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High Tunnel Summer Squash Production

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Introduction

Summer squash can be successfully grown in high tunnels and can be a valuable vegetable crop that provides diversity to small scale and part time farming operations. Growing squash in high tunnels makes it possible to produce the crop approximately 4-6 weeks earlier and 6 weeks later than field grown squash. When added to other vegetables grown in high tunnels, squash will increase marketing opportunities, improve early cash flow, and complement other high tunnel crops like tomatoes. High tunnels are inexpensive to build, passively heated and cooled, and in many locations in Utah planted as early as mid-March. Squash harvest begins about one month after transplanting and has been harvested as late as November.

High tunnels are becoming more common on Utah vegetable farms as growers expand their production earlier and later in the growing season. Tunnels are covered with a single layer of greenhouse grade plastic which is supported by a steel or PVC frame. With Utah's numerous sunny days, growing in tunnels is logical because sunlight passively heats the enclosed growing environment. Low tunnels inside the high tunnel further protect plants from cold injury at night. Growers need to ventilate tunnels during the day to prevent temperatures from exceeding the optimal range for the crop being grown. For construction details on a low cost high tunnel or to see other crop production guides, visit the Utah State University High Tunnel website at: http://extension.usu.edu/htm/publications/by=category/category=197

Variety Selection

There are numerous types and varieties of summer squash capable of growing in high tunnels. Selection should be based on fruit type (crookneck, straightneck, scalloped, specialty), fruit color (gray, green, yellow), earliness, and disease resistance. One important issue to consider with tunnel grown squash is the need for pollen transfer from male to female flowers. This is accomplished in the field with bees but their access to tunnels in the early spring may be limited when doors and side walls are closed. One way to avoid this problem is to grow known parthenocarpic squash varieties. Parthenocarpy is the ability of a plant to set fruit without fertilization. This will limit the choice of varieties early in the year. Once the tunnel cover is removed or doors and sidewall remain open, natural pollination by bees will occur. Hand pollination is not an option due to the large numbers of flowers produced and the time commitment required. Consult with your seed salesman or search reputable seed catalogs for detailed information on squash growth characteristics. While we have not conducted any squash variety trials for high tunnels at Utah State University, most varieties could be adapted to high tunnels provided the pollination issue is considered.

Site Selection

Most soils are good for squash production as long as the soil is well drained, fertile, and there is no salt build up. Squash plants may be sensitive to residual soil herbicides, so pay special attention to tunnel site selection if constructing a tunnel where herbicides have been used in the past. The high tunnel should be located near a year-round water source in order to facilitate irrigation in the early spring and late fall when seasonal irrigation water is not available. In areas prone to high winds, tunnel orientation and extra bracing may be necessary (http://www.hightunnels.org/). In high snowfall areas, extra purlins or support posts are required so the tunnel does not collapse. Some growers remove the plastic in the fall and replace it in the spring to avoid snow damage during the winter.

Site Preparation and Fertility Management

Prior to planting, have the soil tested to determine nutrient needs and deficiencies. It is a good idea to incorporate composted organic matter before planting to sustain soil fertility, regardless of your interest in organic crop production. An initial application of 5 tons per acre of high quality compost of known nutrient analysis is recommended. Compost improves the aeration and drainage of heavy clay soils, improves the water-holding capacity of sandy soils, and increases the ability of all soils to retain nutrients. Specific fertilizer rates recommended for summer squash production based on soil tests are listed in Table 1. Generally part of the required nitrogen fertilizer and all the phosphorous and potassium are applied and incorporated into the soil prior to planting. Some studies suggest small additions of P and K when plants start flowering help boost productivity. Additional nitrogen is then added during the production season. Making several nitrogen fertilizer applications during the growing season allows for less leaching, generally improves plant growth and yield and may reduce total nitrogen needs.

High tunnel summer squash can be grown with organic fertilizers and yields are often equal to squash grown using conventional fertilizers. Organically grown produce can at times have higher market value. Composted chicken manure has been used for squash production due to its high nitrogen mineralization capacity and good levels of phosphorus and potassium. In high tunnel studies at Utah State University comparing composted chicken manure and conventional fertilizers, squash yield and fruit quality between the two production systems were comparable. The initial application rate of compost was quite high (15 tons per acre) and yearly additions of compost were reduced as soil fertility increased. When growing vegetables using organic approaches, you should regularly test the soil to ensure that nutrient balances in the soil are maintained, and that salt accumulation is avoided. Additional information about organic squash or pumpkin production can be found at: http://www.attra.org/attra-pub/PDF/pumpkin.pdf

After enriching the soil with nutrients, incorporate the fertilizers 4-6 inches deep with a tractor mounted or hand operated tiller. Some high tunnels can accommodate small machinery for soil tillage and other operations.

Drip irrigation is well suited for squash production in high tunnels and should be used in combination with black plastic mulch. Plastic mulches decrease water evaporation from the soil, reduce weed pressure, and warm the soil to promote early growth and fruiting (Image 1). Lay plastic at least one week prior to planting to help increase soil temperature. Be sure to place the drip tape under the plastic mulch and water the beds after installation.

Irrigation Management

Squash require regular, uniform watering during the growing season. Water stress at flowering causes blossom end rot, contributes to poor fruit shape and affects fruit sizing. Monitor soil water status with resistance block sensors such as the Irrometer® Watermark. Place sensors at various locations and depths in the soil profile to get a more accurate measure of soil water content. Since water demand changes with plant size, temperature, and growing season, monitoring soil moisture in the top 18 inches ensures that plants are not stressed. Soil texture (clay, loam, sand) influences the soil's ability to hold water (Table 2). Other low cost tools and methods to monitor soil water can be found at attra.ncat.org/attra-pub/soil_moisture.html.

Table 1. Recommended fertilizer rates based on soil tests for transplants in plastic mulch [4&5]

Nitrogen (lb/acre)	P_2O_5 (lb/acre)* Soil Phosphorous level			K_2O (lb/acre)* Soil Potassium level			Application Time
	Low	Medium	High	Low	Medium	High	
50	100	50	0	150	75	0	Incorporate prior to planting
20							2 weeks after transplanting
20	50	50	50	50	50	50	When first flowers open
60§							Additional fertilizer for the rest of the 6 week season
150	150	100	50	200	125	50	Total recommended

* A 14'x 96' high tunnel is 1,344 square feet (.03 acres). One acre equals 43,560 square feet.
§ Fertilizer supplied at 10 lbs N/acre weekly to provide 60 lb N/acre over the 6 weeks.

Table 2. Soil Tension Values for Different Soil Textures when Scheduling Drip Irrigation [4&6]

Soil Texture	0% Depletion of Available Water Holding Capacity (Field Capacity)[1]	20-25% Depletion of Available Water Holding Capacity[2]
	Soil Tension Values (in centibars)	
Sand, loamy sand	5-10	17-22
Sandy loam	10-20	22-27
Loam, silt loam	15-25	25-30
Clay loam, clay	20-40	35-45

[1] At field capacity a soil contains 100 percent of available water holding capacity; any excess water in the root zone has drained away.
[2] Start trickle irrigation for shallow-rooted crops at this point.
Adapted from "Water Management in Drip-irrigated Vegetable Production" (Hartz) and "Knott's Handbook for Vegetable Growers" (Maynard and Hochmuth).

Transplant Production and Planting

Transplanting is recommended for early squash production. Many growers produce their own transplants, but plants can also be purchased from a local greenhouse supplier. Sow seeds into plastic plug trays with 50 cells per tray filled with a good soilless mix. Adequate light levels are essential to produce quality plants that have thick stems that are not etiolated. Water regularly and feed weekly with a soluble complete fertilizer diluted to 100 ppm. Condition or "harden off" transplants for a short time each day by exposing them to cool temperatures (60-65°F) for 1 week prior to transplanting. Allow 4-5 weeks for growing transplants depending on greenhouse growing temperatures. Squash transplants should have no more than 2-3 mature leaves and a well developed root system at transplanting. After transplanting, cover with floating row cover or low tunnels during the first 3-6 weeks after establishment.

Squash planting dates in high tunnels vary depending on the location and climate conditions in Utah. In the cooler northern valleys, squash are generally planted in mid-April. For warmer regions, planting may occur as early as mid March. With some protection, plant 3-4 weeks before the last frost free day for your production area. Squash in tunnels are often spaced 18 to 24 inches apart in rows, depending on the variety with rows spaced 36-48 inches apart (Image 1). A 14′x 96′ high tunnel would accommodate 186 plants if there are three rows (48″ apart) with plants spaced 18 inches apart. Once planted water well and cover with floating or low tunnel row covers (Image 2). Ventilate tunnels whenever temperatures inside exceed 90°F.

High Tunnel Temperature Management

Squash grows best at temperatures between 75 and 85°F, and when night temperatures stay above 50°F. At temperatures between 50 and 60°F, growth is slow and flowering is often restricted. Temperatures above 95°F can damage blossoms causing flowers to fall off or develop misshapen fruit.

Consult the Utah Climate Center website under climate reports (climate.usurf.usu.edu) for local freeze-free dates. This will help determine the date of the earliest, average, and latest recorded spring freeze for your production area. Use this information to help identify potential planting dates. While high tunnels help store temperatures overnight, some frost protection is still needed when planting in high tunnels. Frost protection in a tunnel is limited to 2 - 3°F and helps plants survive temperatures to about 30°F when outside temperatures are near freezing. Row cover cloth can be laid directly on the plants and left on during establishment (Image 1). Low tunnels built inside high tunnels (Image 2) keep night temperatures warmer than cloth covers, but plastic must be vented during the day to avoid excessive heat.

Daily ventilation of the tunnels is needed even when outside temperatures are below 50°F. Venting ensures temperatures inside do not exceed 90°F. Ventilation may entail opening a single door in April, or both sides and doors in May when day temperatures are warm (Image 3). When night temperatures stay above 50°F the plastic on the high tunnel should be removed and can be replaced with a 40-50% shade cloth.

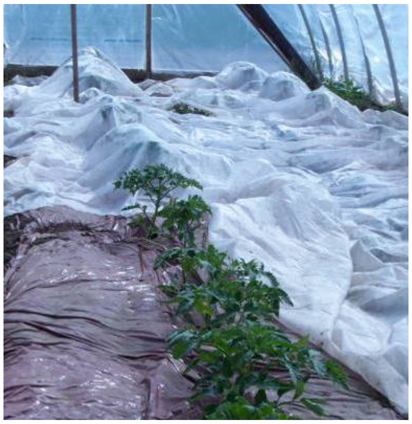

Image 1 (left). High tunnel grown plants are planted through plastic mulch and protected with floating row covers. **Image 2** (center). Low tunnels inside high tunnels are covered with plastic to aid in frost protection early and late in the year. **Image 3** (right). side walls and doors are used to aid in ventilation and allow bees access to the squash.

Pest Management

Pests can reduce yield and threaten fruit quality. Healthy plants grown in a clean environment are less likely to have pest outbreaks that require chemical treatments. Application of chemicals in tunnels is more hazardous than in the open field due to the closed environment. If using chemicals in tunnels, follow the directions on the label closely and always wear appropriate personal protective equipment. If you are having trouble diagnosing a pest problem, contact your county Extension agent or other knowledgeable individual.

Some of the more common insects of the cucurbits may cause issues in high tunnels throughout the year. Cucumber beetles will feed on squash at all stages of growth and are particularly bad during the seedling stage. Squash bugs can be a more serious problem and growers need to watch for them. Adults emerge in the spring and can cause serious damage particularly when plants are small. The adults will seek shelter under leaves and plastic mulches so they can be hard to find. Management includes scouting and early detection, growing healthy plants, and properly timed insecticide applications. Aphids cause poor plant growth and transmit virus diseases. While they appear later in the year in field grown squash, early season populations have been noted in tunnel houses. Silver reflective plastic mulches have helped repel aphids, floating row covers create insect barriers to colonization, and naturally occurring predator insects can help control aphids.

Disease Control

High tunnels trap warm humid air which can promote disease. Disease resistant varieties, proper soil drainage, good ventilation, and crop rotation aid in disease prevention. Most hybrid squash varieties have some disease resistance or tolerance. Common diseases noted in high tunnels include various leaf blights and mildews, several wilts and some viruses.

Foliage diseases, like leaf spots, powdery mildew, and stem blight may occur. These diseases occur during warm, humid conditions which are common in tunnels both early and late in the year. Treatment with fungicide sprays beginning at the first sign of disease may be necessary. Mosaic viruses, transmitted by aphids, can be a problem particularly if plants are infected when they are small. Virus resistant cultivars are available and should be grown if aphids have been a problem in the past. Root diseases like fusarium and verticilium wilts can limit production and can persist in soils for many years and affect numerous other vegetable crops. Long rotations, good sanitary conditions, and cultivar resistance are the best management approaches for wilts.

Physiological Disorders

Squash are susceptible to several physiological and environmental disorders that limit production or affect fruit quality. Most of the disorders are poorly understood and can be induced by many conditions related to nutrition, environments, or cultural practices.

Precocious female flowering sometimes occurs when squash is transplanted early. Plants exposed to cool conditions commonly produce many more female flowers which can affect fruit set due to a lack of pollen bearing male flowers (Images 4 & 5). If the cultivar grown is parthenocarpic, then this is not a serious problem. Blossom end rot is associated with irregular watering. Blossom end rot (Image 6) causes a sunken

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Image 4 (left). Squash plants have large showy male (open) and female (closed) flowers. **Image 5** (right), A close-up of male and female flowers; female flowers have the fruit behind the petals.

Image 6 (left). Blossom end rot in squash. **Image 7** (right). A high tunnel full of squash ready for harvest.

brown to black spot on the flower end of the fruit and is caused by a localized calcium deficiency. Bitter fruit can occur and the cause is not clearly understood. Some think that it is a mutation or out-crossing with wild types during seed production. Often only one or two plants may be affected and if these are identified, rouge them out of the planting

Weed Management

Weeds promote pests and compete with squash for water, nutrients, and light, especially when squash plants are small. Weed management is not difficult in tunnels when squash is grown using plastic mulches and plants are grown at appropriate plant populations (Image 7). The edges of the high tunnel (by the walls) are the primary weed problem areas since foot traffic keeps weeds down in the walkways and water is only being applied under plastic mulch. Weeds can harbor many insect pests (aphids, squash bugs, etc.) therefore control is warranted. Chemical weed control should be avoided since tunnels are used for other crops in tight rotations.

Harvesting and Handling

Squash fruits are generally picked two or three times per week when fruits are 4-6 inches long (1). High quality fruits are tender, have a shiny or glossy appearance and the seeds are immature. Actual size for harvest will depend on the market but are generally picked after the flower opens (Image 8). Since the skin on young squash fruits is very tender and easily scratched, growers often wear cotton gloves when picking. For optimum quality, harvest while fruits are tender and still have a shiny or glossy appearance. When harvesting squash, leave a short piece of the stem attached to the fruit (Image 9). Fruits are commonly cut off the vines and flowers can be removed or left on prior to marketing. Harvest crookneck and straightneck types when fruits are 1¼ to 2 inches in diameter and scallop types at 3 to 4 inches in diameter. Zucchini fruits should be harvested when they are 4 to 8 inches long. Before marketing, squash should be graded into U.S. size (small, medium, or large) categories (http://www.ams.usda.gov/AMSv1.0/Grading). While summer squash can be harvested for many months, the best quality fruits grow in the first 4-5 weeks. Plan to harvest tunnel squash until outdoor plantings start producing and then plan for fall plantings after outdoor production stops in the fall.

Summer squash should not be stored except under unusual circumstances. They can be held 2 to 3 days at 40-50ºF and a relative humidity of 95%. Deterioration is rapid since young fruits dry out quickly in storage and are quite sensitive to chilling injury.

Utah State High Tunnel Squash Trials

Goldrush (yellow zucchini) squash was used for all the trials conducted at Utah State University. In 2007 and 2008, we compared the production of squash when grown using organic or conventional based fertilizers. Squash were seeded in the greenhouse around 15 March and were transplanted around 15 April. Plants were grown with a black plastic mulch and covered with floating row covers for added plant protection early in the season. In all studies, squash were watered with drip irrigation. The plastic covering on the high tunnel was removed in mid-June and tunnels were recovered in mid-September. Tunnels managed by organic approaches used composted poultry manure as the nutrient source. Compost was tested and contained 13 lbs of soluble nitrogen and 33 lbs of organic nitrogen per ton of manure. For the conventionally grown squash, we used urea (46%) as the nitrogen source. We did not side dress the plants during the growing season.

Yield Assessment

Squash were harvested two times per week starting 4 weeks after transplanting. In most years, the spring harvest was completed before the onset of production of locally grown field squash. The overall yield is expressed as pounds/plant and this suggests that it is possible to produce about 225-375 lbs of baby squash (3-4 inch fruits) per 14′x 96′ high tunnel.

Organic vs. Conventional Fertility Case Study

Marketable yield of organically grown squash was similar to those grown with conventional fertilizers in the spring and fall of 2007 and the spring of 2008 (Table 3). Yield differences between the spring production periods of 2007 and 2008 are due to differences in the length of the harvest period. If the soils in high tunnels are sufficiently enriched with compost, yields should be quite similar. There were few cull fruits produced in either system. Culls were generally curved fruits or ones that had blossom end rot. Fall production tended to be less productive as cooler growing temperatures later in the year influenced productivity.

Image 8 (left). Immature fruit 3 to 5 days before harvest. **Image 9** (right). High quality fruits ready for market.

Table 3. Effect of organic or conventional crop production on squash yield in 2007 and 2008.

	Yield (lbs/plant)					
Grade	Organic '07 (spring	fall)	Organic '08 (spring)	Conventional '07 (spring	fall)	Conventional '08 (spring)
Marketable	1.22	0.96	1.86	1.26	1.06	2.04
#1	1.17	0.90	1.62	1.18	1.00	1.90
#2	0.05	0.05	0.24	0.08	0.06	0.14
Culls	0.22	0.02	0.32	0.15	0.03	0.60

Harvest Periods: Spring '07 (18 May to 29 June); Fall '07 (4 Sept to 30 Oct); Spring '08 (16 May to 7 August)
#1 and #2 grades are considered marketable

Nitrogen Fertilizer Rate Study

In addition to assessing how squash growth is influenced by organic or conventional production practices, we also looked at how yield changes as nitrogen rates increased (Table 4). While there was no difference in yields the soil had been regularly enriched so there was between the low and high rate of nitrogen applied, yields tended to increase when more compost or urea was applied. While the differences were not great, these tunnels had received regular applications of compost and adequate nutrients to support high yields. In general, yields were not as high as in the field since getting pollinators into the tunnels was a problem. The use of the parthenocarpic variety, Goldrush, helped to ensure there was some fruit growth. We also harvested when the fruits were quite young and thus average fruit weight is quite low.

Table 4. The effect of organic and conventional nitrogen rates on squash yields in 2008.

	Yield (lbs/plant)		
N-rate (lbs/a)	Organic (compost)	Conventional (urea)	significant
100	1.58	2.28	*
150	2.17	2.59	ns
200	2.09	2.60	ns
sign. 0.05	ns	ns	

- Low rate of organic nitrogen different from conventional nitrogen
- Yield increases as nitrogen rate increases.

Summary

Early and late season squash can provide local farmers additional product to sell at farmers' markets and other local retail outlets at a time when outdoor production is not yet available. High tunnel squash started yielding marketable fruit 1 month after transplanting which was 4-6 week earlier than outdoor production. Yields were not as high due to slower fruit growth rates which were associated with the lack of pollinating insects. However, fruit quality was very good thus making squash an economically attractive product for early markets Utah. High tunnel squash should not be thought of as an alternative to outdoor production. Rather they are an early season compliment to other products, thus allowing farmers to supply additional product to the public for a longer period of time, and during a time when squash is less available and may command a price premium.

Other Useful Websites

Resource Guide to Organic and Sustainable Vegetable Production
http://attra.ncat.org/attra-pub/vegetable-guide.html

High tunnel Resource Collection
http://www.hightunnels.org
http://plasticulture.cas.psu.edu/
http://www.extension.umn.edu/distribution/horticulture/M1218.html

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