ORGANIC POTATO PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers

Introduction

Potatoes can be a good addition to a small-scale, mixed specialty crop system. With access to the proper tools for mechanized weed management, hilling, and harvest, they are relatively easy to grow. Multiple varieties offer an array of shapes, sizes, and colors to make potatoes an excellent choice for direct sales, including Community Supported Agriculture (CSA), farmers' markets, specialty markets, and restaurants.

The Central Coast's climate is ideal for potato production. Yields can reach an impressive 10 tons per acre. This guide describes the steps involved in growing potatoes organically, reviews equipment needs, and provides information on "new" and "creamer" potato growth habits and recommended varieties.

Features of potato production

- Can be harvested as "new," "creamer," or fully cured storage potatoes, all of which can be grown on the same production schedule
- Easy to store when fully cured
- Mechanization makes weed management and harvest extremely efficient
- A good rotation crop where symphylan pressure is high, being extremely tolerant to symphylan feeding pressure; they have been shown to reduce symphylan populations in subsequent crops

PRODUCTION PRACTICES — SUMMARY

Soil type and pH

- Potatoes grow best in loose, well-drained, non-crusting, sandy loam or loam soils with high organic matter content and pH between 5.5 and 6.5.

Site selection

- Isolate successive potato plantings, and plant as far as possible from other susceptible crops such as tomatoes to minimize the risk and impact of late blight *(Phytopthera infestans)*.

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch).
- Compost, as needed (5 tons/acre).

Soil temperature

- Seed pieces can germinate when soil temperatures are cool (less than 55°F).

Bed spacing

- Bed spacing of 48" allows for a balance of workability and yield potential.
- 30" bed spacing is possible if using 4-gang Lilliston cultivators, disc hillers, or shovels.
- 60" beds provide for ease of field operations, but may reduce yield potential.
- Potatoes grow best planted in a single line per row to allow for "hilling" (see page 5) to ensure that potatoes are covered with soil. Potatoes exposed to sunlight turn green and become unmarketable.

Plant spacing within row

- 8–12" between plants in the row. Closer spacing will result in smaller tubers (see page 9, New and Creamer Potatoes).

Planting size and depth

- Use 1.5–3 ounce seed pieces with at least 2 "eyes."
- Place seed pieces 2–4" deep.

Irrigation

- Pre-irrigate beds with overhead sprinklers and cultivate for weed management.
- Use drip irrigation after planting; overhead irrigation increases risks of fungal infection, *Phytopthora infestans* (late blight).

Days to maturity

- Most varieties suitable for the Central Coast region reach full maturity in 100 to 120 days.
- Harvest "new" potatoes at the growth stage following bloom when the canopy is full, typically 8–9 weeks after planting, depending on variety and weather.
- Harvest "creamers" 10–12 weeks after planting, depending on variety and weather.

Crop rotation

- Rotate ground out of solanums and strawberries for a minimum of 4 years to break disease cycles.

PRODUCTION SEQUENCE — OVERVIEW

(crop day -25*)
In spring, mow cover crop to facilitate breakdown.

(crop day -25) Incorporate cover crop residue.

(crop day -11) Form beds with rolling cultivator or listing shovels.

(crop day -21) Begin chitting potato seed.

(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -3) Cut potato seed in preparation for planting.

(crop day -1) Work bed surface lightly with cultivator to terminate weeds and re-form beds.

(crop day 0) Create a trench down the center of the bed using a small furrowing shovel or an "Alabama" shovel. Plant potatoes, cover seed lightly with 3–4" of soil using a rolling cultivator (run slowly).

(crop day 11) As soon as first weeds appear, cultivate furrow bottoms and bed sides with sweeps and knives. In the same pass, run chisels in furrow bottoms to break tractor tire compaction.**

(crop day 11) Set up drip irrigation

(crop days 30, 40) Hill plants with soil as potato stems elongate (usually twice prior to bloom).

(crop day 30) Begin drip irrigation. Note: Drip irrigate to maintain even moisture until the tubers for main crop harvest are ~75% of desired size, then cut irrigation and let vines die. Potatoes will continue to size up.

(crop days 55–95) Check tuber size after flowering. Harvest new potatoes at 8–9 weeks after planting; creamers at 10–12 weeks.

(crop day 60) Spot weed large flowering weeds.

(crop day 116) Run overhead irrigation (0.25–0.5") prior to harvest of main crop to make harvest easier and avoid scuffing.

(crop days 120, 140) Harvest main potato crop.
(crop days 160) Pull drip lines.

Drill cover crop seed prior to fall/winter rains.

(crop day 180) Disc plants, prepare soil for fall cover crop.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 12) for more on crop days and related activities.

**Some growers use a flame weeder at this stage, ideally just before potato leaf emergence, but even just after emergence, if necessary.

Production Practices — Additional Details

Soil type

Potatoes grow best on light textural soil classes: sands and silts with organic matter (O.M.) >3%. Potato tubers have a high respiration rate, and require ample oxygen in the soil. Lighter soils let in air that allow potatoes to breathe. Lighter soil textures also offer less physical resistance to tuber formation; thus the plant can put more caloric energy into forming large, cosmetically even tubers. Lighter, sandier soils also make harvest easier.

Heavier soils higher in clay content tend to provide better fertility and water holding capacity, but can cause tuber deformation, and make washing challenging. Although you cannot change the texture of soil, you can enhance its structure by increasing its organic matter content by adding compost and incorporating cover crops (green manures).

Fertility

Potatoes yield well when planted following incorporation of a mixed legume/cereal cover crop, e.g., bell bean (30–35%), peas (20–30%), vetch (30%), and triticale (10–15%). When incorporated well, the cover crop residue leaves the soil loose and friable, and microbial decomposition releases nutrients to provide adequate fertility (available nutrients).

If applying compost, use a rate of not more than 5 tons per acre (100 lb. N per acre) to avoid over-application of nitrogen (N). Excess nitrogen can:

- Make plants more susceptible to late blight *(Phytopthora infestans)*
- Delay tuber set and maturation
- Increase water content in tubers, which leads to a shorter storage life and more post-harvest physiological disorders

Bed spacing

Plant potatoes in a single line system to facilitate hilling. Depending on equipment available and standard bed spacing used on your farm, beds can be spaced from 30" up to 60" center to center. Hilling potatoes is more challenging with narrower beds; 4-gang Lilliston cultivators, disc hillers, or shovels are potential options with this spacing. Wider bed spacing means loss of yield potential. Consider the trade-offs between ease of hilling operations, efficiencies of land use, and labor required to adjust equipment. Take into account the other crops you grow, and choose the bed spacing that works best for your farming system as a whole.

Timing of planting

Spring is the best time to plant potatoes on California's Central Coast. Potato seed pieces can easily germinate in cool soils (less than 55°F). Plant following incorporation and initial breakdown of cover crop residue, typically in late April or early May. The goal is for the crop to develop prior to the onset of foggy conditions that favor late blight infestations in late summer (August). Staggered plantings are not recommended in areas where fog may be a factor. Some growers successfully plant in late July, growing a fresh market crop for fall holidays.

In inland valleys, potatoes are usually planted in February so that tuber maturation takes place prior to high summer temperatures that can delay tuber formation.

Preparing seed potatoes for planting

"Certified seed" sold for planting has been inspected and meets the tolerance for pest and disease disorder symptoms established by an agricultural certification program (e.g., White Rock Specialties seed is certified by the Colorado Board of Agriculture). This use of the word "certified seed" is complementary to, and distinct from the meaning of seed that is "certified organic." The National Organic Program (NOP) requires that organic growers purchase organic seed, unless the variety needed (or an equivalent variety) is not commercially available in an appropriate form, quantity, or quality.

To prepare seed for planting (also called "greening" or "chitting"), bring potatoes to room temperature (or warm up your cooler to 50–55°F) two to three weeks before planting to initiate sprouting. Expose to bright shade, but do not let them dry out while sprouting.

Seed potatoes that are large enough can be cut into smaller pieces to extend planting stock volume. Cut tubers into

FIGURE 1. Preparing seed pieces for planting. *Photo: Elizabeth Birnbaum*

FIGURE 2. Alabama shovels with "drop tubes" for placing seed pieces. *Photo: Martha Brown*

FIGURE 3. Plant potato seed into furrows created by furrowing or Alabama shovels. *Photo: Martha Brown*

1.5–3-ounce pieces (a little larger than a hen's egg) with at least two "eyes" on each cut piece (Figure 1). Cut through the center of the potato and allow the cut to heal over for 3 days prior to planting. Seed cut immediately before planting may experience decay in the ground, especially if soil is too dry or too warm at planting.

Planting technique

Because tubers form adjacent to and above the seed piece, place seed as deep as possible. Deep planting leaves room to "hill" the plant as the stems elongate (see below). However, plant no deeper than the depth of your harvester to reduce risk of slicing potatoes during harvest.

Create a depression down the middle of the planting bed—to the depth of the furrow if possible— using a small furrowing shovel or an "Alabama" shovel (Figure 2). Drop the seed pieces into this depression or trough (Figure 3) and cover with 3–4" of soil (enough to cover the seed pieces and keep them from drying out) by re-forming the bed using a rolling cultivator, reverse disc hillers, or shovels.

Hilling potatoes

Re-form the beds after planting deep, then again after the plants emerge, building the beds higher to keep potatoes covered with soil as the stems elongate (Figure 4). This re-forming of the bed, or "hilling," is essential for potato production because it blocks sunlight from the tubers as they form. Any light contact causes "greening"; the presence of chlorophyll and potential for accumulation of toxins (glycoalkaloids), render any green tuber unmarketable. Hilling also facilitates weed management and boosts yields.

Potatoes grow remarkably fast once they emerge (usually about 14 days after planting). Do the first mechanical hilling once plants reach a height of 8–10" (within 30–33 days after planting). Use a rolling cultivator during this time of initial growth to smother any weeds germinating in the bed, and to keep furrows clean of annual weeds. Work the furrows with shallow chisels to break tractor wheel compaction and deepen the furrows. Do the second hilling 5–7 days after the first (Figure 5). On small plots, hilling can be done by hand with a shovel.

FIGURE 4. Potatoes developing in a "hill." *Illustration: Laura Vollset*

FIGURE 5. Hilled potatoes at the UC Santa Cruz Farm.
Photo: Elizabeth Birnbaum

Irrigation

Drip irrigation is the best option for potatoes, allowing you to control irrigation rate and timing, and apply water directly to the growing plants. At planting, set the drip lines in the center of the bed on top of the seed pieces; cover it as you close the furrow and bury it further as you hill the potatoes (note that you can also lay drip tape after the plants have emerged). See the irrigation sequence at right.

Potatoes can be irrigated overhead, but this method favors development of late blight due to prolonged periods of leaf wetting. If overhead sprinklers are used, irrigate mid-day following dry-down of foliage from morning dew, and shut down the sprinklers early enough for leaves to dry prior to sunset.

IRRIGATION SEQUENCE

- Pre-irrigate with a minimum of 1–1.5" using overhead irrigation (if available) to bring up weeds and provide adequate deep soil moisture to support the early growth stage of the potato seed pieces. Cultivate before planting. (See *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.)
- Plant seed pieces into residual moisture.
- Lay drip line at time of planting or once plants have emerged.
- Initiate drip irrigation after plants have emerged and are well established (between 2 and 4 weeks after planting), and the first hilling has taken place. Depending on weather and soil conditions, pre-irrigation moisture deep in the soil may be adequate to support up to 3 or 4 weeks of growth.
- Schedule irrigations based on regional evapotranspiration (Et) data (available at cimis.water.ca.gov):
  - When plants are at 25% canopy (percentage of the bed's soil covered by crop foliage), irrigate at a rate roughly equal to 25% of the estimated daily Et.
  - Follow this percent canopy rule to determine irrigation rate; when plants are at 100% canopy, irrigation will match Et.
  - During the period of tuber enlargement (usually days 60–90), field capacity should not drop below 60–65%. Uneven irrigation in this phase leads to uneven tuber formation and jeopardizes marketability.
  - Water can be cut to "dry off" and cure crop once plants start to show signs of senescence (yellowing of leaves) and tubers have reached ~75% of marketable size. Wait another 10–14 days before harvest for skins to cure.
  - Apply .25–.5" of water prior to harvesting the main crop to make harvest easier, and to avoid scuffing spuds, which can compromise salability and storage life.

GROWTH PHASES

Phase 1: Vegetative establishment, 0–30 days

Most vegetative growth occurs during this phase. Adequate pre-plant nitrogen (in the nitrite form) ensures a large, effective plant that can support tuber development through sugar and starch translocation.

Phase 2: Stolen and tuber initiation, 30–60 days

Flowering begins at approximately 40–50 days (Figure 6). Dig "new" potatoes during this phase (see sidebar, page 9).

Phase 3: Tuber enlargement, 60–90 days

It is critical to provide adequate irrigation during this phase. Dry down should be less pronounced than in phases 1 and 2; never let the plants get to less than 60–65% field capacity. Dig "creamer" potatoes during this phase (see sidebar, page 10).

Phase 4: Tuber enlargement, skin set and curing, 90–120 days

Tubers enlarge, increase in starch content and individual varietal characteristics. Skins set and thicken, allowing for long-term storage.

FIGURE 6. Potatoes begin to flower at approximately 40–50 days post planting. *Photo: Elizabeth Birnbaum*

Harvest and harvesting equipment

"New" potatoes (see next page) must be harvested by hand. Push a garden fork under the cluster of potatoes and gently lift the plant by the leaves as you push down on the fork handle to raise the tubers to the surface (Figures 7 and 8). New potatoes are extremely delicate; handle very gently to avoid damaging the skin.

When harvesting mature tubers by hand, the process is the same. Take extra care not to "fork" through the potatoes, but get under the tubers.

Use a dedicated potato harvester or an under-cutter pulled behind a tractor for mechanized harvest. For potato production areas much larger than one-quarter acre, it is best to harvest mature tubers with a dedicated potato harvester, such as a single-row PTO- operated digger with an undercutter bar and shaker cage. The harvester lifts the spuds and leaves them on the soil surface to pick up (Figures 9 and 10). Break the furrow tire compaction with chisels before harvest to ensure that the under-cutter or harvester can get below the lowest tuber and work effectively.

FIGURE 7. Harvest new potatoes using a garden fork. *Photo: Elizabeth Birnbaum*

FIGURE 8. Handle new potatoes gently to avoid damaging the fragile skins. *Photo: Elizabeth Birnbaum*

"NEW" POTATOES AND "CREAMERS"

Both new potatoes and creamers offer good niche marketing possibilities, including CSA projects, farmers' markets, roadside stands, and restaurants.

NEW POTATOES are simply young, small, freshly-dug potatoes. They must be marketed quickly (within a few days of harvest) and will last only 7–10 days (refrigerated).

The possibility of digging 100–200 pounds per day for 2–3 weeks offers early season income and a premium price. Also, if well done, new potatoes can create a loyal following of customers and improve your "brand."

In theory, any variety can be used for new potatoes, but those described as early season (maturing in <90–100 days) work best, as they tend to set ample tubers early, and size up evenly.

Suggested varieties include–

'Red Gold'

'Early Red Norland' (distinct from 'Dark Red Norland', which is a high-yielding, mid-season variety)

'Mountain Rose'

Planting seed of the above varieties are easy to source. They are all spectacularly early and high yielding, producing 2.5–3 pounds/plant at 60+ days from planting.

The following also offer a reasonable ratio of pounds per plant to days in the ground (most are red varieties)–

'Anoka' (very early, difficult to source)
'Caribe'
'Cherry Red'
'Desiree'
'Early Purple'
'Kerr's Pink'
'Purple Viking'
'Red LaSoda'
'Rose Gold'
'Yukon Gold'

Tips for Growing New Potatoes

- Use small, whole seed potatoes (1–2 ounces)
- Plant seed 8–9" apart, using standard row spacing
- Plant 2–4" deep in 6–8" deep trenches
- Hill plants at 20–30 days from emergence
- Dig when size of 6–10 tubers reaches 2–8 ounces, usually 60–75 days post planting
- Dig when soil is dry; box and let sit 1–2 days, then wash and pack
- Note that some nicked skins are inevitable with new potatoes. It identifies them as truly new and freshly dug.

CREAMER POTATOES offer another niche market that can generate some early season income due to high demand and relatively low supply.

Creamer potatoes are similar to new potatoes in that they are small (2–4" in diameter, 2–4 ounces). They may be dug early or at full maturation. The main distinction is that they have thicker skins and are thus easier to dig and pack than new potatoes, and rival storage potatoes in their shelf life.

Although not as moist, light, and sweet as new potatoes, they do have an intense, earthy taste and texture that makes them more distinctive than full-size storage potatoes, and offer more nutritional value than new potatoes.

Creamer potatoes show themselves off both on display and on the plate. They can be displayed for loose pack in small net bags by mixing varieties, shapes, sizes, and colors.

As with new potatoes, choose early varieties with plants that mature at <90–100 days. In addition to those listed for new potatoes, preferred varieties include:

'Austrian Crescent' (fingerling)

'Early Ohio'

'Viking Purple'

Fingerling varieties (2–3" long) can also be adapted for this format.

Tips for Growing Creamer Potatoes

- Use close in-row spacing when planting (5–6")
- Grow for 10–12 weeks
- Kill vines (mechanically)
- Dry off (no irrigation) 7–10 days before harvest to set skin
- Hand dig, box, and refrigerate
- Wash only when needed for packing and distribution

FIGURE 9. Example of a PTO-driven harvester with "shaker cage." *Photo: Martha Brown*

FIGURE 10. Shaker cage deposits harvested potatoes on the soil surface. *Photo: Martha Brown*

Post-harvest handling

Tubers going direct to market are usually washed immediately after harvest, especially if the soil is prone to sticking. Tubers harvested for storage should not be washed, as water can spread disease (especially fungal spores that cause late blight), and increase potential for higher incidence of infection while in storage.

Crop rotation

Because potatoes are host to many of the same diseases commonly found on other Solanaceae family crops (tomatoes, peppers, etc.), as well as strawberries, rotate ground out of solanums and strawberries for a minimum of 4 years.

Late blight *(Phytophthora infestans)* is the primary disease of potatoes in the Central Coast region. Because the fungal spores that cause late blight move easily with water and wind, it is best to keep a significant buffer between blocks of potatoes and tomatoes since the blight will most often start on the foliage of potatoes (early season) and spread to tomatoes.

Pests and Diseases

Before you select varieties and plant your potato crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main potato arthropod pests in the Central Coast region are:

- Tuber moth. *Phthorimaea operculella:* larvae cause economic damage when they tunnel into potato tubers, both in the field and in storage.
- Aphids and viruses—Green peach aphid, *Myzus persicae* and Potato aphid, *Macrosiphum euphorbiae:* aphids act as vectors that transmit Potato Leaf Roll Virus (PLRV), cucumber mosaic and alfalfa mosaic (calico) viruses.
- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata,* and Western striped cucumber beetle, *Acalymma trivittatum:* damage foliage.
- Tuber Flea Beetles, *Epitrix tuberis*: beetle larvae feed on tubers.
- Wireworms. Common local species of wireworms include: Pacific coast wireworm, *Limonius canus.* Sugarbeet wireworm, *Limonius californicus.* Dryland wireworm, *Ctenicera pruinina:* wireworms are click beetle larvae that live in the soil. They cause economic damage by eating potato seed pieces or roots of young plants, or burrowing into developing tubers.

The main potato diseases in the Central Coast region are:

- Late Blight, *Phytophthora infestans:* late blight develops rapidly, and can defoliate a crop within a few weeks.
- Verticillium Wilt, *Verticillium dahliae*: this wilt appears as yellowing (chlorosis) and death (necrosis) of lower leaves; it interferes with the plant water transport (vascular) system, so the impact becomes visible quickly in hot weather.
- Scab, *Streptomyces* spp.: causes potato tubers to be unmarketable.

See *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for additional information on the pests and diseases listed here, and suggestions for their control in potatoes.

ADDITIONAL RESOURCES

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Ospud participatory organic potato project, Oregon State University. horticulture.oregonstate.edu/content/publications-and-presentations-ospud-project

Pest management strategic plan for organic potato production in the west. Summary of workshops held on February 16, 2006, Buhl, Idaho and January 9, 2008, Portland, Oregon. Jennifer Miller, Ronda Hirnyck, Lisa Downey-Blecker. Issue Date, December 19, 2008. www.ipmcenters.org/pmsp/pdf/CA-CO-ID-OR-WAOrganicPotatoPMSP.pdf

Potatoes: Organic production and marketing, by Rex Dufour, Tammy Hinman, and Jeff Schahczenski. NCAT IP337, 2009. attra.ncat.org/attra-pub/summaries/summary.php?pub=96

Selecting, cutting and handling potato seed, Bulletin #2412, 2015, by Steven B. Johnson, Ph.D., Extension crops specialist, University of Maine Cooperative Extension extension.umaine.edu/publications/2412e/

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	Sub Crop/Variety	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Amt. (#)	Unit Price ($/#)	Harvest Value ($)
-25		20	Flail Mow:heavy	2.5	0.2		$26.04			
-25		20	Spade	4.8	0.2		$46.00			
-21		20	Begin Chitting		0.5	$8.05				
-11		20	Mark Lines	2	0.2		$21.70			
-11		20	List	1.25	0.2		$15.19			
-11		20	Overhead Irr:set up	3.75		$24.15				
-10		20	Overhead Irr:run		0.5	$8.05				
-3		20	Cut Potatoes	24.2		$155.85				
-3		20	Overhead Irr:break down	3.75		$24.15				
-1		20	Light cultivation	1.25	0.2		$15.19			
0		20	Plant:driver	4.84	0.4		$50.69			
0		20	Plant:planters	9.68		$62.34				
11		20	Cultivate	2	0.2		$21.70			
11		20	Drip:set up	10	0.25	$68.43				
30		20	Hill	1.25	0.2					
30		20	Drip:run x 2/wk; @ 9 wks		2.7	$43.47				
40		20	Hill	1.25	0.2					
60		20	Hand Weed:spot weed	2		$12.88				
80	Yukon Gold, Red Gold	10	Flail Mow:light	1.25	0.2		$9.77			
94	Desiree, Austrian Crescent	10	Flail Mow:light			-				
115		20	Overhead Irr:set up	3.75						
116		20	Overhead Irr:run		0.5					
100	Red Gold	5	Harvest	83	1	$149.73	$39.06	1,800	$2.0	$3,600
120	Yukon Gold	5	Harvest	83	1	$149.73	$39.06	2,900	$1.5	$4,350
120	Desiree	5	Harvest	83	1	$149.73	$39.06	2,200	$1.5	$3,300
140	Austrian Crescent	5	Harvest	83	1	$149.73	$39.06	2,900	$2.0	$5,800
160		20	Drip:break down	2		$12.88				
180		10	Disc:x1	0.5	0.2		$6.51			
-		10	Drill/Cover Crop	1.6	0.2		$11.28			
					Sub-total:	***$1,019.16***	***$380.31***			

Harvest Assumptions	
Harvest (#/acre)	
Red Gold	18,000
Yukon Gold	29,000
Desire	22,000
Austrian Crescent	29,000
Harvest (row'/hr)	180
Harvest Rate (hr/ac)	80
Price ($/#)	1.5-2

Labor + Machine Cost ($)	
Per Block (.4 Acres):	***$1,399.48***
Per Acre:	***$3,470.48***

Yield		
Per Block (.4 Acres):	***9,800***	***$17,050***
Per Acre:	***24,500***	***$42,625***

Input Costs			
Item	***Cost per unit***	***Cost per acre***	***Notes***
Seed - Non-Fingerling	$.45/#	$816.75	.125#/row'; 1 row/bed; 14520 row'/ac; 1815#/ac;
Seed - Fingerling	$1.30/#	$2,359.50	.125#/row'; 1 row/bed; 14520 row'/ac; 1815#/ac;
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Bags	$.19043/bag	$186.62	25#/bag; 24500#/ac
Total Expenses (per acre):		***$3,595.19***	

Per Acre Totals	
Income:	$42,625.00
Labor + Machine Cost ($):	-$3,470.48
Expenses:	-$3,595.19
Production Profit:	**$35,559.33**

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

ORGANIC DRY-FARMED TOMATO PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers

Introduction

Where appropriate climate and soil conditions exist, growing dry-farmed tomatoes can be a good option for specialty crops growers. Dry farming generates an intensely flavored crop much prized by consumers and retailers.

A limited number of geographic regions are suited to dry farming, which requires adequate winter rainfall and—in the case of annual crops—a summer-time marine influence that generates cool mornings and warm afternoons. These climatic conditions, combined with careful soil preparation, appropriate variety selection, adequate plant spacing, and vigilant weed control are all required to successfully produce dry-farmed crops.

This guide describes the steps involved in growing dry-farmed tomatoes organically on the Central Coast of California, with a focus on proper soil preparation, planting, and weed control.

Features of dry-farmed tomato production

- Heightens the intensity of crop flavors
- Produces a desirable specialty crop that can command a good price
- Creates options for value-added products
- Maintains production in areas where water is limited
- Minimizes weed seed development
- Makes it easier to deal with problem weeds
- Facilitates the extraction of nutrients that have leached below the root zone of most irrigated crops by forcing deep rooting

PRODUCTION PRACTICES — SUMMARY

Appropriate conditions

- Minimum 20" winter rain.
- Early morning fog, mild afternoon temperatures (max to mid 80°s F).
- Evapotranspiration (Et) rate approximately .15"/day.

Soil type

- Relatively high clay content (works best).
- Sandy loam soils or loam soils that overlay deeper clay soils also work well (see sidebar, page 4).

Crop placement

- Plant tomatoes in isolation from potatoes and other solanums to minimize potential for spread of late blight *(Phytopthora infestans)* from potato foliage.

Fertility requirements

- Fall/winter cover crop: single species legume or primarily legume mix.
- Fall-applied compost.

Recommended timing of planting / Successions

- Plant when soil warms to approximately 60°F at 8" depth and incorporated cover crop has decomposed (residues brown, leaves no longer recognizable).
- Successional plantings can extend the harvest season. Depending on climate, growing season and markets, successions can be planted 2–3 weeks or 4-6 weeks apart.
- Warmer soil conditions promote the rapid growth rates and deep root development essential for successful dry-farmed tomato production.
- Early and late plantings face lower soil temperatures, cool and moist weather, risk of rain or frost, have slower growth rate and vigor, and increased susceptibility to pests and diseases.
- Early or late plantings that succeed have the potential to mature during market windows when there is less crop availability and therefore may command higher prices *(there are rarely any guarantees about pricing!)*.

Plant and row spacing

- 18"–24" between plants; 6' between rows.
- Lower winter rainfall may necessitate wider spacing.

Planting technique

- Transplant starts in furrows formed in the bed middles.
- When planting to moisture, plant well-hardened plants that are at least 12" tall.
- Ensure that root ball is surrounded by moist (darker) soil; if necessary, hand dig into deeper moisture to get the roots as deep as possible into moist soil.
- Firm the soil around the roots to re-establish capillarity.

Days to maturity

- Fruit matures approximately 90 days after transplanting; earlier in hot weather.

Harvest tips

- Harvest at full ripeness (uniform deep red color) for maximum flavor.
- Ensure that tomatoes are still firm, not soft.
- Harvest thick-skinned varieties into 5-gallon buckets; handle fruit gently.
- Harvest with calyx intact to improve appearance for immediate direct sales.

Post-harvest handling

- Sort and pack in the shade.
- Store in cool, shady location to hold up to a week without refrigeration.

Crop rotation

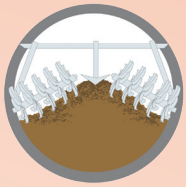
- Rotate crops (plant different plant families) to break disease cycles.

PRODUCTION SEQUENCE — OVERVIEW

(crop day -25*) In spring, mow cover crop to facilitate breakdown.

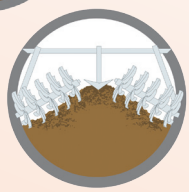
(crop day -25) Incorporate cover crop residue.

(crop day -11) Form beds with rolling cultivator or listing shovels.



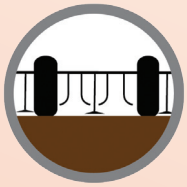
(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5″). Wait for dry down and weed emergence.

(crop day -1) Do a shallow cultivation with a rolling cultivator to terminate weeds and create a dust or soil mulch. If planting is delayed, maintain dust mulch with rolling cultivator as needed until planting time.



(crop day 0) Break open bed middles with Alabama shovels and promptly plant tomato transplants deep into moist soil using hand trowels; on larger acreage, plant with mechanical planter.

(crop day 11) Cultivate with sweeps, side knives, and shallow furrow chisels when first weeds appear in furrow bottoms or as necessary to maintain dust mulch.



(crop day 12) Once plants reach adequate height (~12″), hill tomatoes with rolling cultivator.

(crop day 21, 43, 63) Stake and string plants no later than when the plants reach 1′ in height; continue stringing as plants grow.

(crop day 68) Initiate harvest when tomatoes reach full color; harvest may extend for 8–10 weeks, depending on variety and weather.

(crop day 150) Disc plants and prepare soil for fall cover cropping to enhance infiltration of winter rains.

Drill cover crop seed prior to fall/winter rains.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

Production Practices — Additional Details

Soil amendments

Dry-farmed tomatoes will extend roots up to 8′ deep or more to access moisture. Because there is no irrigation to carry solubilized nutrients to the root zone, dry-farmed tomatoes can be considered a "scavenger" crop in terms of nutrient uptake and demand.

Plant a winter cover crop ahead of a dry-farmed tomato crop to keep the soil covered over the winter, minimize soil erosion and nutrient leaching, fix nitrogen and build soil organic matter, stimulate microbial activity, improve water infiltration deep into the root zone, and enhance overall soil conditions. Use either a single species legume or primarily legume mix to grow a low-lignin cover crop whose residues break down quickly to facilitate earlier spring planting and maximize use of winter rains.

Because dry-farmed tomatoes are so deeply rooted, the crop will benefit from a fall application of compost prior to planting a cover crop. Compost applied at the time of cover crop incorporation would not benefit the dry-farmed tomato crop, although slow-release of nutrients would benefit subsequent irrigated crops.

Soil preparation and weed control

Soil preparation to conserve or "trap" winter rainfall is critical for successful dry farming. To maintain the winter moisture bank, follow this two-step process:

- **Step 1: Incorporate the cover crop**

Mow and incorporate the winter cover crop early to minimize water loss from the soil through transpiration from the cover crop. Specific timing of incorporation is linked to your particular soil type and stage of cover crop maturation. Ideally, it will take place during a spring break in the weather that allows entry into the field with tillage equipment without undue soil compaction, and allows for subsequent decomposition of the cover crop.

To determine the optimum time to incorporate the cover crop, use a shovel or probe to assess the soil at various depths. Incorporate the cover crop and till when the soil is at about ~70% field capacity. This is on the wetter side of what is normally considered ideal; you will need to take care to prevent compaction.

- **Step 2: Create a "dust mulch"**

Once the cover crop is incorporated and adequately decomposed (this may take 10–20 days depending on the type of cover crop, its maturity, and soil conditions at the time it is worked in), list up beds in the field with a rolling cultivator. In the absence of adequate spring rainfall or if soil moisture is low, pre-irrigate beds with 1–1.5" of water using overhead irrigation to facilitate further breakdown of the cover crop; when spring rains are adequate (>1" after listing the beds) this step is unnecessary.

Wait for weed flush, then cultivate the weeds when they are at the pre-emergent "white thread" stage or still small (see Figure 1) and create a dust mulch. Use relatively shallow (4–6") mechanical soil tillage tools such as a rolling cultivator, rototillers, or disc harrows, often followed by secondary tillage implements such as spring tooth harrows. The loose soil created by this cultivation pass is referred to as a dust mulch or soil mulch. Because of the loose aggregation of the soil, the capillary action that would normally wick soil moisture to the surface is broken. Thus, the dust mulch provides an effective barrier to evaporative loss of moisture held within the root zone of the soon-to-be-planted dry-farmed crop.

Timing is critical for creating the initial dust mulch: you must trap as much rain moisture in the soil as possible, yet avoid working the soil when it is too wet. Tractor operations on wet soils, especially "heavier" soils high in clay content, can cause clod formation and compaction.

Similarly, it is important to minimize tillage depth when preparing soil for planting annual dry-farmed crops, since deeper tillage could disrupt the lower soil capillaries that are critical for soil water movement below the tilled zone.

Maintain the dust mulch and control weeds with light and fairly frequent tillage operations (every two or three weeks) from the time of initial tilling until the crops are too large to cultivate effectively.

FIGURE 1: Control newly emerged weeds (bottom left and right) with timely cultivation. *Photos: Jim Clark*

ASSESSING YOUR SOIL FOR DRY FARMING

The best soils for dry farming have relatively high clay content; sandy loam soils or loam soils that overlay deeper clay soils also work well. Soils higher in sand content do not hold soil moisture as well as clay and clay loam soils and therefore are typically not used for dry farming.

If you are considering dry farming, bore numerous holes up to 4′ deep throughout the production area using a 2" slide hammer soil probe or a soil auger to obtain soil "plugs." Soils that are suitable for dry farming will exhibit continuity within the different horizons and a loam or sandy loam upper horizon with clay directly below it.

Preparing and planting a small area of the field is the best way to determine whether the site and conditions are suited to dry farming. Although conditions vary from year to year, and management practices may be refined, it is less risky to experiment with dry farming (or any substantially new practice) on a small scale. If the small plot does well, you can expand it in future years.

Varietal recommendations

Varieties that do well as dry-farmed crops typically have an aggressive root system capable of reaching deep into the soil horizon to tap the stored moisture.

Growers in the Central Coast region have trialed literally hundreds of varieties of heirloom, open pollinated, and hybrid tomatoes. To date, none has compared to the hybrid 'Early Girl' in its ability to set deep roots and consistently produce a good yield of high quality, flavorful, and marketable fruits with no irrigation. 'New Girl', a recently introduced variety, is closely related to 'Early Girl' and appears to have many of the same favorable characteristics, but produces lower yields.

Some newer varieties have been bred with the pollen parents of 'Early Girl' yet (unlike 'Early Girl') claim to be resistant to spotted wilt virus, but these are not yet commercially available.

Seedlings

Depending on your farm's greenhouse facilities, tomato seedlings can either be grown on site or purchased from an organic seedling supplier. Plant well-hardened, "tall" plants (at least 12" tall) so that the seedlings can be planted deep to ensure root contact with moist soil.

Pre-irrigation

As noted above, dry spring conditions may make it necessary to pre-irrigate the beds before planting, with either overhead irrigation or drip lines, to establish an optimal stand. This pre-irrigation should always be followed by a cultivation to take advantage of planting to moisture, which gives the tomatoes a jump start on weeds (please see the publication *Tillage, Bed Formation, and Planting to Moisture* in this **Grower Guide** series for additional details).

On a garden scale, you may need to hand water the newly planted starts to ensure rooting and uniform establishment.

Plant spacing and planting technique

A typical spacing for dry-farmed tomatoes (depending on soil type and rainfall amounts) is 6' between rows and 2' between plants. Some growers use a closer spacing to further "stress" the plants for increased flavor; however, closer spacing will likely limit harvest windows, making additional successions necessary to increase overall yield (see page 2 for successional planting information).

FIGURE 2. Alabama shovels open planting furrows. *Photos: Carolyn Lagattuta*

Note that the recommendations below assume that you are planting into beds that have been prepared with a rolling cultivator and that the moisture is fairly close to the surface.

On the day of planting, set up a tractor-mounted tool bar with a wide Alabama shovel and open the middle of the bed to be planted (Figure 2). This pass with the shovel should remove the dry soil on the bed top and form a "V" down the length of the bed middle, allowing for easy access to deeper soil moisture in the bed middle and providing a "guide" for planting and follow-up cultivation.

FIGURE 3

Water the starts so they are well hydrated prior to planting, and do not allow them to dry out before planting into moist soil.

Plant seedlings at the desired spacing, as deep as possible, either by hand or with a mechanical transplanter. Plant vertically and ensure that the roots are in contact with moist soil (Figures 3 and 4).

Check plants following transplanting to make sure the roots have good contact with soil moisture. If you notice uniform wilting in the early morning on the day following transplanting you may need to "water in" the transplants to ensure survival. Slight wilting in the late afternoon—especially during warm weather—is common during the first week following transplanting. Tomatoes are aggressive rooters and will survive and root with very limited soil moisture as long as daytime temperatures are not extreme (>85°F).

To minimize weed pressure and maintain a soil mulch, cultivate the soil frequently (every 2–3 weeks) following planting. The first cultivation will typically focus on furrow bottom weed management using a three bar cultivator running sweeps, side knives, reverse disc hillers, and shallow furrow chisels. Once the crop's stems have lengthened enough, use a rolling cultivator to throw dirt into the planted line to smother any

FIGURE 4. Plant tomato start deep into moist soil. *Photo: Carolyn Lagattuta*

FIGURE 5. Use a rolling cultivator to "hill" or "dirt" tomato plants. *Photos: Martha Brown*

newly emerged weeds there (Figure 5). Unless high clearance cultivating tractors are available this cultivation will be the last.

Support system options

Although dry-farmed tomatoes may be grown without support, most Central Coast growers stake and tie their crop in order to increase crop yields, minimize fruit contact with the soil, and make harvest easier.

The following system is used at the UCSC Farm (see Figure 6):

- Once plants reach 1' in height, place untreated 5' wooden stakes a foot deep every 4' (every 2 plants) within the plant row, using a metal t-post every 4th spot for stability.
- Place a t-post at either end of the row at an angle as an anchor.
- Wrap string lines around the stakes starting at 8" above the ground, with a second line placed a foot above the first, and a third a foot above the second.
- Use a "basket weave" system to train the plants between the strings (for a similar system, see www.youtube.com/watch?v=XSf3aSj46jo).

Harvest and post-harvest considerations

Growing 'Early Girl' or similar thick-skinned varieties makes harvest easier since the tomatoes resist bruising or damage from handling. Tomatoes can be harvested into 5-gallon buckets; fruit at the bottom of the bucket will hold up under the weight of the tomatoes above them as long as the bucket is handled gently and the tomatoes aren't overly ripe.

If you grow and harvest heirloom tomato varieties grown in a dry-farmed system, use extreme care during handling since these fruit are generally much more delicate than thicker-skinned varieties. The rest of the discussion below assumes production of small, thick-skinned, red tomato varieties. If you are growing heirloom varieties, please disregard those parts of this discussion that are not applicable to your crop.

For the best eating quality and flavor for direct market sales, harvest mature fruit just at the point where it develops a uniform color on the plant. Orange fruit will ripen to red post-harvest, but the fruit will taste much better when left to mature on the plant.

When harvesting, leave the calyx attached by carefully breaking off the tomato at the abscission zone just above the calyx. This takes some practice but will provide a more pleasing product at the point of sale (see Figure 7). When stacking in the bucket at time of harvest, place the tomatoes so that the stem will not puncture tomatoes as they are added.

FIGURE 7. Dry-farmed tomatoes at UCSC's farm stand. *Photo: CASFS*

Transport tomatoes from the field to a shaded packing area for sorting and packing into suitable boxes for transport to market. Never refrigerate tomatoes! They lose flavor quickly at lower temperatures. Tomatoes will hold for up to a week after harvest without refrigeration in a cool, shady place.

For best quality and appearance tomatoes should be sold within a week of harvest. If you need to store them longer prior to sale, remove the calyx at harvest time as it will dry out and reduce the visual quality of the fruit.

'Early Girl' tomatoes will hold on the plant for up to a week after ripening even in warm weather, so harvest intervals can be as long as a week; however, every two or three days is optimal once fruit ripens.

FIGURE 6. A basket weave system using metal t-posts and wooden stakes. *Illustration: Laura Vollset*

Pests and Diseases

Before you select varieties and plant your dry-farmed tomato crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main tomato arthropod pests in the Central Coast region are:

- Green peach aphid, *Myzus persicae*. Potato aphid, *Macrosiphum euphorbiae*: both green peach and potato aphids spread viruses that severely affect tomato plants.
- Tomato russet mite, *Aculops lycopersici*: mite nymphs suck the life out of plant cells, causing leaves and stems to bronze, dry up, and die.
- Stink bugs. Consperse stink bug, *Euschistus conspersus*. Redshouldered stink bug, *Thyanta pallidovirens (= T. accerra)*. Sayi stink bug complex, *Chlorochroa sayi* and *Chlorochroa uhleri*. Southern green stink bug, *Nezara viridula*: several stink bugs feed on and damage tomatoes.

The main tomato diseases in the Central Coast region are:

- Late blight, *Phytopthora infestans*: a serious disease that develops rapidly and can destroy an entire tomato field in a few weeks' time.
- Tomato spotted wilt virus (TSWV) in the tospovirus group, spread by Western flower thrip: plants infected with TSWV do not usually produce marketable fruit.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for additional information on the pests and diseases listed here, and suggestions for their control in dry farmed tomatoes.

ON CALIFORNIA'S CENTRAL COAST,
'Early Girl' and/or 'New Girl' are currently the best tomato varieties for dry farming. The fruits are easy to handle, they don't crack, and the flavor is remarkable. However, when grown without irrigation, these varieties are prone to a physiological condition known as blossom end rot.

Blossom end rot is related to the plant's inability to move calcium to the blossom end of the fruit; this is exacerbated when water is limited or irregular. The symptom is a brown or black sunken spot on the blossom end of the fruit that—depending on the severity of the symptom—is prone to rot.

Although the condition often becomes less prevalent as the season progresses, it may affect 10–20% of the crop. Fruit showing symptoms of blossom end rot are not marketable.

FIGURE 8. Advanced damage caused by blossom end rot.

ADDITIONAL RESOURCES

Common misconceptions and key points about dry farming: Case study of dry farmer with more than 40 years experience, by Amy Garrett. Small Farms Program, Oregon State University, 2014. smallfarms.oregonstate.edu/sfn/su14dryfarming

Dry farming. California Ag Water Stewardship Initiative. agwaterstewards.org/practices/dry_farming/

Dry farming at Molino Creek Farming Collective. The Water Stewardship Project, Ecological Farming Association. agwater.wordpress.com/dry-farming/

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Organic tomato production, by Steve Diver et al. NCAT IP439, 1995, revised 2012. attra.ncat.org/attra-pub/summaries/summary.php?pub=33

Overview of dry farming on the Central California Coast, by Jim Leap. Supplement 4, Unit 1.5: Irrigation, principles and practices *in* Teaching organic farming and gardening: Resources for instructors. Santa Cruz, CA: Center for Agroecology and Sustainable Food Systems, 2016. casfs.ucsc.edu/about/publications/Teaching-Organic-Farming/part-1.html

Organic Dry-Farmed Tomato Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by and Martha Brown and Ann Baier.

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Photo, p.1, left: Carolyn Lagattuta; p. 2: Elizabeth Birnbaum. Icon illustrations, p. 3, Laura Vollset.

CASFS The CENTER for AGROECOLOGY & SUSTAINABLE FOOD SYSTEMS

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Week	% total harvest	Harvest Amt.	Harvest Value
-25	10	Flail Mow:heavy	2.5	0.2		$15.19				
-25	10	Spade	4.8	0.2		$25.17				
-11	10	Mark Lines	2	0.2		$13.02				
-11	10	List	1.25	0.2		$9.77				
-11	10	Overhead Irr:set up	3.75		$12.08					
-10	10	Overhead Irr:run		0.5	$8.05					
-1	10	Light cultivation	1.25	0.2		$9.77				
-1	10	Shape/JD 71 Seed/Furrow	2	0.2		$13.02				
0	5	Transplant:1 line	58	0.5	$101.43					
11	10	Cultivate	2	0.2		$13.02				
12	10	Hill	1.25	0.2		$9.77				
21	5	Trellis:stakes	48.4	0.5	$85.97					
21	5	Trellis:tie up	48.4	0.5	$85.97					
42	5	Trellis:tie up	48.4	0.5	$85.97					
63	5	Trellis:tie up	48.4	0.5	$85.97					
68	10	Harvest x 2 @ 75#/hr	259	1	$42.50		1	5%	194	$388.40
75	10	Harvest x 2 @ 75#/hr	259	1	$57.80		2	5%	194	$388.40
82	10	Harvest x 2 @ 75#/hr	259	1	$141.20		3	15%	583	$1,165.20
89	10	Harvest x 2 @ 75#/hr	259	1	$182.90		4	20%	777	$1,553.60
96	10	Harvest x 2 @ 75#/hr	259	1	$182.90		5	20%	777	$1,553.60
103	10	Harvest x 2 @ 75#/hr	259	1	$141.20		6	15%	583	$1,165.20
110	10	Harvest x 2 @ 75#/hr	259	1	$99.50		7	10%	388	$776.80
117	10	Harvest x 2 @ 75#/hr	259	1	$57.80		8	5%	194	$388.40
124	10	Harvest x 2 @ 75#/hr	259	1	$57.80		9	5%	194	$388.40
150	10	Disc:x1	0.5	0.2		$6.51				
-	10	Drill/Cover Crop	1.6	0.2		$11.28				
				Sub-total:	$1,429.04	$126.51		*Sub-total:*	3,884	$7,768.00
			Labor + Machine Cost ($)				***Yield***			
				Per Block (.2 Acres):		***$1,555.55***	***Per Block (.2 Acres):***		**3,496**	***$7,768.00***

Harvest Assumptions	
Harvest (#/acre)	19420
Harvest (#/row')	2.675
Harvest Rate (#/hr)	75
Price ($/#)	2

Item	*Cost per unit*	*Cost per acre*	*Notes*
Tomato Starts	$.025/plant	$90.75	1 line/bed; every other bed; 7260 row'/ac
Tomato Stakes	$3/stake	$4,356.00	5' grade stakes, 1 stake/5row';
T-posts	$5/stake	$1,815.00	6' (every 20'); 363/acre
Twine	$.002/ft	$87.12	
Boxes	$.98/box	$1,274.00	.98/bx; 1300bx/ac
Total Expenses (per acre):		***$7,622.87***	

Per Acre Totals	
Income:	$38,840.00
Labor + Machine Cost:	-$7,777.74
Expenses:	-$7,622.87
Production Profit:	**$23,362.92**

Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

ORGANIC PEPPER PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers

Introduction

Peppers are an excellent addition to most small-scale, organic mixed cropping systems that focus on local sales. Peppers are highly productive, and will reliably produce fruit from July through October without season extension technologies (such as hoop houses). They are relatively easy to grow and harvest, and provide multiple marketing and culinary options. Peppers can be harvested green or left on the plant to develop color. They offer many possibilities for adding value through processing or drying. Flavor options range from sweet to very hot. A variety of colors, shapes, and sizes allows for striking presentations at farmers' markets and in Community Supported Agriculture (CSA) boxes.

This grower guide addresses the basic production steps in growing peppers organically in California's Central Coast region and provides a varieties' overview for those interested in adding peppers to their specialty crops.

Features of pepper production

- Peppers grow well in most Central Coast locations
- Relatively pest- and disease-free
- Easy and fast to harvest
- Do not bruise or crack easily
- Provide continuous harvest over a long period
- Highly sought after by chefs, retailers, wholesalers, and home cooks
- Highly adaptable from fresh market to processing
- Season can be extended using high tunnels

PRODUCTION PRACTICES — SUMMARY

Climate

- Warm season crop.
- Perform best when daytime temperatures don't exceed 90° F; higher temperatures limit pollination and increase potential for sunburn of fruit.

Soil type

- Grow well on soil types from sandy loams to heavier clay soils.
- Perform best on heavier soils with CEC (cation exchange capacity) ratings greater than 12.
- May require supplemental fertility throughout the growing season on lighter-textured soils.
- Require good drainage to minimize soil borne fungal diseases.

Fertility requirements

- Peppers require relatively high fertility.
- Incorporate legume/cereal cover crop and 5–7 tons/acre of compost before planting.
- Peppers may require supplemental fertility to maintain growth and good fruit production (see page 6).

In the greenhouse

- Buy fresh seed every year.
- Start plants in greenhouse early to mid February, 8–10 weeks before transplanting.
- Use heat mats under seed flats to promote seed germination.

Soil temperature

- Transplant when the threat of frost is past, and soil temperatures are greater than 60° F at planting depth (6") for 5–7 days.
- The best window for transplanting on the Central Coast is mid April through May.

Plants per acre

- 12,000–14,000, varies depending on spacing and growth habit.

Planting technique

- Transplant starts by hand, or with a mechanical transplanter for blocks larger than 0.25 acres.

Bed spacing

- Plant peppers in a single line on beds spaced 36" center to center; single line planting facilitates cultivation.
- Plant in double lines on beds spaced 40–60" center to center (standard spacing in most production systems). Double lines may help shade fruit and protect against "sunburn."

Plant spacing

- 1–2' between plants, depending on row spacing and growth habit of the variety.
- Total plant populations of 12,000–14,000 plants per acre, vary depending on spacing and growth habit.

Planting depth

- Place transplants as deep as possible into pre-irrigated beds that have adequately dried down while keeping all foliage above ground.

Irrigation

- Drip tape facilitates uniform water application, saves on water costs, and minimizes both weed and disease pressure.
- Avoid excessive soil moisture to prevent *Phytopthera* spp. (root rot).

Days to maturity

- Depends on varieties and weather conditions—most peppers are ready to harvest approximately 90 days after transplanting.

Harvest tips

- For small-scale production (blocks < 1 acre), harvest into 5-gallon buckets; walk buckets to the edge of the field for sorting/packing.
- Cull in the field: pick and discard fruit that is sunburned, insect damaged, or has had soil contact that will cause rotting.

Post-harvest handling

- Easy post-harvest handling: light to carry, do not bruise easily, and do not require washing.
- Store well in cooler for 7–10 days.

Crop rotation

- Rotate peppers from other solanums and strawberries every four years, if possible, to minimize buildup of soil-borne fungal disease pathogens.

PRODUCTION SEQUENCE — SUMMARY

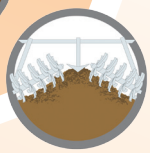
(crop day -25*) In spring, mow cover crop to facilitate breakdown.

(crop day -25) Incorporate cover crop residue.

(crop day -11) Form beds with rolling cultivator or listing shovels.

(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -1) Work bed surface lightly with cultivator to terminate weeds.

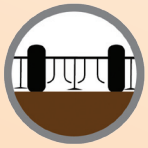


(crop day -1) Shape beds using rolling cultivator or rototiller/shaper combination. Mark planting rows.

(crop day 0) Plant transplants.

(crop days 0, 1, 4, 7) Irrigate (overhead) to water in and establish transplants.

(crop day 11) Cultivate for weed management (sweeps, knives).



(crop day 11) Hoe out small weeds on bed tops. Lay drip lines.

(crop day 12) Initiate drip irrigation; run drip irrigation weekly.

(crop days 35, 65) Hand weed large weeds as needed or cultivate with furrow chisels and sweeps.

Apply supplemental fertility as needed through drip lines.

(crop day 120) Initiate harvest; harvest weekly July through October.

(crop day 175) Remove drip lines from the field. Mow following last harvest. Prepare ground for cover crop planting.

Drill cover crop seed prior to fall/winter rains.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

Production Practices — Additional Details

Initial fertility

Because pepper plants have a long season—they may be in the ground for up to 8 months with a production window up to 4 months, or longer if season extension is used—they have a relatively high fertility requirement compared to many other crops.

Adequate early season fertility is critical to help plants develop a strong scaffold to hold fruit, and adequate foliar coverage (enough leaves) to protect fruit from sunburn. On heavier soils (CEC ratings greater than 12), fertility requirements of peppers through the season may be met by incorporation of a legume/cereal cover crop, and 5–7 tons per acre of high quality compost prior to planting.

Timing

Plant as early in the spring as is reasonable based on the estimated date of last frost and soil temperatures. Peppers continue to produce fruit as long as temperatures allow for pollination (< 90° F), and fertility and moisture are adequate. Harvest weekly from first fruit (July) through late fall. Because a single planting has a long harvest season, there is no need to stagger plantings.

HIGH TUNNELS FOR SEASON EXTENSION

Commercial pepper producers in the Hollister area (San Benito County) have increased yields and extended harvest of peppers using high tunnels. The temperatures in the tunnels significantly extend the season and allow peppers to develop their full color (red, yellow, "chocolate," etc.). These fully mature peppers typically sell for a premium in the specialty and wholesale markets.

Planting

In a hand-transplanted, single-line system, form a trench approximately 4" deep down the middle of each bed using a small shovel or bed shaper, and transplant into the trench). This shallow trench will improve soil water retention at time of planting, will allow for easy placement of the drip line, and will greatly facilitate weed suppression.

Plant transplants that are tall, with a well-established root system, and well hardened off (Figure 1). Soak the nursery trays prior to planting to ensure good moisture at time of transplant. Plant as deep as possible (keeping foliage above ground) to ensure good root contact with moist soil and encourage adventitious rooting (roots that sprout from the buried stem); Figure 2.

FIGURE 1. Use tall transplants with well-developed root systems. *Photo: Elizabeth Birnbaum*

FIGURE 2. Deep planting ensures good root contact with moist soil and encourages adventitious rooting. *Photo: Elizabeth Birnbaum*

Irrigation

Irrigate (overhead or drip) as soon as possible after transplanting to ensure good initial growth and minimize transplant stress. Keep plants moist until deeper roots are established (~10 days; Figure 3). Assuming there is deep soil moisture from winter rains or pre-irrigation, initial irrigations can be light (2–3" in first 2 weeks). If using overhead for initial irrigations, switch to drip lines after 2 weeks.

Once the plants have extended roots below the root ball, decrease irrigation frequency until the canopy is established. As the weather warms up, irrigate weekly on heavier soils, and 2–3 times a week on lighter soils.

Calculate irrigation amounts based on estimated evapotranspiration (Et) losses using local CIMIS station data (cimis.water.ca.gov) or other source. During the initial growth stages, multiply estimated Et losses by percent canopy. For

FIGURE 3. Initial overhead irrigation on pepper transplants helps establish plants. *Photo: Elizabeth Birnbaum*

example, when the canopy is at 25%, replace 25% of the daily estimated Et loss. Increase proportionally until the plant is in full canopy and irrigation amounts equal the estimated Et loss as reported by CIMIS. Avoid overwatering to minimize both weed pressure and nutrient leaching.

Weed control

Good weed management in peppers begins with careful field selection. Avoid weed pressure from grasses and perennial weeds, since these are both difficult and expensive to manage once the peppers are established. This is critical to organic pepper production, because the peppers will be in the ground for up to 8 months.

Use pre-irrigation whenever practical; it can save significant weeding costs and ensure deep moisture to facilitate good initial crop growth and establishment. Form beds, then overhead water with 1–1.5" of water. Following weed flush, rework beds with a rolling cultivator or other suitable cultivation tool to destroy newly germinated weeds prior to planting. See the publication *Tillage, Bed Formation, and Planting to Moisture* in this **Grower Guide** series for additional details.

Once plants are established, move the soil toward the plant using a rolling cultivator. This "dirting" pass will fill in the planting trench, smother newly emerged weeds within the plant line, brace the plants, and cover the drip line. However in milder climates where peppers do not grow tall before fruiting, dirting or hilling must be done minimally, if at all, in order to prevent fruit set on the hilled soil that can lead to rot.

During the early stages of crop growth weeds can be easily managed between planted lines using standard row crop cultivation equipment including sweeps, side knives, and small chisels in the furrows to break wheel compaction.

When planting double lines per bed, you may need to hand weed between plants, since it is much more difficult to manipulate soil to bury weeds within the plant line.

Assuming there are no problem perennial weeds in the field, and irrigations are well-timed and not over-applied, the field should remain relatively weed free for the duration of the crop cycle. Hand pull any escaped weeds during harvest and irrigation operations.

Peppers at the Everett Family Farm's farmstand, Soquel, California.

VARIETAL OVERVIEW

Select "trendy" varieties for direct sales. Consumers are especially attracted to large and "mini" fruit. Spicy peppers high on the Scoville scale (spicy heat index; see en.wikipedia.org/wiki/Scoville_scale) are not big sellers at farmers' markets. Plant hot peppers in small quantities, if at all, unless you have a known sales outlet.

Popular, attractive pepper types:

LARGER BELLS

Lamuyo (elongated bells) source: Reimer Seeds

Reina
Gemini
Mama Mia Giallo
Lido Lamuyo

Bullhorn varieties

FULL SIZE

Corno Di Toro
Carmen (red)
Escomillo (yellow)

MINIS

Cornito Rosso (red)
Cornito Giallo (yellow)

Blocky Bells

Flamingo (orange/red)
Gourmet (yellow/early)
Double up (red)
Admiral (yellow)
Quadrato D'Asti Giallo/Rosso
Aristotle (red)

New Mexico pod types (red or green) a.k.a. Anaheim, Hatch, etc.

Anaheim (late)
Joe E. Parker (heirloom)
Highlander (big, high yield)

Minis: pimientos, lunch box, snack types: Johnny's seeds lunch box varieties

Eros
Cupid

Ethnic frying types

Jimmy Nardello
Cubanelle/Biscayne
Padron
Shishito
Banana types (sweet and hot)

Note that both padron and shishito peppers are good "niche" peppers that have become important income generators on small farms.

Other small-fruited varieties

Pimiento types (Round of Hungary)

Aura, Lipstick, Glow (4–5" top shape, early, sweet)

These varieties are as sweet or sweeter than bell peppers, easier to grow, and much earlier.

Anchos/Poblanos

Tiburon (biggest, best variety)

Jalapenos

El Jefe and Jalafuego (biggest, best taste)

Supplemental fertility

Apply supplemental fertility to peppers grown on lighter-textured soils with low CEC (<12) to maintain good leaf growth (essential for minimizing sunburn) and adequate production through the last few months of the production cycle. Check soil nitrate levels following initial crown set to assess the need for additional fertility; N>20–25 ppm is required to support ongoing fruit set.

Although expensive (approximately $7/lb of N), organic liquid formulations (4-2-0 or 4-0-0) applied directly through the drip lines via injection into the irrigation header may be the most viable option for post-plant amendment application.

Alternately, you can "band" dry, granulated or pelleted formulations of N-based animal waste products into the soil close to the plants for root uptake. However, it is more effective to incorporate fertilizer ahead of planting.

Staking

Some growers support pepper plantings by placing stakes along the outside of the rows and running a single string line from stake to stake. This helps keep the plants upright and minimizes broken branches from both wind and heavy fruit set. The stakes are typically only as high as the pepper plant (+/- 2').

FIGURE 4. Gently move foliage aside to find ripe peppers for harvest. *Photo: Jim Clark.*

Harvest

Harvest is systematic—it requires tracking where harvest has occurred to maximize efficiency and minimize loss. Inspect each plant for mature fruit by gently moving branches and leaves to reveal hidden peppers (Figure 4). Remove peppers by hand and place them in a 5-gallon bucket while moving down the row.

To harvest a pepper, pull fruit gently from the stem end of the pepper, taking care not to break either the stem or the branch holding the fruit. Many varieties can be harvested with a single hand by placing the thumb near the zone of abscission (the point where the stem attaches to the branch) while gently pulling at an angle to separate the fruit from the branch (Figure 5). This takes practice! Some varieties require two hands and significant care to harvest successfully.

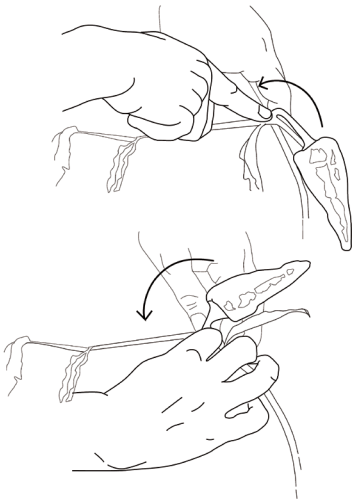


FIGURE 5

During the harvest, remove any unmarketable fruit (e.g., misshapen, insect-damaged, sunburned, rotten) from the plant and leave it in the field. This maximizes future harvest efficiency. Early fruit often sets between branches where it will become deformed as it grows; such fruit should be removed and discarded. Most fruit that contacts the soil will develop a rot spot at the point of contact; this too, must be discarded.

Harvesting small-fruited varieties (e.g., padrons) requires significant labor, not only because of their size, but because they are harvested at a relatively immature stage for optimum market quality, and thus must be harvested more frequently than larger varieties. Leaves easily camouflage the dark green 'Padron' variety, requiring significant "searching" to harvest them properly.

Other varieties can be harvested when fully sized and still green; most can also be left on the plant to mature and color up. Colored peppers (orange, red, yellow, brown) sell for a premium price. However, because of the additional time needed to reach full maturity, there is significant risk in getting a marketable fruit at the fully mature and colored stage, since this growth stage is much more prone to sunburn and insect feeding.

Post-harvest handling, storage

Weigh and pack harvested peppers into crates or boxes (no washing necessary, Figure 6). Peppers will store well in the cooler for 7–10 days if not marketed immediately.

FIGURE 6. Bell peppers harvested for UCSC Dining, UCSC Farm. *Photo: Martha Brown*

Post-harvest field care

Following the final harvest, pull the drip lines, mow the plants, and disc the field in preparation for a subsequent crop or cover crop. Pepper plants are easily chopped up by the mower, producing minimal biomass and a clean seed bed for cover crops. A single pass with a disc is more than adequate.

Crop rotation

Rotate peppers from other solanums and strawberries every four years, if possible, to minimize buildup of soil-borne fungal disease pathogens. Plant peppers into production blocks that are free of perennial weeds and grasses, are relatively high in fertility, and have good soil tilth and drainage—in other words, plant peppers in your best ground, whenever possible.

Pests and Diseases

Before you select varieties and plant your pepper crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, prevention practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database (www.ncat.org/attra-pub/biorationals), neighboring farmers, and other knowledgeable professionals.

The main pepper arthropod pests in the Central Coast region are:

- Thrips. Western flower thrips, *Frankliniella occidentalis*. Onion thrips, *Thrips tabaci*. Chili thrips, *Scirtothrips dorsalis* and other species: can be vectors of Tomato Spotted Wilt Virus (TSWV; see below).
- Aphids: Green peach aphid, *Myzus persicae*: feed on plant juices and can transmit viruses; exude honeydew that can coat fruit and be difficult to remove.
- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata*. Western striped cucumber beetle, *Acalymma trivittatum*: feed on foliage and fruit calyxes.

The main pepper diseases in the Central Coast region are:

- Powdery mildew caused by *Leveillula taurica* (*Oidiopsis taurica*): infected leaves curl up and leave fruit vulnerable to sunburn.
- Tomato spotted wilt virus (TSWV) in the tospovirus group: symptoms vary with the stage of growth infected, the cultivar, other viruses, and environmental conditions, but typically include spotting, bronzing, dying leaves, and ringspots on fruit. Affected fruit is not marketable.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for information on the pests and diseases listed here, and suggestions for their control.

ADDITIONAL RESOURCES

ATTRA question of the week: What do I need to know about organic sweet pepper production and where can I get the information? attra.ncat.org/calendar/question.php/what_do_i_need_to_know_about_organic_swe

Introduction to weed management in a small-scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Resource guide to organic and sustainable vegetable production, by Steve Diver et al. ATTRA 2001; updated 2012. NCAT IP188. attra.ncat.org/attra-pub/summaries/summary.php?pub=19

UC IPM pest management guidelines: Peppers. University of California, DANR Publication 3339. ipm.ucanr.edu/PMG/selectnewpest.peppers.html

Organic Pepper Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Orin Martin, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by Martha Brown and Ann Baier.

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Photo, p. 1, left: Elizabeth Birnbaum. Illustrations, pp. 3 and 6, Laura Vollset.

CASFS The CENTER for AGROECOLOGY & SUSTAINABLE FOOD SYSTEMS

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Week	% total harvest	Harvest Amt.	Harvest Value
-25	10	Flail Mow:heavy	2.50	0.2		$15.19				
-25	10	Spade	4.80	0.2		$25.17				
-11	10	Mark Lines	2.00	0.2		$13.02				
-11	10	List	1.25	0.2		$9.77				
-11	10	Overhead Irr:set up	3.75		$12.08					
-10	10	Overhead Irr:run		0.5	$8.05					
-1	10	Light cultivation	1.25	0.2		$9.77				
-1	10	Shape	2.00	0.2		$13.02				
0	10	Transplant:1 line	58.00	0.5	$194.81					
0	10	Overhead Irr:run		0.5	$8.05					
1	10	Overhead Irr:run		0.5	$8.05					
4	10	Overhead Irr:run		0.5	$8.05					
7	10	Overhead Irr:run		0.5	$8.05					
11	10	Overhead Irr:break down	3.75		$12.08					
11	10	Cultivate	2.00	0.2		$13.02				
11	10	Drip:set up	10.00	0.25	$36.23					
11	10	Hoe:1 line	36.00		$115.92					
12-169	10	Drip:run x 2/wk @ 22 weeks		0.3	$106.26					
35	10	Hand Weed:big weeds	8.00	0.2	$28.98					
65	10	Hand Weed:big weeds	8.00	0.2	$28.98					
120	10	Harvest x 2	532.40		$171.43		1	10%	799	$1,197.90
127	10	Harvest x 2	532.40		$171.43		2	10%	799	$1,197.90
134	10	Harvest x 2	532.40		$171.43		3	10%	799	$1,197.90
141	10	Harvest x 2	532.40		$257.15		4	15%	1,198	$1,796.85
148	10	Harvest x 2	532.40		$257.15		5	15%	1,198	$1,796.85
155	10	Harvest x 2	532.40		$342.87		6	20%	1,597	$2,395.80
162	10	Harvest x 2	532.40		$171.43		7	10%	799	$1,197.90
169	10	Harvest x 2	532.40		$171.43		8	10%	799	$1,197.90
175	10	Flail Mow:light	1.25	0.2		$9.77				
-	10	Drill/Cover Crop	1.60	0.2		$11.28				
				Sub-total:	$2,289.90	$120.00				

Labor + Machine Cost ($)	
Per Block (.2 Acres):	***$2,409.90***
Per Acre:	***$12,049.52***

Yield		
Per Block (.2 Acres):	**7,986**	***$11,979.00***
Per Acre:	**39,930**	***$59,895.00***

Harvest Assumptions	
Harvest (#/acre)	39,930
Harvest (#/row')	2.75
Harvest Rate (#/hr)	75
Harvest (hr/ac)	532.4
Price ($/#)	1.5

Item	*Cost per unit*	*Cost per acre*	*Notes*
Starts	$.025/plant	$363.00	1 row/bed; 14520 row'/ac; 1' spacing
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Boxes	$2.067/bx	$4,878.12	20#/box; 47190#/ac; 2360 box/ac
Total Expenses (per acre):		***$5,473.44***	

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).

Per Acre Totals	
Income:	$59,895.00
Labor + Machine Cost ($)	-$12,049.52
Expenses	-$5,473.44
Production Profit:	**$42,372.04**

ORGANIC WINTER SQUASH PRODUCTION ON CALIFORNIA'S CENTRAL COAST:
A Guide for Beginning Specialty Crop Growers

Introduction

Winter squash production can be done with low capital investment and simple infrastructure. Squash has low seed cost, modest fertility needs, and relatively little labor requirements during the growing season. The broad leaf canopy minimizes weed pressure, and many varieties are fairly resistant to pests and diseases. "Winter" or "hard" squash is grown in the warm season and can be stored for some months (through the winter). Unlike "summer" squash (zucchini and other "soft" squashes) that must be harvested daily and stored in a cooler, winter squash has a flexible window of harvest and sale (with proper dry storage). These characteristics make winter squash a viable crop for beginning specialty crop growers.

Growing a mix of varieties provides an assortment of colors, textures, and flavors to diversify marketing opportunities or add variety to a Community Supported Agriculture (CSA) program.

Depending on markets, varieties, and yields, winter squash can provide excellent cash returns. Adequate dry storage allows sales to be spread over a period of two to four months for best price.

This guide addresses the steps involved in growing winter squash organically on the Central Coast of California, with a focus on planting to moisture to minimize weed pressure.

Features of winter squash production

- Winter squash grows well in cooler coastal areas as well as the warmer inland valley locations (it has few climatic limitations in the Central Coast region)
- Requires little labor throughout the growing season
- Stores well with minimal infrastructure (dry storage only; no cooler needed), which is useful for extending direct sales/CSA season
- Resists or tolerates pests and diseases
- Grows well in most soil types and requires only moderate soil fertility levels
- Produces reasonable yields with relatively little irrigation; can be dry farmed in the right climate and soil type (see Dry-Farmed Tomato Grower Guide)
- Provides for excellent crop rotation to improve soil quality and decrease weed pressure for future crops

PRODUCTION PRACTICES — SUMMARY

Soil type and pH

- Does well on a range of soil types but grows best on well-drained sandy loam soil with pH 5.8 – 6.5.

Site selection

- Avoid planting where infestations of cucumber beetle have been heavy or common.
- Plant upwind and separated from older sequential blocks, and other crops highly susceptible to cucumber beetles, such as potatoes, cucurbits, beans and corn.

Fertility requirements

- Fall/winter cover crop (bell beans, triticale, vetch).
- Compost, as needed (5–7 tons/acre).
- Post-plant fertility may be needed on sandy soils with minimal residual fertility and low CEC (cation exchange capacity).

Soil temperature

- Optimum soil temperature is 60°F or higher at planting depth.

Amount of seed needed

- 2–3 lbs/acre.

Plants per acre

- 3,000 – 4,000 (vining types).
- 6,000 – 8,000 (bush types).

Planting date

- Mid May through early July, depending on variety.

Planting technique

- Sow directly into moisture.
- Plant in beds or on the flat.
- Can be transplanted (intensive garden system) but are rarely transplanted on a field scale system.

Plant and row spacing

- Bush types: 36–60" between rows; plants should be 24" apart.
- Vining types: 60–80" between rows; plants should be 36–48" apart.
- Plant closer and thin to the desired spacing in the row to ensure a uniform stand of healthy plants.

Planting depth

- Bush types (typically smaller seed size): up to 1" deep depending on soil type and depth to moisture
- Vining types (typically larger seed size): up to 2" deep depending on soil type and depth to moisture

Irrigation

- May be planted to moisture and dry farmed.
- If planted to moisture and irrigated, lay drip lines following the first cultivation and hold off as long as possible before the first irrigation.
- Note that some growers use overhead irrigation early in the production cycle to minimize powdery mildew.

Days to maturity

- 85–110 days depending on variety and weather conditions.

Harvest/Post-harvest handling

- Leave squash on vines until plants begin to senesce (die after maturing) .
- Cut squash with hand-held clippers, leaving a short stalk once foliage dies back and the tendril begins to dry (opposite the squash attachment stem on the main vine).
- Windrow in field to facilitate pick up.
- Store for short periods of time in cardboard bins.

Crop rotation

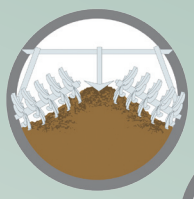
- Managed well, a winter squash crop will suppress weeds and scavenge fertility, making it a good crop to follow more intensive mixed vegetables that require higher fertility inputs. Few weeds grow or set seed among a squash crop that is planted to moisture and drip irrigated once full crop canopy is established. This reduces weed seed in that field, to the benefit of subsequent crops.
- Prepare fields with relative ease and minimal tillage for subsequent crops or cover crops; winter squash residue breaks down well.
- Where Verticillium wilt *(Verticillium dahliae)* is present, use long rotations (2–3 years or more) out of susceptible crops such as cucurbits, solanums, and strawberries to non-susceptible crops, such as grasses and legumes.

PRODUCTION SEQUENCE — OVERVIEW

(crop day -25*) In spring, mow cover crop to facilitate breakdown.

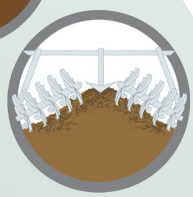
(crop day -25) Incorporate cover crop residue.

(crop day -11) Form beds with rolling cultivator or listing shovels.



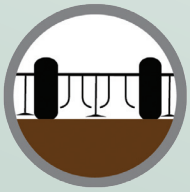
(crop day -10) Pre-irrigate beds with overhead irrigation (1–1.5"). Wait for dry down and weed emergence.

(crop day -1) Work bed surface lightly with cultivator to terminate weeds, re-form beds, and create "dust mulch" to trap subsoil moisture.



(crop day 0) Direct seed squash seeds with a JD 71 planter (or equivalent).**

(crop day 20) Cultivate for additional weed control using standard 3-bar cultivator with sweeps, knives, and disc hillers.



(crop day 21) Lay drip lines.

Apply drip irrigation once canopy forms and continue weekly.

Hand weed large weeds as needed.

(crop days 120, 140) Clip squash from vines, let cure in field.

(crop days 150, 160) Harvest.

Drill cover crop seed prior to fall/ winter rains.

Following harvest, prepare ground for subsequent planting or cover crops.

***Numbers in parentheses refer to crop day, with crop day 0 = planting day, based on a typical season at the CASFS/ UC Santa Cruz Farm.**

See Appendix (page 8) for more on crop days and related activities.

** On garden scale, plant transplants

Production Practices — Additional Details

Pre-plant fertility

A legume/cereal mix cover crop incorporated prior to bed preparation should provide adequate fertility for winter squash on most soil types. If additional fertility is required, apply high quality compost (5–7 tons/acre) at time of cover crop incorporation. Supplemental post-plant fertility is seldom needed, although winter squash grown on very low CEC (cation exchange capacity) sand with minimal residual fertility may require additional nutrients, which can be applied via drip injection.

Bed preparation and planting

Although winter squash can be planted "on the flat" (i.e., without forming beds), a bedded system improves moisture retention and weed management.

Perform standard tillage practices to incorporate crop or cover crop residue (Figure 1), break compaction, and adequately loosen soil. Then, form the planting beds using bedding shovels or a rolling cultivator.

If there is no rainfall following bed formation in the spring, pre-irrigate (1–1.5") with overhead irrigation to wet the root zone and germinate weeds prior to planting. This pre-irrigation further improves soil conditions and tilth by breaking down soil clods or clumps of cover crop residue, leaving the soil loose, moist, and friable.

Following the pre-irrigation (or spring rainfall of 1–2"), eliminate newly germinated weeds with a rolling cultivator or other suitable cultivation technique. If timing is good and the moisture is uniform, such a run can work wonders. This initial cultivation breaks surface crusting and provides a "soil mulch" to slow evaporative loss of deeper soil moisture.

Once crop or cover crop residue is adequately decomposed (residues brown, leaves no longer recognizable) and soil temperatures are above 60°F, use a suitable planter (see below) to push aside the drier soil on the bed tops and plant the squash seeds into the deeper moisture in the bed.

Timing of planting

In general, winter squash can be planted from mid-May through June on California's Central Coast. Shorter-maturing varieties can be planted in early July. Planting dates are based on timing of adequate seedbed preparation (allowing for thorough cover crop residue decomposition), soil moisture (adequate for germination), and optimal soil temperature (>60°F).

FIGURE 1. A spader can be used to incorporate cover crops. *Photo: Elizabeth Birnbaum*

FIGURE 2. John Deere 71 "flexi" planter. *Photo: Jim Leap*

Plant late enough in spring to allow for rapid plant growth; this will help limit cucumber beetle and other herbivore damage to seedlings. Planting dates must be early enough to allow the crop to mature and adequately field cure before fall rains, heavy dew, or frost.

Planting to moisture

Winter squash seed can be planted to moisture by hand with a shovel or trowel. There are also "seed stick" planters that are very effective for planting winter squash. Push planters such as the Planet Jr. are effective for garden-scale production, but require a special "deep" opening shoe to get the seed far enough into moist soil.

On larger field-scale blocks (>.25 acres), use a tractor-mounted planter such as the John Deere 71 "flexi" planter or other similar plate-type planter (Figure 2). The planter's double disc openers cut through residual cover crop or crop residue. Adjust planting depth with a rotating cam on the side of the planter, which changes the angle of the press wheel in relation to the disc openers. For mixed blocks (multiple varieties) of winter squash on relatively small plots, the planter hopper can be removed and the seeds hand dropped into the drop tube. This circumvents the need for multiple seed plates to match each variety.

Note that it is better to plant into soil on the drier side. On many soil types, if the soil is too wet at planting, soil surface crusting can impede successful crop emergence. Squash plants that struggle to break through crusted soil may remain stunted.

In cases when the soil is either too wet or too dry, you can form a "cap" of soil over the seed line to either minimize crusting (too wet) or to minimize further evaporative loss (too dry). Run soil cappers behind the planter to create a loose cap of soil right over the seed line behind the planter's pack wheel (Figure 3).

With optimum soil conditions (>60°F and minimal crusting) and planting depths, plants should emerge in 7–10 days. Uniform emergence is the best sign of optimal planting conditions and potential for a successful crop.

The most critical aspect of effectively "planting to moisture" is your ability to judge soil moisture and decide on seed depth. Decisions related to seed depth will vary depending on soil type, seed size, and weather and soil conditions at the time of planting. Because of the challenges associated with planting to moisture,

FIGURE 3. Soil cappers run behind the pack wheel create a loose "cap" of soil over the seed line. *Photo: Jim Leap*

less experienced growers may opt to irrigate up their newly planted squash seed. This practice is effective and will ensure a good stand, but results in more weed competition and management costs. Please see the publication *Tillage, Bed Formation, and Planting to Moisture* in this Grower Guide series for additional details.

Thinning

Thin winter squash to the desired spacing once plants are fully emerged and well established but still relatively small. As needed, weed in the plant line at the time of thinning (by hand or with a hoe).

Irrigation

Drip irrigation minimizes weed pressure, although some growers use overhead irrigation prior to fruit set to help control powdery mildew.

Timing of the first drip irrigation depends on the water-holding capacity of the soil, the initial soil preparation, the amount of winter rainfall, and the amount and timing of any pre-irrigation. Lay out drip lines when the plants have been thinned but are still small, and the first cultivation is complete (Figure 4). Delay irrigation as long as possible to encourage deep rooting of the squash plants. To minimize weed pressure, the first irrigation ideally would take place once squash leaves grow a full canopy to shade out weeds that may emerge once irrigation is initiated.

From this point on, use evapotranspiration (Et) estimates from your local CIMIS station (cimis.water.ca.gov) or another source to inform irrigation decisions. Irrigation rates will likely range from 1–2" per week for the duration of the crop's development. Once the squash fruits are sized there is no need for further irrigation and the water can be cut.

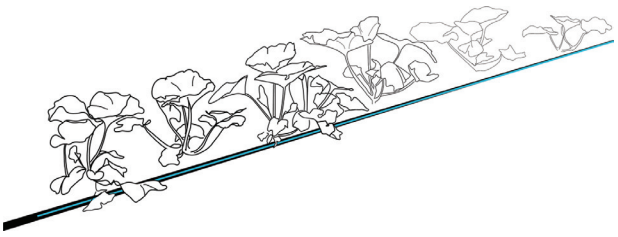


FIGURE 4. Lay drip tape when plants are still small, following first cultivation. *Illutration: Laura Vollset*

VARIETAL OVERVIEW: Popular winter squash varieties

Acorn ***(Cucurbito pepo)*****:** A small, green, thin-skinned type with sweet "caramelized sugar" flavor and smooth flesh. Short storage window (~1 month). To maintain best flavor and texture, skip field cure and bring them into cool storage once they have colored up. This type keeps best at slightly cooler storage than other winter squash. **VARIETIES: Sweet Reba, Table Queen, Carnival (Acorn x Sweet Dumpling)**

Delicata ***(C. pepo)*****:** A mild, sweet, early season, small (1–2 pounds), thin-skinned type with very sweet, smooth yellow flesh. As it ripens, color goes from white with green striping to pale yellow with orange and green striping. Storage life is longer than acorn but become drier and starchier in the 2nd–3rd month of storage. Skin is edible. **VARIETIES: Zeppelin Delicata, Sweet Dumpling**

Butternut ***(C. moschata)*****:** A bell-shaped fruit with thin tan skin. Widely grown for its bright orange, sweet, moist flesh, this type has a long storage life (~6–8 months), and seems to get better with age. **VARIETY: Waltham**

Spaghetti ***(C. pepo)*****:** A large, oblong fruit. The pale yellow flesh is quite mild, only slightly sweet, and breaks apart to look like strands of spaghetti when cooked. It has a short storage life (~4–6 weeks).

Hubbard ***(C. maxima)*****:** A large, hard-skinned, tear drop-shaped type with several color varieties, from pale blue to bright orange skin, with pale yellow to deep orange flesh, which is sweet and savory. Great as a pie filling or puree. Can be stored up to 6 months in proper conditions. **VARIETIES: Red Kuri, Blue Ballet**

Kabocha ***(C. maxima)*****:** A squat-shaped Japanese type with rough, thick skin in several colors, with dark green most common, but also in shades of gray to light blue, or bright orange. The flesh is distinctively dry and flaky with a rich, nutty flavor. Long storage life (~6–8 months). **VARIETIES: Sunshine (bright orange-red), Cha-Cha (dark green)**

Buttercup ***(C. maxima)*****:** Compact and green, closely resembles a kabocha type, but is distinguished by a round ridge on the bottom. The flesh is dense, firm, and somewhat dry. **VARIETIES: Burgess, Bush** ***(compact plants, good for garden scale)***

NOTE that some varieties are resistant to powdery mildew, a major disease of winter squash. When you search seed catalogs, look for the abbreviations "PMT" for Powdery Mildew Tolerant.

Clockwise from top left: Red Kuri, Winter Luxury (pumpkin), Sweet Reba, Zeppelin, Sunshine. *Photo: Elizabeth Birnbaum*

FIGURE 6. The squash canopy shades out weeds as fruit develops.
Photo: Elizabeth Birnbaum

Winter squash commonly show signs of wilting on hot afternoons. This is not always related to lack of available water, so don't use the afternoon wilt symptom as a guide for irrigation frequency. If the plants appear wilted in the morning, then the plants are water stressed and you need to irrigate.

Weed control

When squash seeds are planted to moisture, late season rains are minimal, and drip irrigation can be delayed until there is a full canopy of leaves between plants within the row, there may be no weeding necessary during the entire cropping cycle. This type of management can significantly reduce production costs, keep the field clean of unnecessary weed seed, and maintain profitability.

If between-row weed management is needed after thinning and in-row weeding, use a three-bar cultivator mounted with disc hillers, sweeps, and knives. Because of the low growing point of squash plants, it is not advisable to move soil towards the plant following emergence. Rolling cultivators are therefore not an appropriate tool to effectively manage weeds in winter squash.

Run shallow chisels behind the tractor tires to break tractor tire wheel compaction, especially in situations where soil moisture is high at the time of cultivation. This will aid fall tillage and minimize clod formation. Generally, only one or two cultivations are needed for weed management in winter squash. The few weeds that escape cultivation can be hand pulled once the squash is in full bloom. After that, the canopy should prevent further weed germination or growth (Figure 6). Additional passes may be needed to control bindweed or other perennial weeds.

Harvest

Color is probably the best indicator of harvest timing. Most varieties will develop a deep color as the stems dry down, the rind loses its sheen, and the fruit hardens. For example, Butternut will go from light green to deep tan; Sweet Dumpling and Delicata will go from white/green to deep yellow/orange

Once the squash foliage has fully senesced, cut the squash from the vine with hand-held clippers, leaving a short stalk on the fruit. Take care not to break off the stem as early post-harvest decay can develop at the point of detachment. Windrow the harvested squash in the field to facilitate pick up after curing (Figure 7). Field curing—leaving squash in the sun for 1–2 two weeks (depending on weather)— allows fruit to shed some moisture, concentrates sugars, hardens the skin, and slows respiration, allowing for better long-term storage. Curing for more than two weeks may cause sunburn and make fruit susceptible to insect damage. If rain or a heat wave (temperatures over 95°F) is forecast, squash should be picked up and stored.

Cardboard bins may be used for field removal and temporary storage. Handle squash carefully to avoid cutting or bruising the skin. Remove dirt from squash and cull damaged fruit while filling bins; do final quality assessment and grading when packing boxes from the bins for market. Bins on pallets may be moved with a three-point forklift attachment on a tractor, or a forklift. Store squash in a shady, covered area.

Post-harvest considerations

When kept dry and rodent free, most winter squash varieties will store well at ambient temperatures for 2–5 months, and some varieties (e.g., Butternut, Hubbard) will store for up to 8 months or longer. Consult seed catalogues and post-harvest storage charts (see Additional Resources) for optimal storage temperatures of the squash varieties you grow.

Post-harvest field care

Shortly after harvest, retrieve all drip lines and prepare the ground for a subsequent cash crop or winter cover crop. Mow the squash vines after harvest to eliminate large clumps of plant material prior to discing. If left intact, large vine pieces can cause "wrapping" and "gathering" problems with some follow-up tillage implements (e.g., chisels and spring tooth harrows).

Because squash requires minimal tractor and foot traffic on moist ground during the cropping cycle, the soil should be easy to work following harvest. Typically the winter squash field will only need mowing and one or two passes with a disc to adequately prepare the ground for planting. Optimal soil conditions support good cover crop stands and rainwater infiltration rates.

FIGURE 7. Windrowed winter squash curing at the UCSC Farm.
Photo: Elizabeth Birnbaum

DRY FARMING WINTER SQUASH

Many varieties of winter squash are well suited to dry farming in California's Central Coast region, especially in areas with marine influence and generally cooler daytime highs. Primary considerations for dry farming winter squash include:

- Minimum 20" of winter rainfall.
- Deep soils with high clay content in lower horizons.
- Timely (early) incorporation of cover crop to minimize loss of deeper soil moisture due to transpiration by the cover crop.
- Tillage practices that promote water holding and minimize loss of moisture through surface evaporative.
- Use of wider-than-standard plant spacings to allow for greater soil/water volume for each plant. Wider spacing means fewer plants and lower yields.

Pests and Diseases

Before you select varieties and plant your winter squash crop, look up common pests and diseases that affect the crop in your area. Learn about pest and disease life cycles, preventive practices, and possible treatments using resources such as the UC IPM website (ucipm.edu), your county Cooperative Extension offices, ATTRA's Biorationals: Ecological Pest Management Database www.ncat.org/attra-pub/biorationals, neighboring farmers, and other knowledgeable professionals.

The main winter squash arthropod pests in the Central Coast region are:

- Cucumber beetle: Western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata*; Western striped cucumber beetle, *Acalymma trivittatum*: feed on foliage and fruit.
- Melon Aphid, *Aphis gossypii* and other aphids: transmit plant viruses, feed on leaves of older plants, honeydew can lead to mold infections.

The main winter squash diseases in the Central Coast region are:

- Powdery mildew: *Sphaerotheca fuliginea* (=*Podosphaera xanthii*) and *Erysiphe cichoracearum* (=*Golovinomyces cichoracearum*): affects leaves and stems of older, fruit-bearing plants.
- Verticillium Wilt, *Verticillium dahliae*: interferes with water transport, can reduce fruit yield and quality, or kill plant.

Please see *Organic Pest and Disease Management in Selected Crops on California's Central Coast* in this **Grower Guide** series for information on the pests and diseases listed here, and suggestions for their control in winter squash.

ADDITIONAL RESOURCES

Introduction to weed management in a small scale organic production system (video). Produced by the Center for Agroecology & Sustainable Food Systems. www.youtube.com/user/casfsvideo

Knock weeds out at critical times, by Mark Schonbeck. eOrganic, 2010. articles.extension.org/pages/18882/knock-weeds-out-at-critical-times

Organic pumpkin and winter squash marketing and production, by Janet Bachmann and Katherine Adam. NCAT IP371, 2010. attra.ncat.org/attra-pub/summaries/summary.php?pub=30

Powdery mildew resistant winter squash varieties are valuable addition to management program. Vegetable MD Online, Cornell University. vegetablemdonline.ppath.cornell.edu/NewsArticles/Winter_PM_Resistant.html

UC Davis postharvest technology postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/(see Pumpkins)

Organic Winter Squash Production on California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, and Kirstin Yogg-Comerchero, with contributions from Ann Baier and Doug O'Brien. Edited by and Martha Brown and Ann Baier.

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APPENDIX: PRODUCTION SCHEDULE, ECONOMIC DATA

Crop day	sub crop	# beds (1 bed = .02ac)	Action	work rate (hr/ac)	fixed rate (hrs)	Total labor cost @ $16.10/hr	Total machine cost @ $21.70/hr	Harvest Amt.(#)	Harvest Value($)
-25		10	Flail Mow:heavy	2.5	0.2		$15.19		
-25		10	Spade	4.8	0.2		$25.17		
-11		10	Mark Lines	2	0.2		$13.02		
-11		10	List	1.25	0.2		$9.77		
-11		10	Overhead Irr:set up	3.75		$12.08			
-10		10	Overhead Irr:run		0.5	$8.05			
-1		10	Light cultivation	1.25	0.2		$9.77		
-1		10	JD 71 Seed	4.82	0.2		$25.26		
0		10	Plant:drop seeds	9.64	0.2	$34.26			
18		10	Thin plants	2		$6.44			
20		10	Cultivate	2	0.2		$13.02		
21		10	Drip:set up	10	0.25	$36.23			
21-119		10	Drip:run x 1/wk; @ 15wks		2.25	$36.23			
45		10	Hand Weed:big weeds	8	0.2	$28.98			
70		10	Hand Weed:big weeds	8	0.2	$28.98			
120	Red kuri	2	Clip	6		$3.86			
120	Delicata	4	Clip	6		$7.73			
140	Butternut	4	Clip	6		$7.73			
150	Red kuri	2	Harvest	37.23		$23.98		1,162	$871.20
150	Delicata	4	Harvest	14.17		$18.25		884	$663.00
160	Butternut	4	Harvest	23.27		$29.97		1,452	$1,089.00
			Pack						
-		10	Drill/Cover Crop	1.6	0.2		$11.28		
					Sub-total:	$282.75	$122.47		

Harvest Assumptions	
Harvest (#/acre)	
Delicata	18,000
Butternut	29,000
Red Kuri	22,000
Harvest (#/hr)	780
Harvest Rate (hr/ac)	
Delicata	14.17
Butternut	23.27
Red Kuri	37.23
Price ($/#)	0.75

Labor + Machine Cost ($)	
Per Block (.2 Acres):	*$405.23*
Per Acre:	*$2,026.15*

Yield		
Per Block (.2 Acres):	*3498*	*$2,623.20*
Per Acre:	*17488*	*$13,116.00*

Item	Cost per unit	Cost per acre	Notes
Drip Tape	$120/7500'	$232.32	1 row/bed; 14520 row'/ac; $.016/row'
Seeds	-	$200.00	Seed cost per acre: butternut $70; Delicata $140; Red Kuri $580
Boxes	$.98/box	$490.00	.98/bx; 35#/box; 500 box/ac
Total Expenses (per acre):		*$922.32*	

Per Acre Totals	
Income:	$13,116.00
Labor + Machine Cost:	-$2,026.15
Expenses:	-$922.32
Production Profit:	**$10,167.53**

Complete irrigation schedule available online at casfs.ucsc.edu/about/publications/growerguides. Data reflect direct field production costs and do not include other potential overhead (e.g., water, electricity, land rent).