, involve more labor input in terms of transporting containerized plants into and out of the structure.

The key to successful containerized bramble high tunnel production lies in maintaining plant health. Pay careful attention to selection of plant materials, growth medium, and containers. It is also important to provide adequate soil moisture and nutrients during plant establishment and growth.

Figure 22. Containerized bramble production.

Plant Spacing and Selection

Plants should be arranged in rows with approximately a 2-ft in –row spacing and a minimum of 5.5 to 6-ft between row spacing for floricane raspberries. Keeping the rows far enough apart for blackberries (preferably 9 ft minimum), is important in keeping the foliage dry, and in decreasing the disease incidence. Primocane raspberries and may be set closer together with a 7-ft between-row spacing.

Be sure to leave at least a 3 ft space between the tunnel sides and the outside rows. Estimate the total number of containerized raspberries needed for the size tunnel selected. Be sure to include extra plants to use as replacements for any plants which may not survive from year to year.

Three types of plant materials are available for establishing container-grown raspberries: tissue culture plug plants, dormant short canes, and dormant long canes. Table 2 lists advantages and disadvantages for each type of plant material.

Characteristics	Tissue culture plug plants	Dormant short canes	Dormant long canes
Plant growth and development	Consistent stand of plants, fruiting at approx. same time.	Vary in growth rate, dormancy, and time of fruiting.	Vary in growth rate, dormancy, and time of fruiting.
Plant material	Certified virus-free. No pre-existing diseases and pests.	Virus-indexed. Possibility of pre-existing diseases and pests.	Virus-indexed. Possibility of pre-existing diseases and pests.
Climatic restraints	Sensitive to drought. Susceptible to frost damage.	Sensitive to pre-plant desiccation. Frost tolerant.	Sensitive to post-plant heat stress. Frost tolerant.
Years to harvest	3 (some fruit year 2) Does it really take this long?	2, 1 with primocane-bearers? We got a lot of fruit in year 1....	1 (smaller yield)

Table 2. Plant materials types for containerized raspberries.

Establishing Plants

The growth medium selected for containerized high tunnel brambles should be a well-drained medium with high organic matter, and a pH between 5.5 and 6.5. Both custom and commercial mixes have been used with success for containerized bramble growing. It may be advisable to include some sand in the medium you select to add weight and keep containers from tipping over too easily.
Containers range in size from of 3 (minimum) to 7 gallons. Select the smallest pot size needed to get maximum growth at minimum weight as plants are moved frequently!

One tissue culture plug plant or dormant cane is planted in each container. Plant materials should be watered in after planting and receive adequate water during establishment. A layer of compost applied to the pot surface will aid in retaining moisture and reduce evaporation.

Summer fruiting raspberries and blackberries may be grown outside the first season in or near the uncovered tunnel (Figure 23). The tunnel floor should be covered with weed barrier fabric or gravel before plants are moved inside for fruiting.

Figure 23. Brambles grown outside for fruiting under tunnels later in the season.

Potted brambles are then moved into the high tunnel, or plastic applied to the uncovered tunnel over the plants when they begin to flower.

Containerized bramble plants may be used for several successive seasons. After harvest, containers are moved outside until fall. Pruning should be done before plants are moved to winter storage areas to facilitate plant movement and minimize damage during transit. Storage areas should protect plants from sub-freezing temperatures and rodent damage. Plants are then moved outside in successive years in spring. They should be located outside in as close proximity as possible to the high tunnel where they will be fruited.

Currently, little information is available on variety performance for containerized high tunnel brambles. Varieties which performed well in containerized greenhouse production may also be suitable for high tunnel production. Some of these include the primocane raspberry varieties 'Autumn Bliss', 'Autumn Britten', Josephine' and 'Caroline', and floricane raspberry varieties 'Cascade Delight', 'Chilliwack', 'Titan', 'Encore', and 'Tulameen'.

In-Ground High Tunnel Brambles

In ground production requires that the high tunnel be dedicated to bramble production alone, unlike containerized production, where other crops may be produced during off-bramble production periods.

Bed Preparation

Work in compost (6 tons/acre) or manure (10-20 tons/acre) or cover crop to increase soil organic matter content. This builds needed water-holding capacity as only irrigation water will be available to plants under the tunnel. In addition, one may want to work in a slow release fertilizer (100 lb actual N/acre) at the same time to compensate for lower bioactivity and slower nutrient release under tunnel soil conditions. This fertilizer should be sufficient to feed plants for the first year.

Plant Spacing and Selection

Raspberry rows within the tunnel should be at least 6 ft apart to allow for movement of people and equipment. Blackberries rows should be on an 8-ft spacing. Closer spacing becomes a serious management issue due to vigorous cane growth under tunnel conditions, and is not recommended.

In-row spacing should be closer than the 3 ft recommended for field plantings.
Summer raspberries grown for early season production should be spaced approximately 2 ft apart.

Type of Raspberry		
Red	**Black**	**Purple**
Lauren	Jewel	Royalty
Prelude		
Titan		
Tulameen		

Table 3. Floricane raspberries for in-ground high tunnel production

Type of Raspberry	
Red	**Yellow**
Caroline	Anne
Heritage	Golden Harvest
Josephine	Goldie/Kiwigold
Polana	
Autumn Britten	

Table 4. Primocane raspberries for tunnel production

Fall-bearing raspberries may be planted at the same spacing unless a first year harvest is desired. A one foot spacing, coupled with early plastic cover often results in vigorous first year growth yielding a significant harvest for the planting year. Plants should be established as early in the spring as

possible in the planting year to further maximize first year harvest.

Irrigation System Selection and Installation

Water quality and quantity are critical to high tunnel production as the water source provides all moisture inputs for the tunnel, unlike field production, where the water source is secondary to precipitation. Water quality testing should be done prior to site selection in all instances.

Much work has been done on designing and installing drip irrigation, which will not be re-iterated here. See the bibliography for resources on drip irrigation design and installation for more information.

Moisture and Fertilizer Requirements

Soil moisture should be measured using a tensiometer or other methods (see bibliography) at regular intervals. Drip irrigation may be needed as often as 2 to 3 times per week, depending on readings. It is critical to carefully monitor soil moisture and irrigate as needed; no other moisture source is available for sustaining plant growth and development under the tunnel.

Nutrient levels should be sufficient for the establishment year if a slow-release fertilizer was incorporated during bed preparation. Leaf analysis should be done in early summer of the second year. Nutrients should be amended based on analysis results through use of soluble fertilizers applied through an injection system into the drip irrigation. A ball park estimate might be 100 ppm nitrogen twice a week; remember to adjust this based on analysis results.

Controlling Environmental Conditions (Tunnel ventilation)

Temperatures inside the tunnel are moderated by opening and closing sides, end doors, and peak vents. Sides may be rolled up fully, or partially, depending on outside temperatures (Figure 20).

During the summer, sides can remain rolled up day and night. In spring and late fall when temperatures are cold at night, sides should be closed.

Sides should be opened each morning to dry leaves on which condensate collected at night, and closed before sunset to keep houses warm during the night.

Figure 24. Drip irrigation ingress pipe with in-line water filter and faucet for hose attachment.

Peak vents should also be opened in the mornings to (Figure 25) create a draft by allowing warm air to escape as it is replaced by cooler air entering from rolled sides, drying foliage more quickly.

Opening end doors is a quick way of reducing heat build-up on warm days.
During the winter, tunnels may be kept closed to keep snow out and encourage an early start to the spring season.

Figure 25. Venting the tunnel – peak vents.

Care and Management of Established Plantings

Pruning/Trellising

The same techniques apply under high tunnel production as they do for field production for both floricane and primocane raspberries (Figure 26). However, it is highly recommended that the V shape spread should be avoided or kept very narrow due to the narrow confines of tunnel.

Figure 26. Trellis system.

Primocane raspberries require a modest trellis to hold canes erect for harvest. This trellis can be removed each year so canes can be cut to the ground. In-ground floricane raspberries and blackberries require a more substantial trellis to hold canes erect. Because of limited space within the tunnel, the objective of the trellis to is hold canes erect to facilitate harvest – rather than maximizing light interception per plant.

Weed Management

It is not possible to over- emphasize the importance of using cultural methods such as cover cropping to reduce weeds prior to planting. A spring pre-emergent herbicide maybe applied if needed (i.e. Devrinol). A post-emergent herbicide may also be applied 6 weeks later (i.e. Gramoxone). Rototill between rows to reduce weeds as needed. Hand weeding is best for in-row weed suppression. Weeds are most likely to be problematic around outside edges of the tunnel. A narrow width of landscape fabric aids greatly.

Pollination

Unlike greenhouse grown brambles which always require introduction of pollinators, there is plenty of natural pollinator activity in high tunnels with native bumblebees. Bumblebees are especially fond of high tunnels during late season extension and may be found waiting to enter as soon as doors open or sides roll up on warm fall days when plants are in bloom (Figure 27).

Figure 27. Native bumblebees fill the tunnel on fall days when raspberries are in bloom.

Pest Management Considerations

Bramble pest management needs under high tunnels, as with greenhouses, are greatly reduced compared to field production. That said, regular scouting remains the first and foremost line of defense in pest management. Plant health should be monitored frequently (1-2 times/ week) and careful records of growth and development kept from week to week, as well as season to season.

Abiotic (Non-biological) disorders and diseases

Careful tracking of nutrient, moisture, and temperature levels should preclude development of most environmentally–based disorders. Routine soil and foliar analysis will aid in preventing development of nutrient deficiencies.

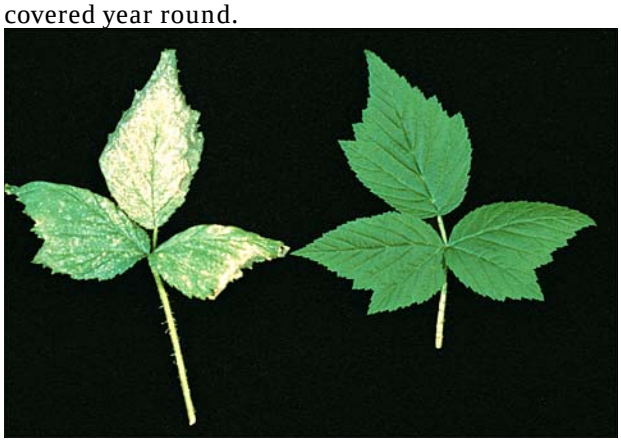
Insects

Insects found to be of concern under high tunnel production include two-spotted spider mites (Figures 28a and 28b) and Japanese beetles (Figure 29). Biological control options are available for both insects and if applied while populations are at or below threshold levels, maybe used with some success under high tunnel conditions.

Figures 28a. Adult two-spotted spider mite.

Management of two-spotted spider mites on brambles may require only two releases of predatory mites during life of the planting.
If serious outbreaks occur and are not caught early enough for biological control measures to be effective, follow conventional field recommendations for their reduction and control.

Mites can be particularly bad when tunnels are covered year round.



Figures 28b. Two-spotted spider mite d damage on raspberries.

Diseases

Disease pressure under high tunnel production conditions is minimal compared to field production. The tunnel structure helps in minimizing environments favorable to disease development by excluding precipitation. Careful ventilation to keep relative humidity at low levels and foliage dry will further offset disease.

The most frequent foliar diseases observed under high tunnel production include powdery mildew and rusts. These diseases are favored more by high relative humidity than actual leaf wetness.

Figure 29. Japanese beetles and damage on high tunnel raspberries.

Powdery mildew is caused by the fungus *Sphaerotheca macularis*, and appears as a white powdery patch covering plant surfaces (Figures 30a, 30b, and 30c). *S. macularis* is an obligate parasite, meaning it can only grow on its live host. Most mildews are also host specific, infecting only one host. Powdery mildew may occur on all parts of the bramble plant, including leaves, flowers, and petioles, fruit (Figures 31a, 31b, and 31c). The white patches (fungal mycelium) produce wind-borne spores (conidia) that continue to cause new infections under favorable disease conditions. Care in locating tunnels away from areas where wild brambles grow may help in reducing disease development and spread.

Powdery mildew may be a problem on susceptible cultivars of red, black and purple raspberries. Blackberries and their hybrids are usually not affected by powdery mildew.

Raspberries show varying degrees of resistance to mildew infection; 'Heritage' is somewhat more resistant to mildew infection than the other varieties tested in high tunnels. Selection of varieties with known resistance to powdery mildew infection is advisable.

Cultural control methods may also be of some benefit in mildew control. Careful attention to ventilation to keep relative humidity low will help to reduce powdery mildew infection. While fungicide treatments for powdery mildew are generally not needed in the field, they may be needed under tunnel conditions to prevent widespread disease.

Fungicides are labeled for use if needed. Consult the berry pest management guidelines for your area for further details.

Figure 30a. Powdery mildew on raspberry foliage

Figure 30b. Powdery mildew on raspberry buds and blossoms.

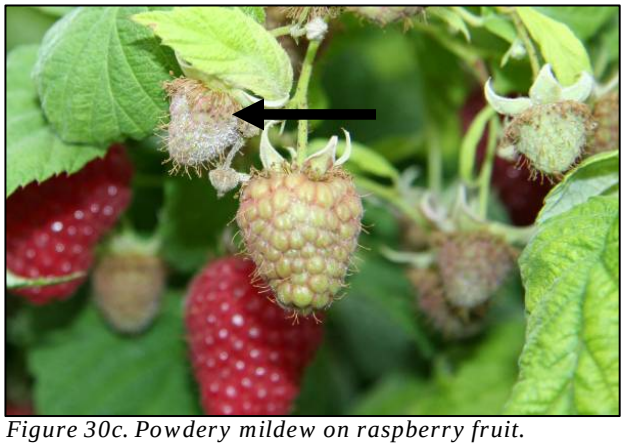


Figure 30c. Powdery mildew on raspberry fruit.

Late leaf rust is a fungal disease of raspberry caused by the fungus *Pucciniastrum americanum* (Figures 28a, 28b, 28c). It does not affect black raspberries or blackberries. This fungus affects many plant parts including canes, leaves, petioles and fruits.

Unlike powdery mildews, rust fungi typically require two hosts to complete their life cycle. White spruce (*Picea glauca*) is the alternate host for late leaf rust. Locating tunnels away from spruce plantings or removing white spruce in the immediate vicinity of the tunnel may be beneficial. Eradication of wild brambles may also help in reducing disease buildup and spread.

Figure 31a. Late leaf rust on the underside of raspberry leaves.

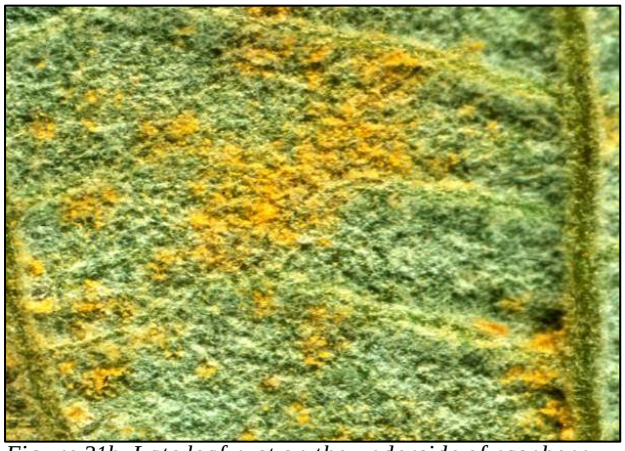


Figure 31b. Late leaf rust on the underside of raspberry leaves; note large light yellow patches between veins.

Very few products are labeled for control of late leaf rust in NY State. Consult your local Extension personnel for more information.

Figure 31c. Late leaf rust on t raspberry fruit.

A different type of rust may occur on purple and black raspberries and blackberries – orange rust (Figures 32a and 32b). This disease is caused by 2 similar fungi; *Arthuriomyces peckianus* on raspberry and *Gymnoconia nitens* on blackberry. Unlike *P. americanum*, these fungi require only one host to complete their life cycle and are systemic in nature; once plants are infected they remain infected for life. Orange rust does not kill its bramble host; however, infected plants are stunted and weakened, producing little or no fruit. Orange rust develops under conditions of low temperature (43 to 72 ^{o}F) and high relative humidity. These conditions are most prevalent early in the season, as opposed to late leaf rust, which develops in late summer early fall.

Figure 32a. Orange rust on lower leaf surface. Note small dark orange spots (pustules) on lower leaf surface.

Figure 32b. Orange rust. Note stunting of canes and foliage.

A fourth fungal disease also occurs under high tunnel conditions. Gray mold, caused by *Botrytis cinerea*, causes disease on bramble fruit and less frequently, on canes. While minimal gray mold occurs under high tunnel conditions as in compared to field production, it may occur at low levels (Figures 33a and 33b)

Figure 33. Gray mold (Botrytis fruit rot) of raspberry.

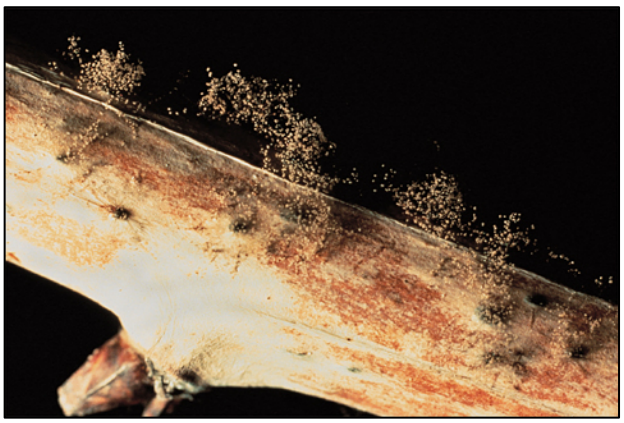


Figure 33. Cane botrytis of raspberry.

Cultural practices to reduce gray mold development and spread include:

- Harvesting all ripe fruit promptly.
- Use of trellising practices that promote air circulation around the berries.
- Removal of infected berries.

Wildlife

Wildlife damage, in general, is not a major concern under high tunnel production. Drip tape, however, is often appealing to mice, moles, and voles as winter habitat and nesting materials.

In addition, tunnels provide favorable habitats for wood chucks (Figure 34).

Figure 34. Woodchuck burrow opening into raspberry high tunnel, Ithaca, NY.

Season Extension

The best prices for raspberries and blackberries fall to those arriving early and appearing late in the season. High tunnel raspberry production is well suited to assist in capturing these market shares. To further enhance season extension capabilities, consider including management practices detailed below.

Early Season Extension

Early season raspberry production under high tunnels may be done with both floricane and primocane raspberries. Raspberries begin growth sooner and develop at a faster rate under the tunnels.

In this instance, raspberries are under plastic for the winter and get a head start in spring as air and soil temperatures in the tunnels rise more quickly than those outside. Light weight floating row cover can be used inside the tunnel, both to increase earliness of growth and to protect tender developing leaves on frosty nights. The cover is removed when plants reach approximately 18" in height. Fruiting may occur as much as 2 weeks earlier than in field grown plants of the same variety using this method.

Careful attention to tunnel venting and row cover removal is *essential* in early season raspberry production to prevent overheating on sunny days.

Floricane raspberries suitable for early season tunnel production include red, purple, black and yellow raspberries (Figure 32). Select early varieties with good cold tolerance for best results.

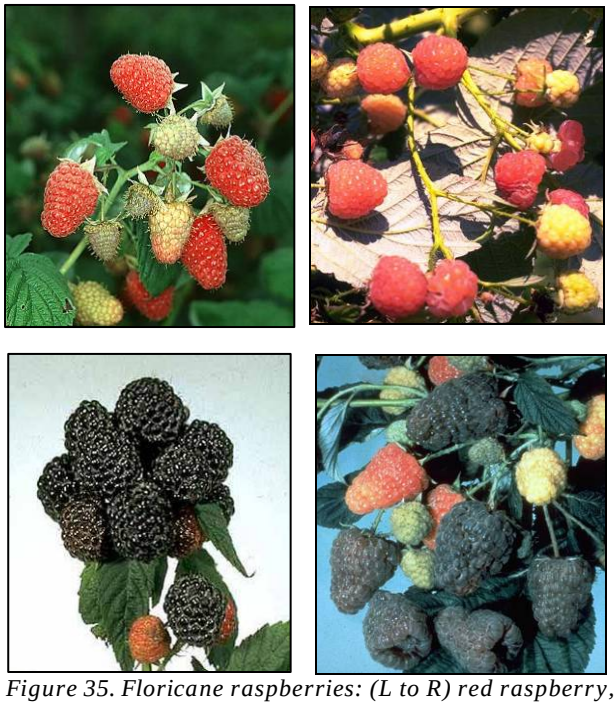


Figure 35. Floricane raspberries: (L to R) red raspberry, yellow raspberry (Rubus idaeus); Row 2: black raspberry, (Rubus occidentalis) and purple raspberry (R. idaeus x occidentalis)

Primocane raspberries (Figure 36) suitable for early season harvest under high tunnels include both red and yellow raspberries. In this instance, cold

tolerance may not be as critical a factor as for floricane raspberries.

Figure 36. Fall-fruiting (primocane) raspberry 'Heritage'

Late Season Extension

Primocane raspberries are well-suited for end of season extension under high tunnel production by planting late cultivars or delaying harvest, protecting fruit, and capitalizing on high prices.

Several techniques have been tested to date to delay harvest. Research results indicate that June pinching of 'Heritage' primocane raspberry can delay flowering and fruiting up to 3-4 weeks in comparison to unpinched controls. Only small differences in yield were observed between pinched and unpinched treatments when pinching occurred during June.

To use this technique, use a soft pinch to remove apical meristems and promote branching when canes are approximately 30 inches in height (Figure 37).

Figure 37. Cultural manipulation of primocane fruiting raspberries – early pinch method.

Season end may be extended further with the use of lightweight floating row covers under the tunnel. Covers are applied when night temperatures are predicted to fall to 25 °F or lower, and then removed in the morning.

Covers are removed during the morning when temperatures begin to rise inside the tunnel (Figure 38).

Figure 38. Light weight floating row cover used inside the tunnel protects fruit and foliage on colder nights.

Harvesting Fruit

Raspberries, in general, are highly perishable and have shorter shelf life than other fruits. That said, raspberries produced under high tunnels have improved shelf life over field produced raspberries and may be kept up to a week in cold storage without significant deterioration. Careful attention to harvest and post harvest handling and storage should provide reasonable shelf life for nearly any market situation (Figures 39 and 40).

Production of high quality raspberries requires special attention to a number of preharvest and postharvest factors, as well as the mechanics of harvest itself. Preharvest factors to consider include cultivar selection, growing site, plant health and nutrition, and disease and pest management.

Harvest conditions should also be considered for maximum berry quality. For example, avoid harvesting wet berries whenever possible. Waiting a few hours after sides are rolled up to begin harvesting can significantly reduce post harvest diseases and improve fruit quality. Visible decay can develop in less than 12 hours on warm, wet berries.

Along the same line, temperature can play a significant role in berry quality. Berries harvested early in the morning or in the evening when temperatures tend to be cooler have better shelf life. Harvested raspberries should never be left in the sun; their dark colors readily cause them to absorb heat.

Berries also continue to respire after harvest, generating their own internal heat, and causing shrinkage and reduced sweetness. Low temperature is one factor that helps to slow the respiration process, which is much faster in berry fruit than oranges or apples, for example. Raspberries should be cooled no later than 4 hours after harvest, sooner if possible. You'll get a much better return on your investment by making several trips to the cooling facility, than by making only one or two trips per day!

Figure 39. Harvesting high tunnel raspberries in late October, Ithaca, NY.

Raspberries ripen quickly, but not uniformly over the plant or planting. This necessitates harvest on as tight an interval as every other day. For best fruit quality, raspberries should be harvested before they are fully ripe. They should be picked when they are uniformly bright red in color, but before any darker color develops. Our rule is to pick them as soon as they release easily from the receptacle. Some varieties just won't pull off until they're really ripe and you only end up with pieces...Because of their highly perishable nature, brambles should always be picked directly into market containers. Half pint containers are preferable; containers should never hold more than 4 layers of berries to prevent crushing of fruit.

Figure 40. Harvesting fruit on cooler fall days.

Rules For Raspberry Pickers

Keep your hands clean at all times. Wash hands after each visit to the restroom.

Do not touch berries before they are ready to harvest.

Do not harvest over-ripe berries and leave immature fruit for the next harvest.

Berries should be removed with the thumb and forefinger, keeping the hand cupped under the berry to avoid dropping it.

Don't overfill your hands to avoid bruising or crushing fruit

Do not put trash or cull berries into the container.

Never allow harvested fruit to remain in the sun. Move harvested berries to the cold room or cooler as soon as possible

Note: Depending on codes and ordinances, the public may not be allowed inside a high tunnel to harvest fruit. Tunnels with public access may be classified as a structure, and be subject to building codes.

Budget for In-Ground High Tunnel Fall-Fruiting Raspberry Production, Ithaca, NY

Site Preparation and Tunnel Construction

- 2880 square foot tunnel (30' x 96')
- 4 rows per tunnel, 90 ft length per row
- Labor ranges from $10 to $15 per hour, depending on skill level

Preplant Costs	Input	Unit	Quantity	$/Tunnel
	lab test	sample	1.0	$ 15
Soil test	labor	hour	0.5	$ 10
	machine	total	0.1	$ 15
Tillage, land preparation	labor	hour	4.5	$ 15
Lime, compost, fertilizers,	materials	total	1.0	$ 50
herbicides	labor	hour	2.0	$ 15
Total				**$ 120**

Tunnel Construction Costs	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Nor'easter greenhouse	package	1.0	$ 6,405	10	$ 641
80 lb concrete mix	bag	4.6	$ 55	10	$ 6
Lumber		1.0	$ 932	10	$ 93
Exhaust shutters and door hinges		1.0	$ 209	10	$ 21
Storm door		1.0	$ 122	10	$ 12
Misc. Hardware	mixed	1.0	$ 118	10	$ 12
Labor	hour	166.0	$ 1,660	10	$ 166
Tufflifte infrared polyethylene covering	roll	0.4	$ 131	3	$ 44
Total			**$ 9,632**		**$ 995**

Planting and Growing

- Plant establishment - plants per tunnel = 144
- Variety: 'Heritage' primocane raspberry.
- Irrigation system: water drawn from municipal supply.
- Trellis construction: Eight ft metal posts, 7 per row. Two 32" metal cross bars per post.

Raspberry plants	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Plants, bare root	bare root	plant	144.0	**$ 173**	10	**$ 17**

High Tunnel Raspberries and Blackberries

Raspberry planting	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Plants, bare root	labor	hour	2.5	$ 25	10	$ 3
	34-0-0	pounds	6.0	$ 1	10	$ 1
Fertilizer	labor	hour	0.6	$ 9	10	$ 1
	mulch	bale	8.0	$ 24	10	$ 2
Straw mulch		hour	2.0	$ 30	10	$ 10
Hand hoe and weed	labor	hour	4.0	$ 60	10	$ 6
Rototill	labor	hour	3.0	$ 45	10	$ 5
Monitoring and ventilation	labor	hour	12.0	$ 180	10	$ 18
Total				**$ 374**		**$ 46**

Irrigation System	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
PVC coupling	material	each	1.0	$ 1	10	$ 0
Disk filter	material	each	1.0	$ 24	10	$ 2
Pressure regulator	material	each	1.0	$ 9	10	$ 1
Poly pipe adapter	material	each	1.0	$ 4	10	$ 0
¾" Poly pipe*	material	per 1oo ft	0.3	$ 9	10	$ 1
Poly pipe reducing tee	material	each	4.0	$ 8	10	$ 1
Poly pipe plug (3/4" insert)	material	each	1.0	$ 2	10	$ 0
18 mm drip in pc drip line	material	per 1000 ft	0.4	$ 108	10	$ 11
Netafilm line end	material	each	4.0	$ 1	10	$ 0
Teflon tape (1/2' x 260")	material	per roll	1.0	$ 1	10	$ 0
Hose clamp (1/2" x 1 ¼")	material	each	4.0	$ 7	10	$ 1
Hose clamp (3/4" x 1 ½")	material	each	10.0	$ 23	10	$ 2
Install irrigation system	labor	hour	1.5	$ 23	10	$ 2
Total				**$ 220**		**$ 21**

Trellis	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Metal posts, 8 ft	material	each	28	$ 210	10	$ 21
Lumber, pressure treated, (2'x4'x8')	material	each	19	$ 108	10	$ 11
Nuts, bolts, washers	material	each	3 x 56	$ 22	10	$ 2
Wire vise (5058v)	material	each	32	$ 75	10	$ 8
High tensile wire*	material	per 1000 ft	1.6	$ 27	10	$ 3
Post pounding	labor	hour	2	$ 30	10	$ 3
Cut, drill, install cross bars	labor	hour	4	$ 60	10	$ 6
Wire installation	labor	hour	3	$ 45	10	$ 5
Total				**$ 577**		**$ 59**

Summary of Initial Capital Investment for Tunnel

Item	$/Tunnel	Expected Life (yrs)	Annual cost
Preplant costs	**$ 120**	10	**$ 14**
Tunnel construction costs	**$ 9,632**	10	**$ 995**
Plants	**$ 173**	10	**$ 7**
Irrigation	**$ 219**	10	**$ 21**
Trellis	**$ 557**	10	**$ 59**
Total	**$10,710**		**$ 1,096**

Year 1 Production and Harvesting

- 4,000 half-pints per tunnel
- $2.50 per half-pint retail price
- Harvest labor per pint $0.50.

Production	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Cover tunnel	labor	hour	6.0	$ 60	1	--
Retighten cover	labor	hour	4.0	$ 40	1	--
Fertilizer	34-0-0	pounds	12.8	$ 2	1	--
	labor	hour	0.6	$ 9		--
Leaf analysis	lab test	sample	1.0	$ 23	1	--
	labor	hour	0.2	$ 2		--
IPM	yellow sticky cards	each	48.0	$ 14	1	--
	blue sticky cards	each	48.0	$ 28	1	--
Scouting	labor	hour	6.0	$ 28	1	--
	Sevin 80S	application	3.0	$ 2	1	--
	Malathion 57EC	application	3.0	$ 1	1	--
	Savey 50DF	application	3.0	$ 7	1	--
Apply pesticides	labor	hour	3.0	$ 45	1	--
Prune	labor	hour	4.0	$ 40	1	--
Train canes, trellis	labor	hour	4.0	$ 40	1	--
Narrow rows	labor	Hour	6.0	$ 60	1	--
Hand hoe and weed	labor	hour	4.0	$ 40	1	--
Monitoring and ventilation	labor	hour	12.0	$ 180	1	--
Total				**$ 621**		**--**

Harvest						
Half pint baskets	container	each	4,000	$ 200	1	--
Half pint shippers	container	each	334	$ 251	1	--
Plastic vented dome lids	container	each	4,000	$ 208	1	--
Picking, packing	labor	half pint	4,000	$ 2,000	1	--
Total				**$ 2,659**		**--**

Yield	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
harvested berries	gross income	half pint	4,000	$ 10,000	1	--
Total				**$ 10,000**	**--**	**--**

Year 2 Production and Harvesting

- 4,000 half-pints per tunnel
- $2.50 per half-pint retail price
- Harvest labor per pint $0.50.
- Replace plastic every 3 years

Production	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
Cover tunnel	labor	hour	6.0	$ 60	1	--
Retighten cover	labor	hour	4.0	$ 40	1	--
Fertilizer	34-0-0	pounds	19.0	$ 3	1	--
	labor	hour	0.6	$ 9		--
Leaf analysis	lab test	sample	1.0	$ 23	1	--
	labor	hour	0.2	$ 2		--
IPM	yellow sticky cards	each	48.0	$ 14	1	--
	blue sticky cards	each	48.0	$ 28	1	--
Scouting	labor	hour	6.0	$ 28	1	--
	Sevin 80S	application	6.0	$ 4	1	--
	Malathion 57EC	application	6.0	$ 2	1	--
	Savey 50DF	application	6.0	$ 14	1	--
Apply pesticides	labor	hour	6.0	$ 90	1	--
Prune	labor	hour	6.0	$ 60	1	--
Train canes, trellis	labor	hour	4.0	$ 40	1	--
Narrow rows	labor	Hour	6.0	$ 60	1	--
Hand hoe and weed	labor	hour	4.0	$ 40	1	--
Monitoring and ventilation	labor	hour	12.0	$ 180	1	--
Subtotal				$ 697		
Total				**$ 697**		--

Harvest						
Half pint baskets	container	each	4,000	$ 200	1	--
Half pint shippers	container	each	334	$ 251	1	--
Plastic vented dome lids	container	each	4,000	$ 208	1	--
Picking, packing	labor	half pint	4,000	$ 2,000	1	--
Total				**$ 2,659**		--

Yield	Input	Unit	Quantity	$/Tunnel	Expected Life (yrs)	Annual cost
harvested berries	gross income	half pint	4,000	$ 10,000	1	--
Total				**$ 10,000**		--

Summary of Annual Cash Expenses (per tunnel)

Year	Expenses	Revenue	Interest (8%)	Cash flow*
(establishment) **0**	($ 10,710)	---	($ 857)	($ 11,567)
1	($ 3,280)	$ 1o,0o0	($ 388)	($ 5,235)
2	($ 3,356)	$ 1o,0o0	($ 0)	$ 1,409
3	($ 3,318)	$ 1o,0o0	($ 0)	$ 8,091
4	($ 3,509)	$ 1o,0o0	($ 0)	$ 14,582
5	($ 3,318)	$ 1o,0o0	($ 0)	$ 21,264
6	($ 3,318)	$ 1o,0o0	($ 0)	$ 27,946
7	($ 3,509)	$ 1o,0o0	($ 0)	$ 34,437
8	($ 3,318)	$ 1o,0o0	($ 0)	$ 41,119
9	($ 3,318)	$ 1o,0o0	($ 0)	$ 47,801
10	($ 3,318)	$ 1o,0o0	($ 0)	$ 54,483

*** Excluding marketing costs**

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