# Strawberry II

## Tuesday afternoon 2:00 pm

**Where:** Grand Gallery (main level) Room A & B
**MI Recertification credits:** 2 (1C, COMM CORE, PRIV CORE)
**CCA Credits:** SW(2.0) CM(0.5)
**Moderator:** Kim Lewers, USDA-ARS, Beltsville, MD

2:00 pm — Soil Health Assessment Soil Health and Composts
- Marvin Pritts, Horticulture Dept., Cornell Univ.

2:45 pm — Building Soil Health for Perennial Crops
- Anne Verhallen, Ministry of Agriculture, Food and Rural Affairs, Ontario, Canada

3:15 pm — Intro to Substrate Culture, Top Ten Principles for Growing Strawberries in Substrate
- Eric Boot, BVB Substrates, The Netherlands

4:00 pm — Low Tunnels for Plasticulture Strawberries
- Kathy Demchak, Plant Science Department, Pennsylvania State Univ.
- Marvin Pritts, Horticulture Dept., Cornell Univ.

4:30 pm — Session Ends

# Strawberry Soil Health and Composts

Marvin Pritts, School of Integrative Plant Science, Horticulture Section, Cornell University, Ithaca, NY 14853

Farmers and researchers are learning that physical and biological characteristics of the soil are major contributors to plant performance, along with the chemical component that has received the most attention in the past. This integrated approach to assessing soils is termed "soil health." While the important role of physical and biological components on overall soil health is intuitive and has long been understood by organic farmers and those desiring to achieve more sustainable production, only recently have methods been developed to quantify the biological components of the soil. The reasoning of soil health practitioners is that cultural practices that positively enhance measurements of biological soil health should then also benefit strawberry productivity.

Strawberry growers face many difficulties in maintaining healthy strawberry fields. In addition to stress from cold and damp weather, soils may contain pathogens that can affect roots that are exposed to suboptimal conditions. Often pathogen levels are often low that they are not detected or expressed in healthy plantings. High organic matter content (OM) is thought to help sustain biological soil activity by facilitating growth of beneficial organisms that compete and suppress pathogenic organisms. A large and diverse soil microbial community also is essential for nutrient cycling. Soil C and N are first immobilized in microbes then slowly released once the microorganisms are decomposed, freeing these nutrients in a plant-available form. Therefore, even though plants exude C from their roots, organic C pools in soil are important not only to increase the cation exchange capacity of the soil, but also for N cycling. Some microbes are also able to fix $N_2$ gas from the air, providing another source of plant available N. The presence of microorganisms in the soil also increases soil aggregation through bacterial mucigel and fungal hyphae. Aggregation improves water infiltration, aeration, and reduces erosion. Without soil C these important microbial populations would decline.

In New York, most strawberries are grown using the matted row production system. Straw is used to protect the strawberry plants over winter, then in the spring, the straw is raked between the rows and incorporated. This straw is useful for suppressing weeds, improving water retention and decreasing fruit rot. In addition, strawberry fields are cultivated regularly since herbicides labeled for use are few. Cultivating for weeds is recommended up to every 10-14 days in new plantings. In this perennial production system, soils is cultivated frequently, straw is applied as mulch (recommendations range from 2-5 tons/acre/season), and is then incorporated into the soil over time.  Straw contains high levels of C, which should fuel the biological health of the soil.

In 2012, through help of SARE funding, seven strawberry fields were given Cornell Soil Health Tests (CSHT, http://soilhealth.cals.cornell.edu/) during a more complete berry soil health survey. However, soil biological measurements from the CSHT were ubiquitously low. On a relative scale of 0-100, most tested biological indicators scored below 26. The CSHT measures soil biological activity with an OM test, an active carbon test, a potentially mineralizable nitrogen (PMN) test, and a root health rating. These tests indicate microbial abundance and root health in the soil. Therefore it was somewhat surprising that strawberry fields tested low for traditional indicators of soil health, particularly since large amounts of straw – a form of organic matter - are added each year.

Several cultural practices are known to impact soil health such as preplant cover cropping, composting, mulching and tillage practices. For example, in one study mulch significantly increased microbial biomass nitrogen (N) and carbon (C), soil extractable N, net N mineralization, and soil microbial respiration compared to bare soil – all of which should benefit strawberry plant growth. However, the quality of the mulch affected the amount of soil improvement. High C:N ratio mulch additions led to N immobilization. Organic material with less than 15-17 g N/kg dry weight can temporarily immobilize soluble N, but annual applications of organic matter (e.g. straw) containing less than 10 g N/kg dry weight can enhance soluble N availability over long periods of time as it decomposes. The rate of mulch decomposition affects the longevity of the change in soil properties after mulching. Wood chips can sometimes immobilize N, damage crops when they are applied, and release leachates that are allelopathic to certain crops, but not all types of wood chips have that effect. Soil can compound an effect as soil mulched for the first time does not have a microbiome adapted to organic matter (OM) decomposition and therefore mulch decomposes more slowly than on a soil that is regularly mulched.

Strawberry fields are frequently tilled, first to break up the soil before planting, then to manage weeds. Tillage and cultivation practices have been found to increase runoff, decrease macro- and micro-porosity, form plow pans, and cause soil organic carbon (SOC) loss over time. Tilling exposes pockets of soil OM that can then be mineralized, causing a flush of plant available C and N in the short term. Microorganisms are stressed after the disturbance and may be unable to assimilate the nutrients effectively, so often C and N are leached away. Switching to a reduced-till system can increase soil and particulate OM. Limited compaction in the absence of pathogens can be tolerated by strawberry plants, but compaction in the presence of pathogens is detrimental.

In a mulched system such as strawberries, the physical separation of the soil and the mulch slows decomposition, but then tilling mixes the soil and OM together, making the OM more accessible to microorganisms in the soil. Consequently, the microorganisms can break the OM more easily. This leads to faster litter decomposition in tilled systems than untilled systems. Therefore, long-term substrate use efficiency is higher in systems with litter left on the soil surface than incorporated litter due partially to slower breakdown of litter.

In some situations, long-term additions of straw have been shown to gradually improve soil productivity due to soil structure properties changes such as increased aggregation, water retention, and N supplying power. Large additions of straw to strawberry fields should therefore demonstrate these improvements. However, the biological indicators of the CSHT scored low, highlighting a disconnect between expected outcomes and test results.

In very degraded soils, the addition of organic matter through cover cropping or compost amendment prior to planting will most always enhance strawberry performance. However, in heavier soils with a previous history of strawberries, compost amendment may be detrimental. Cover crops are usually beneficial, but there are situations where certain cover crops can negatively impact strawberry growth and performance, particularly in replant sites. Similarly, we have found straw amendment prior to planting can have a negative effect on strawberry plant growth.

Life beneath the surface is very complex and this not surprising considering that tens of thousands of species of microorganisms can be present in just a teaspoon of soil. There are a number of processes and interactions occurring there that make generalizations difficult. The table below summarizes what we think we know about organic matter and composts in relation to strawberry plant performance and soil health. And it demonstrates why conclusive generalized statements about cultural practices are difficult to make.

| **Practice** | **Expected response** | **Conditional response** |
|---|---|---|
| Cover cropping prior to planting | Increased soil organic matter and weed suppression | Certain cover crops can harbor diseases and nematodes that can transfer to strawberry plants. Some cover crops can become weeds in strawberry fields if not managed properly. |
| Compost incorporation prior to planting | Enhanced microbiological activity and increased water-holding capacity; decreased pathogen activity through competition. | May hold too much water and create conditions favorable for disease. May increase salt content of the soil. |
| Straw mulch incorporation | Enhanced soil biological activity and improved soil structure. | Strawberry plants may not perform well with preplant straw mulch incorporation. |
| Tillage | Reduced weed pressure followed by quick release of nitrogen and active carbon from organic matter pools. | Nitrogen flush is short-lived and pools are eventually depleted. Soil structure can deteriorate and compaction increase under too much tillage. |
| Organic matter incorporation | Enhanced microbiological activity and increased water-holding capacity. | Soil may not contain the microorganisms at a sufficiently high level to rapidly decompose the organic matter, thereby tying up nitrogen and inhibiting crop growth particularly if the C:N ratio of the OM is high. |
| Soil health testing | Identifies indicators that are low and suggests cultural practices to improve those indicators. | Indicators developed for field crops may not be good indicators for perennial strawberries. |

# INTRO TO SUBSTRATE CULTURE:
# Top Ten Principles for Growing Strawberries in Substrate

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## History

The first modern production of strawberries in substrate started in Holland in the early eighties of last century.

Early strawberry production in glasshouses suffered of soil born diseases, mainly Phytophtora cactorum and Verticilium. Methyl Bromide was no longer allowed and other fumigants were expensive or not effective.

We started off with bucket (5–10 liters) cultivation with early varieties like Primella and Karola.

In this period, also the new variety Elsanta was introduced. A fantastic variety that still is the most grown variety in northern Europe. The big problem with Elsanta however was the susceptibility for a lot of diseases (P. fragariae, P. cactorum, etc..). Luckily, Elsanta performed very well in substrate cultivation.

BVB Substrates introduced the growbags for strawberries in 1987. This made the handling and growing process much easier than in buckets. In the early nineties, soilless cultivation became the standard for glasshouse strawberries in Europe. 100% of glasshouse strawberries are now grown out of the soil. In 1990 the growbag system was also introduced in Switzerland. In the mid nineties, we saw a strong development in France and Italy, and a few years later in the UK. In this period, the whole system was modified by growers and suppliers to a whole range of different systems, varying from growbags on raised beds up to all sorts of pots/containers on wire systems or steel gutters.

## Why growing in substrate

While these systems were being developed, other advantages than only preventing soil born diseases emerged.  Nowadays, for many growers, soil born diseases are no longer the main reason to start these production methods. Growing strawberries in substrate has many other advantages over soil plantings.

**Labor.** Substrate grown strawberries produce higher yields and better quality. With table top systems, the berries are ideal height for the pickers. Modern systems separate the fruits from the leaves. The fruits are very well exposed. Not only does this lead to increased picking speed, but it also leads to much better labor conditions.

**Yield.** In substrate growing systems, the plant density is mostly much higher than in soil plantings. This leads to a higher assimilation surface per hectare. Higher assimilation leads to higher yields, and better quality.
In table top systems, all berries are hanging free in the air. There is less loss of berries due to botrytis or anthracnose but also f.i. snails or birds.

**Reduced use of pesticides.** The use of fresh clean substrate and the protected environmental conditions of the crop make that the use of chemicals can be reduced dramatically. Yields are typically higher in substrate systems. When spraying fixed rates per hectare, the usage per kilogram produced berries decreases.

**Water and fertilizer.** Most systems collect the run-off water. After disinfection, this water and fertilizers can be reused. This brings massive savings in water usage per kg of strawberries.

**Infrastructure.** By growing in substrate, the grower has the assurance that he can grow on the same spot every year again. This makes is worthwhile to invest in a good infrastructure with paved roads, high tech irrigation systems and stable, low labor tunnel structures.

**Growth control.** The limited root volume enables the grower to react very quickly on weather changes and it is also possible to steer the plant into vegetative or generative stages. Because the irrigation and fertigation have a very direct and controllable effect, it is possible to increase fruit size and to improve fruit quality.

**Limitations**

Of course, the cultivation of strawberries in substrate also comes with some limitations. The initial investments are higher than traditional soil planted crops. The grower will have to adapt new knowledge for growing in substrate and for steering the crop with the right fertilizer schedules – EC levels – pH – irrigation volumes and other new parameters. The water quality, that is already very important with soil plantings, is even more delicate in substrate cultivation.

## Water quality.

One of the most important conditions to grow in substrate is the availability of sufficient water of good quality. Before even thinking of starting to grow strawberries in substrate, please first have your fresh water analyzed. Important parameters for judging the water quality are EC, pH, bicarbonate, ballast salts and iron.

**EC** Conductivity (EC) is a useful parameter for the total dissolved salt content of water.
These salts can either be useful nutrients like calcium, magnesium or sulphate but they can also be ballast like chloride or sodium. Sodium and chloride can become toxic to plants when present above certain levels. It is important that all these salts and the total EC level are taken in account when composing the fertilizer mixture.

**pH** The right irrigation water pH is essential for good availability of the nutrients. Growers can be misled in thinking the pH of the fresh water is useful to calculate the amount of acid that is needed to get the right pH. However, the absolute pH tells not even half the story. Much more important than the pH is the concentration of bicarbonate in the water that needs to be neutralized by acid addition. As long as bicarbonate levels are present, the pH will not change significantly when dosing acid. High bicarbonate levels are commonly found in bore waters. Very high levels may make it necessary to pre-treat the water before use.

**Iron** Iron is common in bore or ground water. Water containing iron above 10 micromol/lt can, upon exposure to air, change to iron oxide which is a common cause of blocked drippers and brown staining on surfaces that it comes into contact with. Water with high iron levels needs to be de-ironed before use.

## Substrate

The substrate that is used for the strawberries needs to meet several conditions. The substrate is the base to anchor the plants. It must take up and hold the water and nutrients and also set these available for the plants when it is needed. The tension of binding and releasing the water and nutrients is very important. To create a good and active root system, the roots must be provided with enough oxygen.

Therefore it is essential that the substrate contains enough pores of the right size to allow a free air exchange throughout the whole pot volume. For long lasting optimum characteristics of the substrate, the durability or structure stability of the substrate is a key factor. We can use a wide range of raw materials to design this optimum conditions. Important parameters to design the optimum substrate are AFP (Air Filled Porosity), WOK (Water Uptake Characteristic), water release pattern, nutrient absorb-release pattern, chemical stability, structure stability and more. The most important raw materials that are used in the soft fruit industry are peat, coir and perlite.

**Peat**

Peat is bog moss that has decomposed under low-oxygen conditions. Depending on climatic conditions and age, the structure ranges from more or less decomposed plant remains to a fine dark mass. Peat is produced primarily in the northern hemisphere, from Ireland to Russia and from Sweden to Canada.

All these different origins have peat with their own specific characteristics. Also the harvesting method as well as the handling and screening have a big effect on the physical characteristics of the peat. For instance, the vertically harvested sod peat gives a much better structure stability than the horizontal harvested milled peat and older, more composed black peat has a lower air content than younger white peat.

The humic acids in the peat act as a pH buffer, meaning that it stabilizes the substrate against sudden change in pH. This function is important since substrate pH controls nutrient availability for plants. As their name suggests, they are weak acids that donate hydrogen ions to the solution if the pH rises too high and pick up protons if it falls, thereby buffering against pH change.

**Coir**
The interior of the outside husk of the coconut is filled with fiber and a ‘coconut pulp’. This coir pith, also known as coir dust, can be used as a growing media. Coir has a relatively good structure stability and is very easy to handle.

Coir has a big CEC (Cation Exchange Complex). This is a negatively charged complex, that is naturally saturated with sodium (and potassium). Calcium and magnesium however have a stronger attraction to the coir complex. Fertilizing these elements can lead to lockup in the complex, while sodium and potassium will be displaced, come into solution and be taken up by the plant instead of calcium and magnesium. This leads to all sorts of crop problems – from excessive salt uptake to calcium deficiencies. Therefore, it is of great importance that the coir is always pre-buffered with calcium and flushed after that.

Coir has a very low pH buffering capacity. This makes coir, used as a pure substrate, very susceptible for pH related nutrient deficiencies.

**Perlite**
Perlite is a volcanic glass (silicon dioxide) that is mined in Greece, Turkey or Italy. When heated the structure softens and the enclosed water vaporizes and causes the perlite to ‘pop-up’ to 15-20 times its original volume. Perlite has a very high structure stability. It is used as a component is substrates where it provides aeration and increases the speed of moisture retention.

**Substrate production.** At BVB Substrates we produce about 2,5 million cubic meters of substrate every year. The production process is fully computerized. Every individual batch has its own unique recipe and is checked by our in-house state-of-the-art laboratories.

Together with our R&D department, researchers, consultants and of course the growers, our advisory team designs substrate recipes for all crops and growing systems. We have 30 years of experience with substrates for strawberry production.

The cheapest substrate options are milled white peat mixtures or straight coir. Non-compromising high-quality growers use mostly sod peat mixtures (with or without perlite addition) or recipes containing coir, sod peat and perlite.

**Structures.** Over 95% of the substrate grown strawberries are protected by some kind of covering. This can vary from simple single row plastic covering up to high tech glasshouses. Generally we can say that bigger volumes and higher top-ventilation capacities lead to the best crops.

**Systems.**
We can distinguish 3 basic set-ups. The most simple systems are the *soil-contact systems*. These are bags or containers on the ground or on ridges or substrate-filled elevated-bed systems. These systems are widely used in Germany because they want to combine the advantages of production in substrate with the advantage of earliness thanks to the soil contact. As soon as the substrate is used without soil contact, some earliness is lost. Big disadvantage of these soil contact systems is of course that the strawberries are growing on ground level. Picking efficiency and labor conditions are the same as in soil plantings. If earliness is not the major issue (f.i. everbearers) or if additional heating is available, it is

always more economic to produce on a higher level. In basic polytunnels, we use mostly the *table top or high bed system*. Poles in the ground support the substrate carrier. The height of these systems vary from 80 cm for picking while seated up to about 1,4 meter for stand-up picking.

If the construction is strong enough, the best way to support the substrate system is by using a *hanging system*. Hanging systems make it easier to move around in the production area. Transporting substrate, plants, fruits, spraying equipment is easier if there is no obstacles in the way. Also putting a ground cover or move around with mowers is better without the poles in the way. Please bear in mind that a complete growing system gives an huge weight pressure on the construction.

**Substrate carriers**
There are different systems for holding the substrate itself. We see the *growbags, pot/container systems* and *substrate-direct-systems.*

It is important to have a good free draining system. In some substrate-direct-systems, the drainage channels are very small and they tend to block very easily. The roots could come into direct contact with the run off water. Substrate direct systems need special machinery (or a lot of labor) to fill. They can not be used for crops that need to overwinter at minus temperatures and they offer no flexibility in production scheduling.

Pots and containers have an open surface. This is initially an advantage because of the good microclimate directly after planting. Later on this can turn into a disadvantage when humidity gets too high or fruits can lay on top of the substrate. Therefore, container systems with open top should not be too wide (<18cms). This makes it easier to get all the fruit away from the substrate surface. Filling the containers should be mechanized to ensure all containers get exactly the same volume.

Growbags do of course not have this problem. They are mostly a bit wider (20–26cms), giving the plants a bit more space. Growbags are ready filled, drainage- and planting holes are pre perforated on demand. Growbags are however more expensive, must be cut open after use and leave a lot of plastic waste.

We have a preference for systems with higher connected volumes. 10 plants in 20 liters will perform better than 1 plant in 2 liter. Moisture and nutrient availability are more constant and the plant roots have more space to grow. Unequal drippers and different plant sizes are compensated better in longer substrate units. Longer substrate units also allow more flexibility in steering the plant density.

The volume of the substrate may vary from 15 up to 30 liters per linear meter.

**Irrigation**
Based on the substrate quality and quantity, the optimum watering volume per irrigation loop can be calculated. The frequency of these irrigations depends on a complex of parameters like temperature, humidity, radiation, plant size, growing stage and many more.

**Fertilizing**
All water and nutrients need to be given by drip irrigation. The influence of the water quality on the final irrigation solution is very big. All elements that are present in the fresh water and also the EC of the water must be taken in account when composing the fertilizer recipe. The higher the EC level of the fresh water and the lower the EC level of the required irrigation, the bigger the influence of the fresh water composition is on the final irrigation water. Changing irrigation EC levels do not only change the total amount of required fertilizer but it also changes the required ratio between the nutrients in the fertilizer.

**Technical installations.** Water and fertilizer needs to be dosed very precise. Depending on parameters like climate, variety, crop situation, the required EC level varies between 1,2 and 2,0 and the required pH is commonly between 5,5 and 6,0. To cope with these changing requirements and sometimes also varying water composition, the use of proportional dosing systems is not advised. The irrigation system should have an automatic EC/pH control with the so called A and B tank system with a separate acid dosing system.

**Plant material**

When substrate systems are installed, this needs major investments. We need to avoid any risk of failure where possible. Good plant material is essential. We want to use strong, homogeneous, healthy plants with a high production potential. To guarantee plant health, we see an increase of mother plants grown in substrate and young plants tipped in all kind of trays or plugs. Especially with the use of short day high chill varieties, the production potential at the moment of planting is very important. Therefore, we use more and more trayplants (European trayplants, with designed flower mapping). In the glasshouses, this is a standard for many years already, but nowadays they get more popular in ‘low cost structures’ as well.

**Conclusions**

The way forward for soft fruit production means for many growers : growing in substrate. Mostly, the start of growing in substrate is initiated by the ban on chemicals for soil disinfection. Over the past decades, we have learned however that this is not the most important advantage of the substrate systems. The main reason to grow in substrate and also the choice of how to grow in substrate may vary per region, per market or per grower.

The substrate production has outgrown its infancy, we left the trial and error period behind us.
To all growers that want to start to grow in substrate: we are there to help.

# Low Tunnels for Strawberry Production

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**Low Tunnels for Plasticulture Strawberries**

June-bearing (short-day) strawberries are a high-value crop, but their brief harvest season severely limits the window of opportunity for making a profit with this crop. At most, with a combination of cultivar and production methods, the harvest season might last 6 weeks, but for most growers, it is only about half this long. Rainy weather during these three weeks, especially if it occurs on weekends, can have a significant negative financial impact on growers, particularly if they market through pick-your-own. It would greatly benefit growers if strawberries could be produced over a longer season, into the summer and fall, as this would extend the season and open up new markets.

In the 1980s, varieties of strawberries (day neutral) with the capacity to produce flowers during all day lengths (spring, summer and fall) were released to the public. While there was initial excitement with these new varieties and their flavor was excellent, grower interest waned because 1) yields were low, 2) fruit size was small, 3) berries were expensive to pick, and 4) tarnished plant bugs (TPB) damaged the ripening fruit.

A new generation of day neutral varieties was released in 2004. Although these originated from California, they were relatively well adapted to the Northeast, producing much larger fruits and higher yields than earlier releases. They produce fruit the year of planting and continue fruiting into the fall. After overwintering, they produce another flush of fruit in spring. The fall crop and the second-year spring crop can be protected from rain and cold temperatures by covering rows with plastic on metal hoops – a technology called "low tunnels." The tunnel plastics not only exclude rain but they can decrease the amount of ultraviolet light and infrared radiation - reducing spore germination and heat load on the plants. The combination of day neutrals and low tunnels has the capacity to extend the strawberry season from 3 weeks to 5 months.

Establish raised beds (18 inches or wider) in late fall or early spring so they can be planted as soon as possible in spring. Delaying planting until May or Jun will significantly decrease yields. Each bed should have a trickle irrigation line attached to a fertilizer injection system. Cover each bed with white plastic and plant 'Albion' in a staggered double row, with plants 9 – 12 inches apart in each row. Use a tool that will insert roots into the bed while disturbing the plastic as little as possible. 'Albion' is the variety that has the best flavor and performs consistently well in our climate.

Remove the flowers for the first three weeks, or until vigorous new leaves appear from the crown. Plant grass seed between the rows, or at a minimum place straw mulch along the edges of the plastic beds to to prevent mud from splashing on the berries. Fertilize the planting with 1-2 lbs of actual nitrogen per planted acre per week.

Install tunnels when plants begin to throw new flower trusses. Cover the tunnels with 4 to 6 mil plastic. Dubois Agrinovation (http://www.duboisag.com/) sells kits with plastic that has predrilled holes for ventilation when the plastic is lowered. This cost is recovered in the first year.

At least one side of the plastic should remain up under normal weather conditions to allow for pollination and to prevent heat build-up. Lower the sides when the weather is cold or stormy. A benefit of the plastic is the near elimination of common diseases such as botrytis (gray mold) and fruit anthracnose.

Fertilize with nitrogen according to local recommendations. In NY, it is recommended to increase the nitrogen to 5 lbs/acre per week once the plants begin to set fruit. Failure to provide weekly applications of nitrogen was a major reason why NY grower-cooperators had lower yields than expected.

Harvest the fruit at least twice a week. Peak yields will occur in late August-early September, with production occurring through October.

Once the temperature falls below 40F, lower the tunnel sides. If the temperature falls below 30F in mid-October, cover the entire field with row cover for the night to continue fruiting. This will extend the harvest season should the weather warm again.

Once harvest is over, lower or remove the plastic and cover the beds with straw. 'Albion' does not overwinter well in cold weather. Remove the straw in late March/early April and allow these plants to fruit again. The tunnel can be used to protect from late spring frost.

Over the course of the first year with an April planting date, we harvested 20,000 lb/acre, which is as much as a good June-bearing cultivar will produce in one season. Average berry size of 'Albion' was 15 grams, which is the size of a medium king fruit on a June-bearer. Flavor is excellent. Production peaked in early September with two quarts (four pints) of berries per 10 feet of row, but in October plants consistently produced about a quart of berries every 10 feet of row until a hard frost.

In spring of the second year, a large flush of fruit is produced about the same time as that of early June-bearers. Tunnels can be used to accelerate flowering if desired. Spring yields can be almost as much as the previous year's yield. We have not found it to be economical to hold over these plants into a second summer and fall. Rather, we grow them for about 15 months and then remove them. This past summer, in particular, with 26 days above 90F was not conducive for second-year production.

We found that, while attractive, growers may not be able to "fit" such a crop into their farm operation since day neutrals require constant attention. Plastic has to be raised and lowered, plants have to be fertilized weekly, and once harvest begins, it lasts for months. However, the rewards can be great. Growers have reported gross sales of $50,000 per acre from Albion in New York State. Given that the cost of materials for an acre is about $44,000, sales can pay for the materials in the first year. In the second year, costs include plants, fertilizer, labor and harvest. Conservatively, this can be $20,000, but with sales approaching $30,000 or more, the margins are quite good.

Spotted winged drosophila damage has been minimal in our trials provided that fruit is harvested regularly and not left rotting in the field. In one trial we used netting in place of plastic to determine how it would perform when the sides were down continuously throughout the fall to exclude spotted winged drosophila. Surprisingly, the netting had many of the benefits of the plastic. Sufficient air movement occurred so that flowers were pollinated without bees. Enough moisture was excluded so that fruit rot was low, and enough heat was retained on cold nights to prevent early frosts and extend the season. There was no SWD damage on those fruit, but damage levels were low throughout the plantings.