# *Field Tomato Production Guidelines for Hawaii*

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The tomato, Lycopersicon lycopersici, is the number one vegetable crop in Hawaii in terms of popularity and market value. This unique vegetable, a member of the Solanaceae Family along with the peppers and the Irish potato, is a native of Central and South America. Nutritionally a medium sized tomato (5.3 oz) contains 35 calories, is rich in vitamin C, vitamin A, potassium, and fiber. It is a warm season crop grown in Hawaii from sea level up to 6000 feet in elevation.

In 1991 14 million pounds (6,400 MT) of tomatoes were consumed in Hawaii of which 23% was produced locally in 230 Acres (95 Ha). The farm value of local production of tomatoes in Hawaii for 1991 was about $3.1 million, with production concentrated in Kona, Mt. View, Kula and Molokai. Local production has decreased substantially over the past few years due to crop losses caused primarily by the tomato spotted wilt virus (TSWV).

**Flowering and Fruiting**

The tomato is self-pollinated. Flowers are borne in clusters which are located on the stem between the nodes. Tomatoes, especially the large fruited varieties, are sensitive to high night-time temperatures which may lead to lower fruit set or to development of small, seedless fruit. Optimum temperature for fruit set is 60-70F (15-20C). Fruits reach the mature green stage about 27 days after fertilization. Environmental stress, such as poor nutrition, unfavorable weather, or insect and disease pressure may result in abscission during or after flowering.

**Cultivars**

Cultivar selection is one of the most important decisions made during the crop production process. Selection of cultivars adapted to the local growing conditions and

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seed quality are significant production factors which deserve careful planning and consideration. Cultivars developed by the University of Hawaii, now over 15 years old, have resistance to bacterial wilt, vascular browning, Fusarium wilt race 1, common races of root-knot nematode (gene Mi), spotted wilt virus (gene Swa), Stemphylium solani, and spider mites. Growth characteristics to consider during cultivar selection include plant habit, jointlessness, fruit size, shape, color, firmness, and smoothness. Market traits to consider include pack-out, fruit size and shape, ripening, firmness and flavor.

In Hawaii Celebrity is the industry standard for bush-type tomato, but production of this semi-determinate cultivar has decreased dramatically over the last few years due to its susceptibility to Tomato Spotted Wilt Virus. Petoseed has recently released hybrid cultivar PSR 55289 with resistance to TSWV and with similar horticultural traits as Celebrity. However, its availability in the future will depend on local grower demand.

Cultivars adapted to Hawaii:

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Open Pollinated
a. Large fruited= Healani, Tropic*, 8222, 8248
b. Plum or paste types- Roma, San Marzano
c. Cherry type- Large Red Cherry, Royal Red Cherry.

Hybrid Cultivars
a. Large fruited- PetoSeed PSR 55289; Celebrity, N-52*, N-65*, N-69*, BWN-21,
b. Cherry types- Small Fry, Cherry Challenger, Cherry Grande, Sweet Million.

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* Require staking and pruning

For trial cultivars

Cultivars which have performed well in Hawaii based on Molokai Winter trials (where spotted wilt has not been detected) include Milagro, Celebrity, Carmen, Cavalier, and Carnival. In Molokai Celebrity was the most productive with experimental yields of over 50,000 lbs per acre (56 MT/Ha).

FERTILIZER RECOMMENDATIONS

**Optimum pH** is 6.0-6.5. Liming to raise the pH to 6.0-6.5 may aid in reducing fusarium wilt in the field.

**Nutrient Rates**

Fertilizer applications should be based on crop nutrient demands and on stage of crop growth. Tissue and soil analysis will help to determine how much fertilizer to apply, to complement the nutrient levels already available in the soil. Soil samples should be taken and appropriate fertilizers added as recommended by University of Hawaii Soil scientists for that particular soil type. Excessive fertilizer application, above crop needs, may result in salt buildup, phytotoxic effects on plant growth, ground water contamination, and capital losses due to purchase of unneeded fertilizer. Recommended rates for Hawaii are 1,500 to 2,000 lb/Ac of 10-20-20 or similar type fertilizer, with half applied at planting and the remainder 4-5 weeks later. Supplemental 100 lb/Ac of urea or 200 lb/Ac of sulfate of ammonia (lbs/acre) can be applied every 3 to 4 weeks after harvest begins. Phosphorus is an important nutrient for root development, flower development, fruit set, and to hasten fruit maturity.

On soils which test low for phosphorus apply 1,000 lb/Ac of treble superphosphate. This is preplant applied in 12 inch (30 cm) bands in the plant row worked to a depth of 6-12 in (15-30 cm). Soil magnesium deficiencies are corrected with 150-200 lb/Ac of magnesium sulfate. Minor crop magnesium deficiencies may be corrected as needed with magnesium sulfate (epsom salt) sprays of 10 lbs/100 gallons of water per acre.

An adequate calcium supply is necessary to prevent blossom-end rot in tomatoes. Calcium deficiencies are corrected with weekly foliar calcium nitrate or calcium chloride applications at rates of 10 lb/100 gal and 5 lb/100 gal respectively.

**Fertilizer Placement**

In non-mulched crops, apply all P and up to 1/2 of N and K prior to planting, incorporating with disks or rototilling. Supplemental fertilization during the growing season should be banded on both sides of the row.

For drip irrigated crops apply all phosphorus, micronutrients and 20% to 40% of total N and K prior to laying the plastic mulch. The remaining N and K is applied at levels corresponding with the crop developmental stage. At the seedling stage apply weekly 2-5% of the total N and K requirements. At the early fruiting stage begin weekly applications of 10% of the total N and K requirements.

**Nutrient Tissue Analysis**

Periodic nutrient analyses of foliage tissue may be used to provide an estimate of a crop's nutritional status and serve as a record of crop performance. The tissue analysis should be calibrated with soil fertility levels, according to soil samples taken before planting. For tissue analysis collect a young mature whole leaf (petiole and leaflets), located below the last open flower cluster. A representative tissue sample from a field will consist of 25 to 100 collected leaves free from insect or disease attack. The critical growth stage of phosphorus uptake is when the first flower cluster develops, and tissue levels should thus be maintained above 0.4% to avoid flower abortion. With rapidly growing plants the calcium level must be maintained above 2.5% from the first flower set and preferably throughout the plant life cycle. Excessive nitrogen applications resulting in tissue levels >5% will inhibit calcium and potassium uptake, reduce internode length, and promote excessive vegetative growth. Recommended optimum ranges for tomato are:

| Nutrient | Range | Target level |
|---|---|---|
| N | 3.0-4.5% | 3.0% |
| P | 0.4-1% | 0.5% |
| K | 3.0-7.0% | 3.5% |

| | | |
|---|---|---|
| Ca | 2.0-5.0% | 3% |
| Mg | 0.40-1 .5% | 0.4% |
| Fe | 100-250 ppm | 120 ppm |
| Zn | 25-150 ppm | 25 ppm |
| Mn | 40-300 ppm | 75 ppm |
| Cu | 5-25 ppm | 10 |
| B | 25-100 ppm | 25 |
| Mo . | .15-5.0 ppm | .16 |

CULTURE AND MANAGEMENT PRACTICES

In typical commercial operations, tomatoes are grown in polyethylene-mulched beds with drip irrigation. Irrigation and fertilization can be monitored closely with drip irrigation. The plastic mulch helps to maintain a high degree of water and fertilizer use efficiency. Tomatoes are susceptible to damage from wind and growers in windy areas should consider the use of suitable windbreaks. Wind break your crop in wind-prone areas with wiliwili (Erythrina), yuba cane, or other shrubs suitable to your area. An in-field rotation may be conducted for the following crop by rototilling the row where the windbreak was grown and planting in the row and preparing the bed in that area.

**Time to plant**. In Hawaii tomatoes are grown year round at 1000-3000 ft (300 to 1,000 m)elevation; March through August at 3,000 to 4,500 ft (1,000 to 1,500 m); September through May from sea level to 1,500 ft (500 m) elevation.

**Field preparation**. Plow the soil if a hard pan is present. Liming, when necessary is broadcasted and disked along with any crop residue or weeds. Bedding, fertilizing, and fumigating may also be conducted at pre-plant.

**Propagation**. Tomatoes are normally transplanted in Hawaii to assure proper stand establishment. Seedlings are transplanted 3 to 5 weeks after sowing. About 1 oz of seed is needed per acre if seed is transplanted and 2 lbs per acre if direct seeded.

**Spacing**. Bush tomatoes are spaced 3-4 feet apart in rows spaced 5-7 feet apart. Trellised plants are spaced 14-24 inches apart on 5 feet tall trellises with rows spaced 5-6 feet apart.

**Transplanting**. Seedlings are grown in containerized plastic or styrofoam multi-cell packs or similar systems where the cell surface area is 2 square inches (5 sq. cm). These seedlings can then be transplanted with minimal disturbance to the root system. Early root development is enhanced with soluble 10-52-17 or similar fertilizer when applied at 3-4 lbs per 50 gallons of water. The transplants are kept in a greenhouse or shade house. Follow proper sanitary conditions by using sterile trays and soiless growing media. The seedling should be carefully monitored to maintain proper watering, nutrition, and disease-free material.

**Training**. Staked tomatoes provide ease of harvest and higher fruit quality by keeping fruits off the ground and resulting in less rot. Staked tomatoes are normally pruned to 1-2 main stems. Staking is done 2-3 weeks after transplanting. Wooden stakes 50-60 inches long are driven into the ground halfway between each plant or between alternating plants. Plants are trained by tying the plants with plastic twine or construction wire onto the trellis beginning 3-4 weeks after transplanting and is repeated 3 or 4 times during the growing season. The twine is tied around each stake and on both sides of the plant to provide vertical support. Before re-using, stakes should be sterilized by steaming 1-2 hr at 200F below a plastic tarp, or with methyl bromide fumigation. Height of the stakes and training technique varies depending on wind conditions during the growth cycle, or on traditional practices followed in the different tomato production areas of the state.

**Irrigation**. Drip irrigation for tomatoes has gained popularity because of increased water use efficiency and because it allows for the application of fertilizers and pesticides with the irrigation water. With drip irrigation it is possible to closely synchronize weekly water and nutrient application rates with the corresponding stage of crop development.

PESTS

Tomato yields may be reduced by a myriad of insect and diseases pests. Integrated pest management (IPM) is a systems approach to reduce pest damage to tolerable levels using a variety of techniques such as natural enemies, genetically resistant plants, sound cultural practices, and when appropriate, chemical pesticides. The IPM approach is based on proper pest identification, periodic scouting, and on the application of pest management practices during the precise stage of the crop's development where no control actions would result in significant economic losses. Two additional strategies of an integrated management approach consist of 1) Taking pest control actions during the most vulnerable stage in the pest's life cycle (to maximize results with the least possible effort), and 2) To utilize synthetic pesticide spray applications for pest suppression, only after all other pest control alternatives have been considered and exhausted. The main objectives of utilizing alternative pest controls over pesticide treatments, is to reduce the high capital costs incurred with frequent pesticide applications, and secondly to maximize the abundance of beneficial organisms.

**Insects**

Important insect pests of tomato include aphids, armyworms, cutworms, tomato fruitworm, leafminers, melon fly, mites, root-knot nematodes, tomato pinworm, thrips, and whiteflies. Outbreaks of the sweetpotato whitefly and the greenhouse whitefly is currently a major problem for tomato production in Hawaii. Apply insecticides only when necessary, and when possible rotate pesticide families to delay development of insect resistance. Insects with exploding population growth rates such as thrips, whiteflies, mites, leafminers, and aphids are especially prone to develop pesticide resistance, when exposed to frequent applications of the same insecticide.

Aphids

Aphids feed on plant sap which may reduce plant vigor. Aphids may also act as vectors of plant viruses, and may also introduce toxins into the plant, resulting in growth deformations. Growers should use timely insecticide applications as needed based on close monitoring of aphids and their natural enemies.

Armyworms

Beet armyworm, Spodoptera exigua, and nutgrass armyworm, S. exempta, infestations on tomato may result in up to 25% fruit losses. The armyworms can be distinguished by the inverted "Y" on the front of the head. Adult moths are active at night and can lay eggs on the leaves in groups of 100 or more. Feeding by young caterpillars can reduce leaves to veins leaving behind webs. Caterpillars normally begin feeding on the fruit after molting 3 or 4 times, and later pupate in the soil. Damage to the fruit consists of superficial feeding wounds that dry out as the fruit matures. Small caterpillars, however, may penetrate the fruit and cause damage similar to the feeding damage caused by the tomato fruitworm. A caterpillar normally feeds on more than one fruit. Armyworms should be controlled before they reach 1/2 inch in length. Monitor the crop weekly beginning at fruit set and apply pesticides when more than 0.25 larvae per plant are detected .

Cutworms

These caterpillar pests which include the variegated cutworm, Peridroma saucia, and the black cutworm, Agrotis ipsilon, can devastate young tomato plants, by chewing through the stems at the soil line. Cutworms are active at night. Control is warranted when high populations are present in the field prior to planting. Baits containing Bacillus thuringiensis are available for cutworm control. Control is normally not recommended when the plants are ≥1 foot tall.

Tomato Fruitworm

The tomato fruitworm, Helioverpa zea, damages green fruit. H. zea is also an important pest of corn, lettuce, beans, and other crops. Eggs are laid singly on leaflets close to the small fruits. The larvae feeds on green fruit and later burrows into the soil to pupate. The pupa is formed in a tiny cell 2 inches below the soil

surface. Adults are active at dusk and during the night. Female moths begin laying eggs 48 hours after emergence. Important natural enemies of the fruitworm include the parasitic wasps Trichograma spp., and Hyposoter exiguae as well as some general predators. The critical period for monitoring begins at flowering up until the green fruit stage. Egg counts are made from leaves below the inflorescence. Pesticide applications may be needed when more than 4 viable eggs are found in a sample of 30 leaves. Pesticide treatments are also recommended when a large percentage of young caterpillars are feeding on the foliage before fruit damage has occured.

Leafminers

Leafminers are normally a secondary pest which are kept in check by natural enemies. However both the vegetable leafminer, Liriomiza sativae, and the celery leafminer, L. trifolii, may become primary pests in tomato fields where intensive pesticide use have destroyed their natural enemies. Leafminers are small yellow maggots which form trails beneath the leaf epidermis as they feed. When fully grown, the larvae drop to the soil to pupate. A monitoring program consists of placing white styrofoam or plastic pans at the soil level below the plant throughout the field to collect larvae as they drop and pupate. Insecticides are recommended when average counts rise above 20 pupae per pan per day. Because contact insecticides won't reach the larvae inside the leaf, systemics are recommended.

Melon Fly

The melon fly, Bactrocera cucurbitae, has long been a major pest of tomatoes in Hawaii. The pest has traditionally been controlled in problem areas with protein baits and an insecticide such as malathion applied to corn border rows. Infested fruits should be removed from the field to reduce insect numbers. Do not dispose of culled fruit with live melon fly larvae in areas close to the production field.

Mites

Outbreaks of carmine spider mites, Tetranychus cinnabarinus, and the tomato russet mite, Aculops lycopersici, may occur during hot and dry weather. Tomato russet mites are tiny spider-like animals which feed preferentially on the lower stem, and then move on to feed on the upper section of the plant and on leaves. Their life cycle, egg hatching, and two nymphal stages until maturity, takes one week in hot weather. Presence of the mites is manifested in the bronze and greasy appearance of stem and leaves. Similarly, the carmine spider mite completes its life cycle in about one week. Its feeding causes leaves to become stripped with light colored dots. Leaves may later turn yellow and drop. Silk webbing may be present when infestation is heavy. Wettable sulfur, and other miticides are effective on mites.

Root-Knot Nematodes

Root-knot nematodes are microscopic round-worms which feed on the roots of plants. Symptoms on the foliage caused by the affected root system include stunting, wilting, and leaf yellowing. Infested roots develop gall-like swellings. Adult stages of the nematode reside inside these swellings in the roots. Prior to planting, tomato fields are normally fumigated for nematode control. Many commercial cultivars, including the UH bred-lines are resistant to root-knot nematodes. Several grasses, which are non-hosts to the root-knot nematode such as oats, barley, wheat, and rhodes grass, may also be grown before tomatoes. Other nematodes which infest tomatoes include sting, stunt, reniform, and dagger nematodes. The soil may be tested to estimate the population of parasitic nematodes.

Tomato Pinworms

The tomato pinworm, Keiferia lycopersicella, are small caterpillars which can severely damage tomato. Crop losses can reach up to 80%, despite the application of insecticides. The yellowish-green larvae is 1/4 inch long. Activity of the adult moth peaks between 4:00 and 9:00 PM, in which eggs are layed preferably in leaves just above or below the inflorescence. Young larvae tend to leave in the leaves. The leaf tips are tied together by the pinworm as it feeds, making it difficult to target by insecticide applications. While some pinworms complete their life cycle in the leaf, in most cases third instar larvae perforate the fruit near the calyx area. The

pinworm normally pupates in the soil, but in some cases, it may pupate in the fruit itself. Alternative controls for the pinworm include the enhancement of parasitoids, clearing of weedy areas close to the production field, quick disposal of the crop after harvest, and establishment of crop-free periods. A monitoring program for the tomato pinworm consists of weekly egg and larval counts, assessment of fruit damage, and adult counts with pheromone traps. Insecticide treatments are recommended when larval counts are above 0.25 per plant.

Thrips

The western flower thrips, Frankliniella occidentalis, is a vector for the tomato spotted wilt virus. This disease has caused a dramatic decrease of tomato acreage in Maui over the past few years. These thrips may also reduce plant vigor when feeding on tomatoes in large numbers. Their direct damage to fruit may cause a bronzing effect.

Whiteflies

Recent sweetpotato whitefly, Bemisia tabaci, outbreaks have caused considerable losses in tomato fields state-wide. The main symptom is an irregular ripening of the fruit, which is difficult to distinguish on green-matured tomatoes. The irregular ripening symptom which is probably caused by a toxin injected by the whitefly, is visible only after ripening, when the tomatoes have normally reached the wholesaler. Additional sorting operations, and an in-house ripening step may be required to reduce the numbers of poorly ripened fruit. Full canopy coverage with insecticide sprays is necessary to reach the eggs and adults on the under side of the leaves. Area-wide control strategies may be necessary in places where whitefly numbers are abnormally high. The sweetpotato whitefly-transmitted gemini virus, which has resulted in stunting and reduced fruit size in Florida and California, has not yet been detected in Hawaii.

The greenhouse whitefly, Trialeurodes vaporariorum is also common in Hawaii tomato production areas. Parasitic wasps and predators such as the tomato bug help to keep the greenhouse whitefly below damaging levels. In contrast to the case of the

sweetpotato whitefly, tomatoes can sustain greater population levels of the greenhouse whitefly without yield reductions. Control strategies will therefore vary depending on the specific whitefly species in the field. Before conducting any pest control measures, identify which whitefly species is actually present in your field.

**Diseases**

Bacterial canker

Cornybacterium michiganense can be a serious disease in tomato because it can persist in the soil for many years, and because it is seed-transmitted. Symptoms include wilting and cankers on stem and fruits. Drip irrigation has reduced the incidence of this disease. For control use disease free or certified seed. Contaminated seed may be treated with the following treatments:

1) Fermentation: ferment crushed pulp for 96 hours before extracting seed at temperatures near 70F. Stir it at least twice a day.

2) Acid: Soak freshly extracted seed in an 0.8% acetic acid solution. This is done by adding 1 fluid oz. of acetic acid to 1 gallon of water. Place seed in loosely woven cloth and immerse in solution for 24 hr at 70F.

Bacterial spot

Xanthomonas campestris pv. vesicatoria may become a problem during wet weather. Both foliage and fruits are affected. Infection occurs through natural leaf openings or through wounds in the fruit. Fruits show numerous 1/8 inch spots. Leaves show irregularly shaped, brown spot lesions. Destroy tomato plants after harvest to reduce inocolum levels.

Bacterial wilt

Pseudomonas solanacearum is the most serious disease of tomatoes in the tropics and sub-tropics. Symptoms include rapid wilt and death of the entire plant without any yellowing of the leaves. If the stem is cut and placed in a glass of water, a gray bacterial ooze is visible. The disease is difficult to control because it remains in the soil for many years. Contaminated fields should be rotated with non-solanaceous

crops. Prevent machinery and field personnel from moving from contaminated to non-contaminated soils. The disease penetrates the plant through wound openings in the roots. Old cultivars, Kewalo and BWN-21, developed by the University of Hawaii College of Tropical Agriculture and Human Resources are highly tolerant to bacterial wilt.

Blossom-end rot

This physiological disease may cause severe yield reductions in tomato. The initial symptom will be a slight, water-soaked discoloration on the blossom-end of fruits. The lesions enlarge and turn dark brown or black. An irregular water supply compounded with a fast growing crop may promote blossom end rot. The disease results from a localized calcium deficiency in the fruit. Calcium is translocated in the plant through the transpiration flow. Being the major vascular system sink, the leaves obtain the primary supply of calcium, and when calcium deficiencies occur, the fruits will be the first organs to show deficiency symptoms. Factors which have an effect on the plant's calcium supply should be monitored including cultivar, plant nitrogen status, soil fertility, pH, and an even moisture supply in the root zone. Nitrogen over-fertilization may accentuate blossom end rot by promoting excessive shoot growth.

Blotchy ripening or Gray Wall

This physiological disease also called internal browning is characterized by irregular browning on the side walls of the fruit. The fruits will develop a normal red color except in the affected areas. A cross-section of affected fruits will show brown veins with yellow to gray cells in the blotched areas. The incidence of blotchy ripening is increased with tobacco mosaic virus (TMV) infection, succulent growth, low potassium, and sudden temperature changes. Commercial cultivars have good resistance to this disease.

Catface

A physiological disorder in which fruits show extreme malformation and scarring at the blossom ends. Catface results from any growth factor that affects normal pistil development in the flower. Prolonged heat during blossoming and other stress factors may result in catfacing. Most commercial varieties are not affected by catface. When possible remove affected fruits as early as possible so that remaining fruits are allowed to develop.

Double Streak Virus

This disease is normally a combination of TMV and potato virus X or Y. A combination of tomato spotted wilt virus and potato virus Y can also cause this disease. Initial symptom is light green mottling of leaves followed by development of small grayish-brown spots on leaves. Later, brown spots occur on stem and leaf petioles. Infected plants are stunted and fruits, if produced, are covered with dark spots. The virus complex is transmitted mechanically. Controls include growing TMV resistant cultivars, and the use of determinate cultivars which do not require pruning.

Early blight

Symptoms of the fungus Alternaria solani are concentric lesions of dead tissue on leaves and stems, as well as spotting on leaves and fruits. The disease can result in crop defoliation during wet and warm weather any time during the crop cycle. Controls include a three-year rotation, planting on wide, high beds, and fungicide treatments.

Fruit cracks

Three common types of physiological cracks make fruits unsalable, and permit the entrance of secondary disease organisms.

1. Radial: Cracks radiating from the stem
2. Concentric: Cracks extend more or less in a circular fashion around the stem-end portion of the fruit.
3. Splitting of bursting: Occurs in nearly ripe fruit following rain or irrigation.

Cracking can be partially controlled by providing an even moisture supply, thus preventing alternating stages of fast and slow fruit growth.

Fusarium wilt

Fusarium oxysporum f. lycopersici is a soil-borne fungi which enters the plant through the root and interferes with the plant's vascular system by stopping the transpirational flow. As a consequence the lower leaves are first to turn yellow and wither. The symptoms progress and eventually the entire plant is affected, with a dark-brown discoloration in the bark of affected areas, and with live leaves limited to the branch tips. Commercial cultivars are available with resistance to races 1 and 2. In addition, sanitation, rotation with grass crops, soil fumigation, and soil pH near 6.5 should be used for control of races 1,2, and 3.

Gray Leaf Spot

Stemphylium solani begins as small circular sunken brownish lesions with spots surrounded by a yellow halo. The fungus is favored by hot weather, and can cause severe defoliation in susceptible cultivars. Best control is achieved with resistant cultivars. Promptly destroy the tomato crop after harvest.

Late blight

Phytophthora infestans causes severe defoliation, stem girdling, and severe fruit rot. Cool nights and warm days with abundant moisture favor development of this fungus. Fruit symptoms include irregular watersoaked spots which turn brown and wrinkle at the surface. Control includes careful monitoring and use of fungicide applications.

Puffiness

This physiological fruit disorder is common during the winter or early spring. Affected fruits are light and feel soft. Fruit shape is normal but the surface is flattened or shrunken over the sections between the internal walls. Fruit cross-sections show a normally developed outer wall and poorly developed seed locules, with existing cavities between the locules and the outer wall. Factors which may

promote puffiness include poor pollination, excessive N applications under cloudy weather, excessive irrigation, and temperature extremes.

Sclerotinia

Sclerotinia sclerotiorum can cause serious losses in both tomato greenhouse and field operations. The fungus attacks the main stem at the soil line and is characterized by watersoaked areas which become light to dark brown. Further disease development results in wilting and plant death. Masses of white mold and black sclerotia are identifying characteristics. High moisture and temperatures promote disease development. Control with proper sanitation, soil drainage, crop rotation with grass crops, and fungicide applications. This disease may build up in nearby bean fields.

Tomato spotted wilt virus

Tomato plant growth ceases and senescence is promoted after infection with spotted wilt virus (TSWV), perhaps the major disease of tomatoes in Hawaii. In older plants, leaves near the growing tips show dark, bronze or purplish, circular necrotic spots. Fruits also show circular concentric marks. Tomato spotted wilt virus is the only virus known to be transmitted by thrips. The only effective means of control are resistant cultivars. Celebrity, the standard tomato cultivar in Hawaii is highly susceptible to the new strain of spotted wilt. Currently the PetoSeed hybrid PSR 55289 has shown resistance to TSWV, and has comparable horticultural traits to Celebrity.

Tobacco mosaic virus

Symptoms include mottling or mosaic effects on the leaves. Infections occurring when plants are young can significantly reduce yields. The virus is transmitted mechanically, through pruning, staking, and by field workers. Several commercial varieties are resistant to tobacco mosaic virus.

**Weeds**

An integrated approach can be used to manage weed competition in tomato production. The IPM program for weed control utilizes weed identification, monitoring, sanitation, alternative cultural practices, and timely herbicide applications. The use of a weed map for each field will be helpful in the design of weed control measures, and also as a record of weed problems in the field. Cultural control practices for weed control include shallow cultivation, plowing, disking, hoeing, crop rotation, cover cropping, living-mulches, organic or plastic mulching and herbicides. The benefits of proper field preparation can not be overemphasized to improve tomato growth and also to minimize weed problems during the crop growth cycle. Useful crops for rotation with tomato include alfalfa, sugarbeets, and onions. Solanaceous crops such as potatoes and pepper are not recommended as rotation crops with tomato. Problem weeds in tomatoes include perennials, dodder, weeds of the nightshade family (solanaceous family), and grasses. The critical weed free period for tomatoes (that is the number of days the field has to be kept weed free after transplanting to prevent yield losses due to weed competition) has been estimated to be between 30-35 days after transplanting.

HARVEST AND POST-HARVEST PRACTICES

**Timing**

Time from transplant to first harvest is generally 70 to 75 days for cherry types, 75-80 days for the plum types, and 80-90 days for the large fruited type tomatoes.

**Production yields**

Bush tomato culture in Hawaii: 20,000 lbs/Acre
Trellised tomato culture in Hawaii: 30,000 lbs/Acre
Average Florida yields: 30,000 lbs/Acre
Average Ohio yields: 13,500 lbs/Acre

**Maturity**

Tomato fruits mature about 25-30 days after pollination. Maturity is correlated with increased fruit size, weight, specific gravity, total acidity, and hydrogen concentration. Grades for fresh tomatoes are U.S. No. 1, U.S. Combination, U.S. No. 2, and U.S. No. 3. Fruit categories sizes for tomatoes are large 7.2 oz (205 g), medium 5.3 oz (150 g), and small 4 oz (115 g). Harvesting stages for tomato include immature green, mature green, turning, half-ripe or pink, and ripe or red-ripe. Indices of maturity for green picked tomatoes include 1) size, which varies with cultivar; 2) rounded shape, not angular; 3) a whitish green color development in the blossom end; 4) development of a browny corky tissue on the stem scar of some cultivars, and the preferred method of choice: 5) a representative sample of the fruit's internal appearance (a destructive test). Both cherry and plum tomatoes are normally picked vine ripe.

**Harvesting operation**

In large field operations fresh market tomatoes are hand picked in 40-50 lb buckets and placed in bins, where a truck takes them to the packing shed. An alternative harvesting operation consists of a conveyor belt on ground tomatoes. Pickers travel a few feet to the conveyor where the tomatoes are placed and conveyed into the loading truck. Bruising of tomatoes from excessive handling and unloading is significantly reduced with the conveyor belt harvesting technology. Tomatoes should be maintained under the shade until taken to the packinghouse where they are washed, presized, sorted, graded, sized, packed, unitized for shipment, and shipped to its destination market.

**Washing tomatoes**

Water for washing tomatoes should be at or above the temperature of the tomatoes. Water with cooler temperatures will be absorbed by the fruits. Wash water management practices should be an important consideration during the handling process, to prevent the spread of post-harvest diseases. Decayed fruit should be culled to eliminate potential sources of inoculum. Wash water is chlorinated at 150 ppm and fruits are held in this water for no longer than 2 minutes as a single layer of floating tomatoes.

**Presizing, Sorting and Sizing**

Tomatoes with a diameter of less than 2 inches are culled. This operation is carried through an automatic pre-sizer in large commercial operations. Sorting and grading is conducted visually in the packinghouse by separating tomatoes based on USDA color stages. This operation takes on a double effort when sorting out tomatoes with irregular ripening symptoms brought about by sweetpotato whitefly feeding on the crop during the growing season. Larger commercial operations in the mainland are moving toward the use of automatic electronic color sorters such as the ones developed for apples. Tomatoes are then sized based on market classifications and conveyed to the packing line. Tomatoes are normally packed in 25 lb cartons and unitized in 2000 lb pallets.

**Ethylene treatment**

In Hawaii, some green picked tomatoes are treated with ethylene to enhance and promote ripening uniformity. Some growers have moved to ethylene treatment to overcome the irregular ripening caused by the sweetpotato whitefly. However, preliminary research conducted at the University of Hawaii College of Tropical Agriculture and Human Resources did not show improved ripening uniformity with ethylene treatment, instead it indicated the need to improve harvesting techniques and training of the harvesting crew to pick fruit at the same stage of physiological maturity. Optimum ripening is obtained when the ripening rooms are maintained at 68F and 90-95 relative humidity at ethylene concentrations of 150 ppm. Ethylene is normally applied with on-site catalytic generators or with flow-through systems.

**Storage**

Tomatoes should be stored at temperatures above 55F (13C). To delay ripening of tomato at a particular stage they can be held in a room below 68F (20C). Chilling injury occurs below 50F (10C).

**Packaging**

Mature greens are sold in 25 lb bulk-packed cartons. Fruits are packed in each carton based on fruit number per row and column in a two layered tomato package. Pink and vine-ripe tomatoes are packed in two-layer lug or tray packs. Cherry tomatoes are packed in flats holding 12 1-pint boxes. Plum tomatoes are preferably packed in quart boxes, 8 per carton. To avoid bruising don's stack more than two layers high. Also pack the fruit stem up, to protect the shoulders.

Sizing of tomatoes[1]

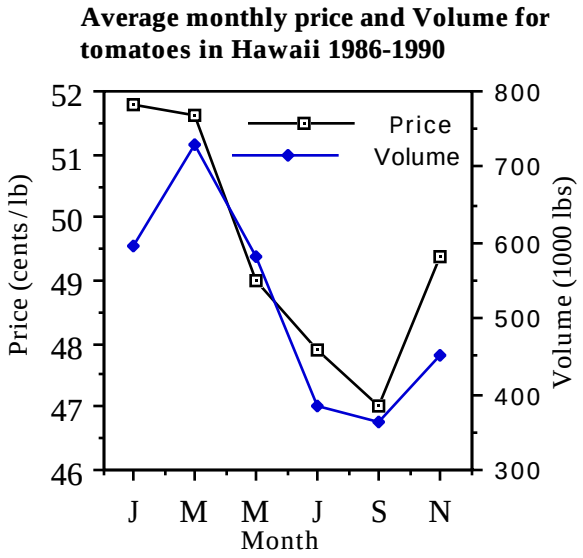
| Name | Size | Inches | |
|---|---|---|---|
| | | min | max |
| maximum large | >4x5 | 3 15/32 | > |
| extra large | 5x5, 5x6 | 2 28/32 | 3 15/32 |
| large | 6x6 | 2 17/32 | 2 28/32 |
| medium | 6x7 | 2 9/32 | 2 17/32 |
| small | 7x7 | 2 7/32 | 2 9/32 |
| extra small | 7x8 | 1 28/32 | 2 4/32 |

[1]In Hawaii growers should check with the Hawaii Department of Agriculture for current tomato grade standards.

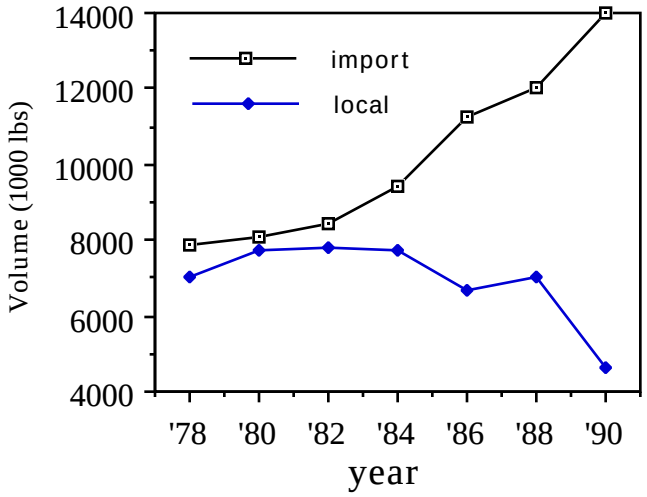
**Market Information**

In 1990 the state imported about 14 million pounds of tomatoes, or ≈70% of the volume consumed locally. The potential for the industry is to produce 100% of the local demand during the summer months, and 40% of the market during the winter months. If the industry could produce 70% of local demand the farm gate value would be $8.46 million based on production of 13 million lbs and the 1990 average per pound price of 65 cents. A solid tomato production program includes a sound and well planned marketing strategy. The prospective grower needs to have a good understanding of annual market trends (see figures below), market competitors, consumer needs, potential buyers, and market windows. To keep abreast of changing market situations and new business opportunities producers need to be in close contact with fellow industry representatives, and with other business, university, cooperative extension, and governmental organizations. Essential to a producer's sound marketing program is also the need to have a clear understanding of the

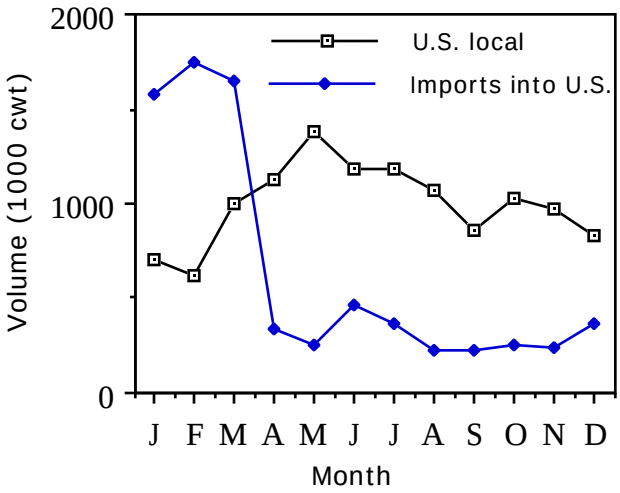
farm's financial situation at all times during the annual production cycle. Updated farm financial records, and the input of financial information in budget generators will help the grower to cut overhead and improve efficiency of production. Updated financial information and well organized farm records are also helpful in the loan application process, in assessment of crop losses by unexpected pest outbreaks, and will help the grower to make timely production and financial decisions to take advantage of potential investment opportunities, or unexpected market windows.



**Hawaii tomato imports and local production from 1978-1990**




**Monthly volume of tomato shippments in the U.S. and imports in 1990**

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