Fruit Production in Tunnels

Curt R Rom
University Professor
Sustainable and Organic Horticulture
Food Systems
Co-Director, Center for Agricultural and Rural Sustainability
The Tunnel Team

C. Rom
E. Garcia
D. Johnson
J. Popp
J. McAfee
H. Friedrich
L. Freeman
D. Dickey
B. Lewis
German Rodriguez
Outline

• Why Tunnels?
• Opportunities for Tunnel Production
• Challenges in Tunnel Production
• Our Experiences with Berry Production
• Tunnel Modifications
• Making Tunnels Work
• Sustainable Berry Production
Why Grow in Tunnels?

Because!
Why Tunnels?

Environmental Modification with
A. Temperature Modification
B. Precipitation and Moisture Modification
C. Light modification
D. Wind reduction

Thereby allowing the grower to
1. Extend the growing season
   • Advance the Spring Season
   • Extend the Autumn Season
2. Minimize impacts of weather (hail, wind, etc.)
3. Mitigate Pest Problems
The Opportunities and Benefits from Tunnels

- Reduced Risk of High Risk Crops
- Never a “lost day” due to rain
  - You will always have crop to sell
- Increase Value of Crops
  - Increased yields; size, total yield
  - Out-of-season production
  - Reduced costs
- Extended Season means Extended Cash-Flow for the farm
- Potential Reduced use of Pesticides
- Opportunity for Sustainable and Organically Produced
- Possible better Economics
Opportunities for Specialty Crops

• Applications for High-Risk of High Value Fruit Crops

• Multi-Scale
  Suited to Multiple Markets
  – On-farm sales
    • Agritourism/Agri-entertainment
  – Farmers’ Markets
  – Local Retail
  – Wholesale
Not without Problems

• Management of the tunnels
  – Daily operation
• Problems with tunnel temperature management
  – Opening and closing the tunnels
  – Over-heating
  – “Super-cooling”
    • Problem of increased frost risk
• Problems with irrigating during the winter
• Soil management
• Insect pests; different pests, rapid population growth
• Pollination
• Problems with markets being open
• Problems with investment costs and return on the investment
A Place for Tunnels

Tunnels have a place in the production system to *compliment* field production.
Potential For Fruit in Tunnels

**Easier**
- Strawberries
- Blackberries
- Blueberries
- Raspberries

**More Difficult**
- Grapes
- Apples
- Peaches and Cherries
Other Potential Opportunities

• Peaches and Nectarines
• Cherries and Plums
• Figs
• Kiwi
• Growing Organically
• Movable Tunnels with other crops
Berry Production in Tunnels
Berry Crops for Tunnels

**Spring Crop**
- Floricane producing Blackberries
- Floricane producing Raspberries
- Blueberries

**Fall Crop**
- Primocane Producing Blackberries
- Primocane Producing Raspberries
Berry Problematic

- Berry production season is short: 4-6 weeks
- Rain can reduce summer floricane cropping harvest
- High temperatures limit raspberry production in South
- High late summer temperatures limit flower formation and fruit set of primocane fruiting blackberry and raspberry cultivars
- Early fall freezes (20-Oct) limit fruiting of primocane cultivars
Our Projects

Sustainable/Organic Berry Production in Tunnels

A. 2006-2010
   Blackberries and Raspberries
   1. Advancing Spring Production
      Blackberries: Navajo, Ouachita, Arapaho
      Raspberries: Dormanred, Prelude, and Encore
   2. Extending Fall Production
      Blackberries: Prime-Jan, Prime-Jim, APF46
      Raspberries: Dinkum, Caroline, Autumn Bliss
   3. Double-Cropping Primocane Cultivars

B. 2012-2014 Studies
   1. Advancing Spring Production
      – Blueberries: Earliblue
      – Blackberries: Natchez
   2. Extending Fall Production
      – Primocane Raspberries: Nantahala, Josephine, Autumn Bliss
      – Primocane Blackberries: PrimeArk 45®; PrimeArk Freedom®, APF###
Tunnels may extend the summer harvest season from 4-6 weeks during summer to 12-20 weeks during the year.
Observations from First Trials

- In both Spring and Fall Trials - Tunnels provided significant yield savings in rainy spring seasons
- Spring Harvest was advanced approximately 10-14 days. Potential for more with tunnel-in-tunnels and/or heat addition
- Across 3 seasons, HT spring blackberries were 30% larger and had >200% greater yields
  - Navaho performed the best although did not shift the season much before earlier ripening field produced cultivars
- Across 3 seasons HT spring raspberries yielded 480% more than field produced
  - Dormanred and Prelude had greatest yields
- Extended fall production until December in 2 of 3 years
- Annual and total Autumn Harvest primocane blackberry yields only 40% of spring floricane yields, but raspberry primocane and floricane yields almost equal
- Across 3 seasons, HT yields were ~150% greater than the field
  - Prime-Jan, although producing larger fruit in tunnels did not have any greater yield of HT vs Field; other cultivars (Prime-Jim and APF 46 had larger yields)
HT vs Field Yield Comparisons

Floricane Berries

- Tunnel: FL-Black ~16qts/10ft row
- Field: FL-Rasp ~9 qts/10ft row

Primocane Berries

- Tunnel: PR-Black ~7qts/10ft row
- Field: PR-Rasp ~1.5qts/10ft row

Average of 3 seasons during establishment; 2007-2009
CV: Natchez
Field vs Tunnel Cumulative Yield

2014 Natchez Blackberry Cumulative Yield

Date

Cumulative Yield (grams)

FD  HT

*Error bars represent standard error from the mean.

Last HT harvest 7/11

Date of 50% of Harvest

CV: Natchez
Field vs Tunnel Yield PrimeArk 45

*Error bars represent standard error from the mean.

CV: PrimeArk45
Cumulative Yield (Lbs / acre)

Production System

Field

High Tunnel

206% Increase

CV: PrimeArk45
Field vs Tunnel Cumulative Yield

CV: PrimeArk45 2014

*Error bars represent standard error from the mean.*
Field vs Tunnel Raspberry Yield

![Graph showing the comparison of total yield (grams per 10 ft plot) between different raspberry varieties grown in field and tunnel conditions. The varieties include Autumn Bliss FD, Autumn Bliss HT, Josephine FD, Josephine HT, Nantahala FD, and Nantahala HT. Error bars represent standard error from the mean.]

*lbs/A calculated at 8 ft row spacing  
*Error bars represent standard error from the mean.

2013
Field vs Tunnel Raspberry Yield

Average Yield (lbs/acre)

137% Increase

Field vs Tunnel

*lbs/A calculated at 8 ft row spacing

2013
Success and Challenges

- Advanced Crop, but not as much as planned
- Difficulty delaying flowering and fruiting of Primocanes to capture season extension
- Pests: Mites, aphids, white flies
- Temperature Problems: excessive heat, frosts
- Pollination
- Only need the tunnels for 3-5 months/year
  - An opportunity for movable tunnels
Observations and Thoughts

• Tunnels can **allow raspberry production** in our region more readily
• Spring production of blackberries, raspberries and blueberries **advanced 2-4 weeks**
  – Must select earliest maturing cultivars to make it work most effectively
• **Not all cultivars perform well** in tunnels.
• Potential for berries; not completely developed methods
• Tunnels may provide significant **opportunity for organic production**
  – May be more sustainable with reduced pesticides and water conservation
Tunnel Modifications

- Strawberries
- Blackberries
- Blueberries
- Grapes
- Raspberries
Tunnel Problems and Solutions

Problems
• Tunnels only provided 2 wks advance bloom; goal was 3-4
• Tunnels provide minimal frost protection

Solutions
• Tunnels in Tunnels
• Supplemental Heat
Tunnels in Tunnels
Tunnels in Tunnels & Row Covers with Supplemental Heat
Methanol chafing dish burners
1/50sqft
Burn 6-7 hrs
Effect of high tunnel and tunnel in tunnel on temperature with supplemental heating over a 48 hour period November 6-7, 2013.
Effect of high tunnel and tunnel in tunnel on ambient temperature difference with supplemental heating over a 48 hour period November 6-7, 2013.
## Do Tunnels Advance Bloom?

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date of Full Bloom</th>
<th>Days Advance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>Field</td>
<td>1-May</td>
<td>6-May</td>
</tr>
<tr>
<td>High Tunnel</td>
<td>18-April</td>
<td>14-April</td>
</tr>
<tr>
<td>HT+ Tunnel in Tunnel</td>
<td>12-April</td>
<td>8-April</td>
</tr>
</tbody>
</table>

CV: Natchez
# Do Tunnels Continue Harvest?

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date of Last Significant Harvest</th>
<th>Days Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>Field</td>
<td>15-Nov</td>
<td>1-Nov</td>
</tr>
<tr>
<td>High Tunnel</td>
<td>15-Nov</td>
<td>12-Nov</td>
</tr>
<tr>
<td>HT+ Tunnel in Tunnel</td>
<td>27-Nov</td>
<td>14-Nov</td>
</tr>
</tbody>
</table>

CV: PrimeArk 45
Summary and Conclusions

- Tunnels provide increased daily heat accumulation
- Tunnels provide minimal heat conservation during a frost
- Tunnels with supplemental heat had some temperature increase; heat added 0-5°F
- TnT provide increased daily heat accumulation over tunnels further advancing bloom and extending the season
- TnT provide increased heat conservation during a frost; added 2-5°F above tunnels
- TnT with supplemental heat had significant temperature increase; added 5-10°F
- TnT can limit pollination
Tunnel Problems and Solutions

Problems
• Spotted wing drosophila in organic production

Solutions
• Screening
Screened Tunnels

- Screened tunnels in combination with lure traps and sticky cards reduced SWD by >95%
- Screened tunnels had significantly increased temperatures
- Screened tunnels had significantly increased mite problems
Tunnel Problems and Solutions

Problems
• Increased heat in screened tunnels
• Early bloom of primocane blackberries

Solutions
• Shading
• Microsprinkler cooling
Materials and Methods

- High Tunnel and Field trials
- **Treatments** included:
  1. **Control** – no shade
  2. **Shade** – 50% shade TnT
- Shade structures were built over plots ~July 1 before flower initiation and were removed ~30 days following before/during early fruit set
- Berries were harvested 2-3x/week as needed until season ended late fall

- Additional sub-studies of time and amount of shade (data not presented)
Effect of Shade in HT on ‘Prime-Ark 45’ Blackberry Yield

*Error bars represent standard error from the mean (N=3). Calculations per hectare based on 2.4 meter between row spacing.*
Effect of Shade in HT on ‘Prime-Ark 45’ Blackberry Quality

Average Berry Weight (g)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NoShade</td>
<td>7.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Shade</td>
<td>7.7</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Marketable Yield (%)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NoShade</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>Shade</td>
<td>78</td>
<td>74</td>
</tr>
</tbody>
</table>

Soluble Solids (%)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NoShade</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Shade</td>
<td>8.2</td>
<td>7.5</td>
</tr>
</tbody>
</table>

*Error bars represent standard error from the mean (N=3). Calculations per hectare based on 2.4 meter between row spacing.*
HT Shade Study Summary and Conclusions for Blackberry

• After 2 years studies, shading had **minimal to no effect on time of flowering** and crop maturation.
• Shade **significantly reduced flowering and fruiting**; not a pollination effect
  – Reduced flower number not set
  – May have delayed flowering beyond the study period
• Shade **significantly decreased cumulative yield** on average 30-40% over two growing seasons
• Shade **increased berry weight** in blackberry but could be attributed to lower yields
• Shade **significantly increased marketable yield percentage** in one growing season but not enough to justify cost and labor of shading
• Shade had **no effect on soluble solids content**
Effects of Shade on Primocane Raspberry Yield

*Error bars represent standard error from the mean (N=3). Calculations per hectare based on 2.4 meter between row spacing. Cv: Nantahala
Effect of Shade on ‘Nantahala’ Raspberry Quality

*Error bars represent standard error from the mean (N=3). Calculations per hectare based on 2.4 meter between row spacing.
HT Shade Study Summary for Raspberry

- Shading ~1 month prior to expected yields significantly increased yield in ‘Nantahala’ raspberry by ~30% for one growing season.
- Additional seasons of data needed to conclude effect on yield.
- Shade reduced berry size and marketable yield percentage.
- Shade did not have any effect on soluble solids content of raspberry.
- Reducing the amount of shade may have potential to reduce fruit quality effects.
HT Evaporative Cooling with Microsprinklers

Materials and Methods

Treatments:

1. HT 1-hr Misting; typically beginning approx. 815-830am
2. HT Continuous Misting
3. HT No Misting
4. Ambient/Field

- Water cooling/mist treatments were implemented when HT temps reached ~29°C
Effect of high tunnel insect screening on **hourly average ambient temperature difference** during mid-late August, 2014.

*Error bars represent standard error from the mean (n=4).*
Effect of misting/cooling on **hourly average temperature** of a screened HT during mid-late August, 2014.

*Error bars represent standard error from the mean (n=4).*
Treatment comparison of **hourly average maximum temperature** to HT No Mist in a screened HT during mid-late August, 2014.

*Error bars represent standard error from the mean (n=3).*
Treatment comparison of **hourly average maximum temperature** to HT No Mist in a screened HT during mid-late August, 2014.

*Error bars represent standard error from the mean (n=4).*
Summary and Conclusions

• Evaporative cooling has potential to cool tunnels
• Micro-sprinklers were not sufficient, but had an effect
• Single hour sprinkling in the morning was insufficient

• Future work
  – Install misters to replace sprinklers
  – Try pulsing linked to leaf wetness gauge or thermostat
Making Tunnels Work
Making Spring Tunnel Production Work

• **Select the right cultivars** for the purpose
  – Examples:
    • For spring blackberries and blueberries, select earliest bearing
      – Examples
        Blackberries: Natchez, Arapaho
        Raspberries: Prelude, Autumn Bliss, Caroline
        (possibly Blueberries: Earliblue, Bluetta)
    » Strawberries – cultivars with proven local track record

• **Select cultivars for field production that span the season; early to late**
Making Spring Tunnel Production Work

• Close the tunnels in mid-Winter
  – Mid-January to Early February

• Cover plants with a row cover “blanket” or TnT to conserve heat

• Add Supplemental Heat when temperatures are below 35°F
Tunnel Temperature Mgmt

• During Day: may be 50°F above outside temps

• During Night: As cold or sometimes colder
  – Tunnels only have 0-2°F temperature nighttime temp conservation
    • They may “super-cool” going below outside temp
  – Needs additional management
Frost Protection

• So, you moved bloom from naturally after the last frost, until before the last frost

  \textbf{YOU NEED FROST PROTECTION}

• Tighten the House
• Increase soil Moisture
• Employ Row-Covers, Frost Curtains, or TnT
• Add supplemental heat starting at about 34\textdegree-36\textdegree F
Additional Thoughts on Tunnel Temps

• Tunnels-in-Tunnels and row covers are important for out-of-season production
• Heat conservation and retention are important; heat sinks
• Soil Moisture
• Black, landscape fabric mulch floor
• Inflated bi-layer poly roof
• Roof Blankets
• Supplemental Heat
  – Gas, biomass furnaces
Making Tunnels work for Extended Autumn Production

• Select *latest* blooming and ripening cultivars
• Delay flowering and fruiting with cultural means (e.g. pruning, shade have not been effective)
• Start closing tunnels when temps (day or night) go below 50°F
• Need pollinating insects
• Have frost protection strategy ready
• Flowering to ripening period extends
  – Last bloom likely in mid-October early November
Pollination

Need to Provide Pollinating Insects

- All of the berries require insect pollination
- Tunnels may bloom before or at cooler temperatures than “outside” pollinating insects are working
Pollination
Pests and Disease

• Possibly fewer insect pests in tunnel
  – Especially with screening
  – Easier to trap insects
  – Easier for seeding beneficials

• BUT - Pest problems can and do occur – requires scouting and vigilance
  – Pest populations can “explode”
  – New pests

• Reduced diseases
  – Less leaf wetness, less free water

• Possibly better control
  – Pesticides will “weather” longer in tunnels
Reducing Pest Problems in Tunnels

• Diseases
  – Use resistant cultivars
  – Sanitation

• Insects
  – Prevention, Sanitation
  – Screening
  – Trapping
Weeds in Tunnels

• Generally less than the field
• Need to minimize with mulches
  – Mulches within the row
    – Wood chips, straw, plastic, etc.
  – Woodchip or plastic mulch between rows
    • Plastic landscape fabric mulch may increase heat capture in spring; advance cropping
    • Plastic landscape fabric mulch may increase heat problems
  – Use mechanical and/or chemical control to “touch-up”
Harvests and Quality

• Increased total yield in tunnels (30-200%)
  – Due to more harvests, larger fruit
• Marketable yield (% for fresh use) is improved in tunnels
  – Fewer sunburns
  – Fewer “rain rots”; water-ruined fruit
  – May see more “heat stressed” fruit
• Requires more harvests and more frequent harvest
Potential for Season Advance or Organic Production

- Blackberries
- Blueberries
- Strawberries
- Peaches
- Cherries
- Plums

Figure 1. High tunnel strawberry production research in Columbia, MO, 2006
The Berry Sustainability Workbook

Curt R. Rom
Heather Friedrich, Luke Freeman, Leah Malvar, Jack McCoy
Elena Garcia, Donn Johnson, Jennie Popp, Hector German Rodriguez
Julia Stover, Spencer Fiser
Before we start.....

Consider...

• What is meant by Sustainable?
• What are we trying to sustain?
• Who should do the sustaining?
• Why are we trying to sustain?
• How do we know if we are sustainable?
Defining Sustainability

Bruntland Commission Report, Finished 1987

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”
Defining Sustainability

“An integrated system of plant and animal production practices having a site-specific application that will, over the long term:

– Satisfy human food and fiber needs
– Enhance environmental Quality and the natural resource base upon which the agricultural economy depends
– Makes the most efficient use of nonrenewable resources and on-farm resources and integrate natural biological cycles and controls
– Sustains the economic viability of farm operations
– And, enhances the quality of life of farmers and society as a whole”

US Congress, 1990 Farm Bill Legislation
Agricultural Sustainability

Sustainable production means to meet the needs of today’s operation without compromising the future of the operation.

In other words..........

a farmer should produce crops in a way that optimizes resource use, optimizes production and provides sufficient economic returns to provide for the grower and his employees, contribute to the community, but can also maintain the operation so that it can continue as a viable farm in the future with continued economic returns and satisfaction.
Three Legs of Sustainability

- **Economic Sustainability – PRODUCTIVTYP & PROFIT**
  - Economically sound and profitable

- **Environmental Sustainability - PLANET**
  - Environmentally sound, biologically interactive

- **Social, Community Sustainability - PEOPLE**
  - Socially Responsible to people, families, and communities
The “Triple Bottom Line”

The “bottom Line” of sustainability

**PROFIT** - Economic Viability

**PLANET** - Environmental Maintenance and Improvement

**PEOPLE** - Social and Community Impact and Justice

Sustainable
So, Are We Sustainable?

How do we know?
How can we measure it?
What are the Metrics?
My Thoughts on Sustainable Production

Sound sustainable managed systems must be based in science; be in reality
- We must recognize and acknowledge truths
- We must recognize what we know and what we do not know
- We must seek, develop and find new information – find new answers
- We need ways to measure and instruct us on how to be sustainable
Because sustainability is a relatively “new” concept to agriculture and the question of how to measure is relatively new,

There are no certain, concrete or commonly accepted metric or models of metrics.

However, they are being developed
The Need for Sustainability Metrics

- Helps Farmers
  - They can farm with more sustainable practices
  - Adds value to the products

- Desired by consumers

- Therefore, adds value to companies that produce and/or sell products

- Early adopters harvest greatest value
  - Last adopters will be left behind
Principles of Sustainability

Metrics should be

• Based in sound science
• Empirical and Quantitative
• Informative and Instructive
  – To producers
  – To consumer
  – To policy makers
• Transparent
• Reported
Means of Measurements

Use of Indices or Indicators
- Indices and Indicators are key components that can be observed and measured
- They provide “indication” of performance either currently or in the future

Score Cards
- Use indices to help make management decisions
- Scoring helps growers know where they are currently
- Scoring helps set management direction and priorities
Criteria for selecting Indicators

1. Easily observable, measurable, quantifiable
2. Sensitive to stresses of the system
3. Respond to stresses in predictable way
4. Be predictive; anticipatory
5. Predict how changes can be affected by management decisions
6. Integrative; cover important aspects of the system
7. Known responses to natural disturbance and anthropogenic stresses
8. Reliable; low variability

(From Zhen and Routray, 2003)
Impact and Sustainability

Relative Impact
Positive

Sustainable

Nonsustainable

Negative
Quantitative Use of Indices

Indicators are then scored on a “negative” to “positive” scale.

Relative Impact

Positive

Negative

Sustainable

Nonsustainable
Quantitative Use of Indices

Instructive Indicators

Relative Impact

Sustainable

Nonsustainable

Needs Improvement

Satisfactory

Excellent
Impacts on Sustainability

Holistic Enterprise Evaluation

<table>
<thead>
<tr>
<th>Productivity &amp; Profit</th>
<th>Planet - Stewardship</th>
<th>People</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-3</td>
<td>-3</td>
<td>-3</td>
</tr>
<tr>
<td>-5</td>
<td>-5</td>
<td>-5</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Domains have sub-components

Planet – Stewardship
Farm Management

Soil
Water
Nutrients
Fertilizers
Pest
Control

-3
-5
The Berry Sustainability Workbook
The Berry Sustainability Workbook

Table of Contents

Introduction........................................................................................................ 2

Chapters
1. Site Selection............................................................................................ 7
2. Site Preparation.......................................................................................... 9
3. Soil and Nutrient Management................................................................. 12
4. Plant Selection.......................................................................................... 15
5. Water Management and Irrigation............................................................ 17
6. Trellising and Pruning............................................................................... 20
7. Insect Management.................................................................................. 23
8. Weed Management................................................................................... 27
9. Disease and Virus Management............................................................... 31
10. Farm Safety.............................................................................................. 34
11. Harvesting, Handling, and Transportation.............................................. 36
12. Business Management............................................................................ 40
13. Marketing................................................................................................ 44
Appendix of Resources.................................................................................. 48
DRAFT COPY

I. Site Selection

The first step in establishing a blackberry or raspberry planting is choosing a suitable site. There are several factors to consider when selecting a site, including soil type, air movement, water drainage, sun exposure, cropping history, water availability, and slope.

Though blackberries and raspberries have very similar requirements in regards to site selection, there are some key differences. Blackberries grow best in warm, temperate regions and are less hardy than raspberries. They are recommended for areas where winter temperatures stay above 10°F. Raspberries grow best where the season is long and summers are mild, with winters uniformly cool and long enough to satisfy chilling requirements. Most of the southern US is not ideal for raspberries, though high elevations in the Appalachian Mountains provide ideal conditions with moderate summer temperatures and consistently cold winters.

Soil Type

Both blackberries and raspberries prefer well-drained soils that are relatively high in organic matter (2-4%). Soils with poor drainage encourage root rot diseases like Phytophthora. An ideal soil would be naturally fertile, have the ability to retain moisture, and have a slightly acidic pH of 6.0 to 6.5. A soil with adequate fertility would contain 50-100 lbs. of phosphorus per acre, 150-200 lbs. of potassium per acre, and 150-200 lbs. of magnesium per acre with a CEC of 8 to 16 meq/100g. Sandy loams or loam soils are more preferred than clay soils, though blackberries are able to tolerate clay soils better than raspberries.

Air Movement
References and Reading List:


Appendix of Resources

I. Site Selection

Web Links:


Publications:

# Sustainable Blackberries & Raspberries

## Self-Assessment Checklist

See “Checklist Explained” for more detail on checklist categories.

## I. SITE SELECTION

<table>
<thead>
<tr>
<th></th>
<th>EXCELLENT</th>
<th>SATISFACTORY</th>
<th>NEEDS IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Soil type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B) Native fertility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C) Air drainage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D) Wind protection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E) Sun exposure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F) Cropping history</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G) Isolation from wild brambles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H) Water availability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I) Slope</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## II. SITE PREPARATION

<table>
<thead>
<tr>
<th></th>
<th>EXCELLENT</th>
<th>SATISFACTORY</th>
<th>NEEDS IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Site clearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B) Remaining weeds eliminated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Berry Sustainability Workbook

<table>
<thead>
<tr>
<th>SUMMARY</th>
<th>EXCELLENT</th>
<th>SATISFACTORY</th>
<th>NEEDS IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each of the previous categories summarize the number of checks in each rating class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Site Selection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Site Preparation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Soil and Nutrient Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Plant Selection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Water Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Pruning and Trellising</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Insect Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Weed Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Disease and Virus Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Farm Safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERALL TOTALS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summarize the totals of the above for each column</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERALL TOTALS from previous year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>List the totals for each column from the previous year evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year to Year change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtract last year totals from current year totals to evaluate change between years. A positive number in Excellent category indicates progress, and positive number in the Needs Improvement indicates areas of weakness</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Plan for Sustainability

From the evaluation of your checklist indicate the following:

<table>
<thead>
<tr>
<th>Areas of Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>List and discuss those areas of management and operation where you are demonstrating satisfactory or excellent performance.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Areas for Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>List and discuss those areas of management and operation where you are needing improvement in performance.</td>
</tr>
</tbody>
</table>

Plan for Increasing Sustainability

Based upon your own evaluation of strengths and areas where you need to improve, list steps you plan to take and/or procedures you plan to implement in the coming year to increase your farm sustainability.
Questions?