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Suggested Cultural Practices for Tomato

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Introduction

Tomato is one of the most widely grown vegetables in the world. The popularity of tomato among consumers has made it an important source of vitamins A and C in diets.

Climate and soil requirements

Tomatoes grow best in temperatures 20–27°C. Fruit setting is poor when average temperatures exceed 30°C or fall below 10°C. Tomatoes prefer well-drained soil because they are sensitive to waterlogging. Optimum soil pH is 6.0–7.0.

Tomatoes benefit from crop rotation. Growing tomato after paddy rice, for example, reduces the incidence of disease and nematodes. Avoid planting tomato in a field planted the previous season with tomato, pepper, eggplant, or other solanaceous crop. These crops share some insect and disease problems.

Choosing a variety

Selecting the best variety is critical for success. There are many factors to consider:

Fruit type. Tomato varieties are grouped into one of three market classes:

(1) fresh market—fruit are usually red but vary in color, shape, and size;
(2) cherry—a small-fruited (less than 30 g) fresh market type borne on long clusters; and

Figure 1. Fresh market tomatoes

(3) processing—fruit have intense red color and high solids content suitable for making paste, catsup, or sauce.

Plant habit. Tomato varieties are also classified according to plant habit: determinate, semi-determinate, or indeterminate. Determinate and semi-determinate varieties produce stems that end with a flower cluster. Determinates are short and bushy while semi-determinate varieties grow slightly taller.

Indeterminate varieties continually produce new leaves and flowers, and can grow very tall. Indeterminate varieties set fruit over a longer period. This longer harvest period is an advantage if market prices fluctuate, because income tends to even out. Indeterminate varieties should be staked and pruned and usually require more labor.

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Disease resistance. Prevalent diseases vary according to location and environment, but bacterial wilt, bacterial spot, tomato yellow leaf curl virus, fusarium wilt, and gray leaf spot are common in the tropics and subtropics. Some varieties are resistant to many diseases. Information on a variety's disease resistance can often be found on the seed packet.

Adaptation to season. Most tomato varieties are adapted to the dry season. Tomato varieties able to set fruit at temperatures greater than 30°C can be grown during the hot season to take advantage of higher market prices. AVRDC has developed tomato lines suited to the hot, wet season. However, successful wet season production requires a combination of a suitable variety and special management practices, such as use of fruit-set growth regulator, raised beds, grafting, or shelters to manage excessive rainfall.

Hybrid or inbred? Hybrid varieties are gaining popularity because they often produce higher yields and more uniform fruit compared to inbred lines. However, a hybrid is not always superior to an inbred variety. Hybrid seed is usually more expensive than inbred varieties, and seed cannot be harvested for future planting. Seeds of inbreds can be harvested and saved for future planting.

Seedling production

About 250 g of seed (approximately 70,000 seeds) are required to produce enough seedlings to plant one hectare of an indeterminate variety and 125 g of seed for a determinate variety. Sow seeds 0.5 cm deep.

Seedlings will emerge within 8 days at the optimal soil temperatures of 20–30°C. Seedlings grown in trays of individual containers are healthier and more vigorous compared to those grown in flats or beds. Seedlings grown in flats or beds suffer root damage when the plants are pulled apart for transplanting.

At AVRDC we grow 33,333 plants/ha for indeterminate varieties (which are pruned), and 16,666 plants/ha for determinates (which are usually not pruned). Plan to sow twice as many seeds as are needed in order to make sure there are enough plants.

Seedling tray method. Fill the holes with a medium that drains well, such as peat moss, commercial potting soil, or a mixture of sand, compost, and burnt rice hulls. Place the trays on benches in a sheltered place. Sow 2 seeds per hole and thin the seedlings 2–3 days after the first *true* (non-cotyledon) leaves appear.

Seedbed method. Choose a well-drained area not recently cropped with a solanaceous crop. Burning a 3–4 cm layer of rice straw on the seedbed before sowing, and forming a raised seedbed of 15 cm or higher to improve drainage, can reduce soilborne disease problems.

Sow the seeds in rows 6 cm apart at a rate of 750–900 seeds/m^2. Cover the bed surface with a thin layer of compost or rice straw mulch. Do not allow the soil to dry and form a crust on the surface that might hinder seedling emergence. Water the seedbed regularly so that it is moist but not waterlogged. Thin the seedlings 2–3 days after the first *true* (non-cotyledon) leaves appear.

At the two-leaf stage, irrigate the seedlings once with a 0.5% ammonium sulfate solution (5 g ammonium sulfate dissolved in 1 liter of water), 0.25% urea solution (2.5 g urea dissolved in 1 liter of water), or 0.1% Nitrophoska solution (1 g dissolved in 1 liter of water). Do not over-apply nitrogen or the plants will grow tall and thin.

Seedling death (damping-off) or poor growth can be due to fungal infection. Fungicides, such as Ridomil Gold (mefenoxam), can be applied to the seedbed at or before seeding to control pythium damping-off. Seed can be treated with broad-spectrum fungicides, such as captan and/or thiram to reduce losses from damping-off.

Insects, such as whiteflies, thrips, and aphids, can transmit viruses to young tomato plants. Admire (imidacloprid) is effective as a seed, soil, or

foliar treatment for these insects. If whiteflies are a problem in the nursery, we recommend that tomato seedlings be covered with a net, 60-mesh or finer, to prevent insect infestation.

Transplanting

Harden the seedlings by slightly reducing water and exposing them directly to sunlight 6–9 days before transplanting. Thoroughly water the seedlings about 12 hours before transplanting to the field. A good seedling is in the four- or five-leaf stage (about 4 weeks old), vigorous and stocky (Figure 2).

Transplant in the late afternoon or on a cloudy day to minimize transplant shock. Insert the seedling in a hole so the cotyledons are above the surface. Tall, thin (spindly) seedlings should be buried deeper. Press soil firmly around the root, and water around the base of the plant to settle the soil. Irrigate the field as soon as possible after transplanting.

Plant spacing depends upon cropping system, soil type, and plant habit. At AVRDC we establish two rows per 1-m-wide bed (60 cm between rows) and 40 cm between plants within the row for indeterminate varieties (pruned) for a plant density of 33,333 plants/ha. For determinate varieties (not pruned) we establish one row per bed with 40 cm between plants (16,666 plants/ha).

Figure 2. Spindly and healthy seedlings.

Field preparation

Shaping the land into beds and growing tomatoes on top of the bed facilitates furrow irrigation of the crop and drainage after heavy rain. Beds can be prepared in many ways. At AVRDC, beds are made with a mechanical bed shaper and are about 1 m wide with furrows (ditches) 50 cm wide. Bed height varies with the season: 20 cm in the dry season and 35 cm in the wet season.

A mulch of rice straw, thin polyethylene plastic sheets, or other material is used to cover the soil surface. Mulches reduce fertilizer leaching, conserve moisture, and reduce weeds. If average air temperatures exceed 28°C, plastic mulch should be covered with rice straw to prevent it from getting too hot.

Nutrient management

Tomato plants should be fertilized with organic (animal manure) and/or chemical fertilizers to produce high yields. The total N (kg/ha) required to achieve a target fruit yield is estimated by multiplying the target yield (t/ha) by 2.4. Requirements (kg/ha) of P_20_5 and K_2O are estimated by multiplying N uptake by 0.35 and 1.45, respectively.

For example, for a potential tomato yield of 40 t/ha, you need 40 × 2.4 = 96 kg of N. For P_2O_5 and K_2O, multiply the N requirement of 96 × 0.35 = 34 kg P_2O_5, and 96 × 1.45 = 140 kg K_2O.

The amount of NPK already in the soil can be estimated by a laboratory soil test. Addition of fertilizer is needed to make up the difference between the NPK requirement for the target yield and the NPK available in the soil. However, fertilizer uptake efficiency by a crop is highly variable and depends upon many factors, including fertilizer form and placement (surface versus incorporated versus banded), as well as irrigation and other management practices.

In the tropics, common fertilizer application rates are 60–120 kg N/ha, 60–140 kg P_2O_5/ha, and 60–120 kg K_2O/ha. It is recommended that half of the

fertilizer be applied as a basal dose and the remaining fertilizer be added at first fruit-set.

Water management

Insufficient water at any growth stage will reduce yield and fruit quality. Tomato is most sensitive to water deficit during flowering, somewhat sensitive immediately after transplanting and during fruit development, and least sensitive during vegetative growth. Because indeterminate varieties flower and form fruit continuously, they are always sensitive to water deficits.

Tomato grows well in moist but not soggy soil, and well-timed furrow or drip irrigation is effective. Wilting in the late morning indicates that the crop should be irrigated.

As a general rule in the dry season, irrigate weekly for the first month after transplanting, and then every 10 days until crop completion. The root zone of young transplants is shallow so irrigation should be frequent and just enough to recharge the root zone. As the crop develops, the root zone enlarges and less frequent but heavier irrigation is required. Tomato plants are sensitive to waterlogging and flooded fields should be drained within 1–3 days.

Staking

Staking or trellising tomato plants with bamboo poles, wood stakes, or other sturdy material provides support and keeps the fruit and foliage off the ground. Staking can increase fruit yield and size, reduce fruit rot, and make spraying and harvesting easier.

Indeterminate varieties should be staked to facilitate pruning, pinching, harvesting, and other cultural practices. Determinate varieties should be staked in the wet season to prevent fruit contact with the soil.

Many staking arrangements are possible (Figure 3). Plants should be fixed securely to the stake or string supports, beginning about two weeks after transplanting. Rice straw, plastic strips, horticultural fixing tape, or other material can be used for fixing. Fixing should be done so fruit clusters are supported.

Pruning

Pruning (selective removal of side shoots to limit plant growth) can cause fruit to mature earlier and grow to greater size and uniformity. Pruning improves air circulation within the canopy, which reduces foliar diseases, and facilitates spraying and harvesting. Indeterminate varieties should always be pruned so that they do not produce too much vegetative growth. The degree of pruning varies according to the season (see AVRDC Cooperators' Guide, *Pruning and Staking Tomatoes*).

At AVRDC, we prune indeterminate plants to one stem during the cool-dry season and maintain two branches per plant (main branch and second branch below the first fruit cluster) during the hot-wet or hot-dry seasons. Two branches provide more shade to the fruit, and thereby reduce sunburn and blotchy ripening. If the market prices are higher for larger fruit, it is possible to increase fruit size by keeping four fruits per cluster and pinching off extra flowers.

Weed control

Weeds should be controlled in tomato crops because they compete for light, water, and nutrients. Sometimes they host tomato diseases, such as tomato yellow leaf curl virus. Mulches suppress weed growth on the beds. Remove weeds from furrows by pulling or hoeing.

Disease/insect control

Suggestions for control of selected tomato disease/insect problems in the tropics and subtropics are presented in Table 1. We recommend that you regularly scout your fields and properly identify disease and insect problems before taking control measures.

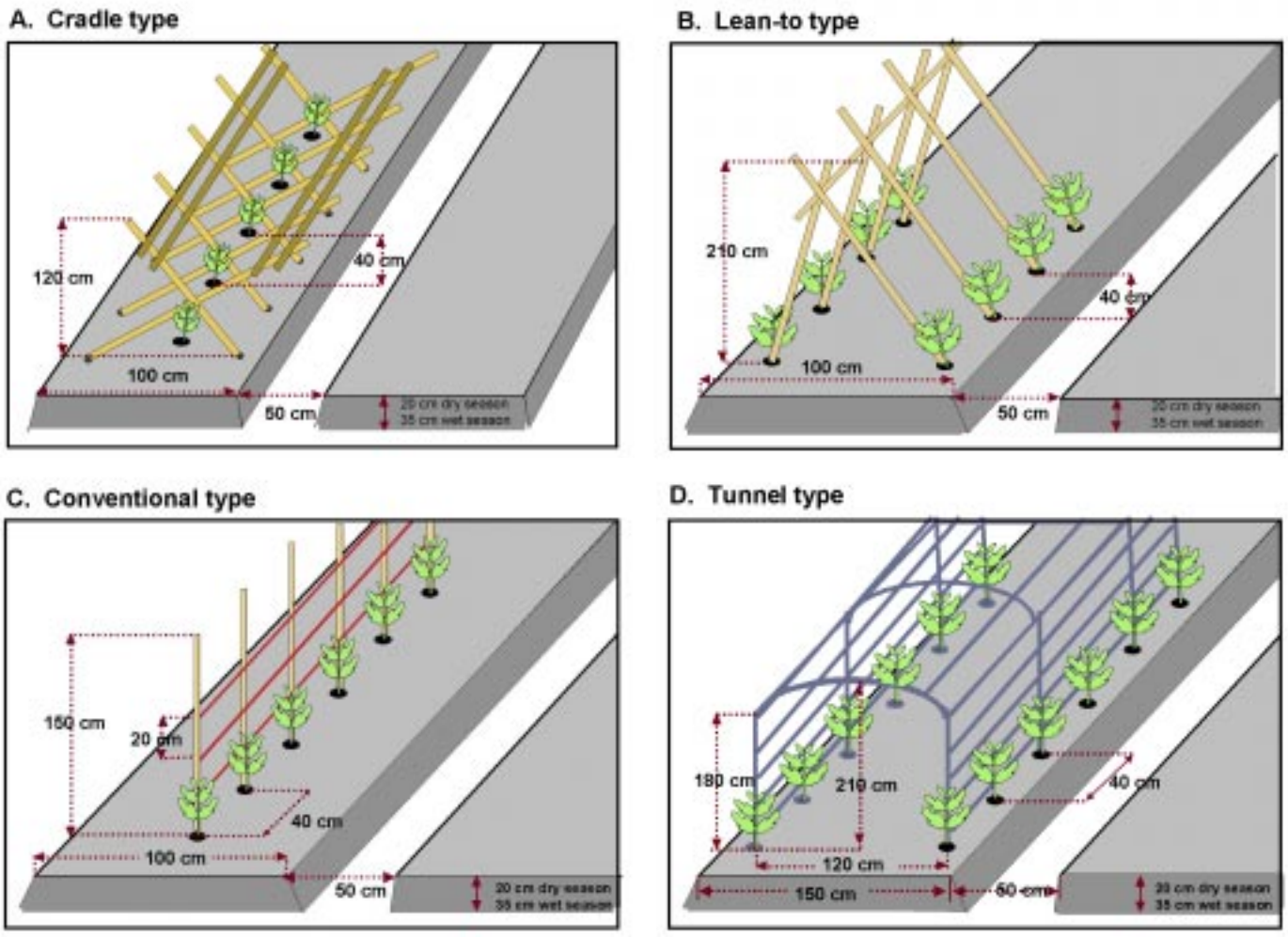

Figure 3. Tomato trellising arrangements

If you use a pesticide, make sure that it is effective for the disease or insect problem in your field, and that it is registered in your country for use on tomato.

Carefully read the label and apply recommended spray rates at recommended intervals with accurately calibrated equipment. The label will also indicate the minimum time between last application and harvest. Excessive pesticide use can be dangerous to you and the environment.

Persons applying pesticides should wear protective clothing to reduce pesticide exposure through skin contact or inhalation.

Fruit-set growth regulator

High (exceeding 30°C) or low (below 10°C) temperatures will reduce tomato fruit-set. Under such conditions, application of growth regulators with trade names such as Tomatotone or Tomatolan can increase yields. In general, heat tolerant varieties respond best to growth regulators. If the above products are not available, growth regulator CPA (4-chlorophenoxyacetic acid) can be prepared (Table 2).

Prepare the growth regulator solution according to the instructions on the label. Pour it into a spray bottle. Over the nozzle, fit a paper cup large

Transmission	Appearance	Control
Late blight: *Phytophthora infestans*		
Promoted by cool, wet weather.	Large, irregular, greenish or water-soaked lesions on the leaves, stems and fruit. Rapid blighting of entire plant.	Fungicides such as Bravo (chlorothalonil), Dithane (mancozeb); copper compounds, premixes of these with Ridomil Gold (mefenoxam), or Quadris (azoxystrobin); some resistant varieties available; destruction of infected tomato or potato debris; avoid planting near potato fields or in fields previously planted in potato.
Bacterial spot: *Xanthomonas campestris* pv. *vesicatoria*		
Spread by rain-splash or sprinkler irrigation; favored by warm and wet conditions; seed transmitted.	Small, water-soaked lesions on leaves and stems that turn dark and often are surrounded by yellow ring; raised black or brown specks on fruit, sometimes surrounded by white ring.	Copper compounds and copper compound tank mixes with mancozeb; keep seedbeds separated from production fields; use mulches to reduce rain splashing; furrow irrigation; removal of infected crop debris.
Early blight: *Alternaria solani*		
Promoted by warm, wet conditions and heavy dews.	Older lesions are concentric rings that resemble a target. Found on leaves, stems or fruit.	Fungicides such as Bravo (chlorothalonil), Dithane (mancozeb) or Quadris (azoxystrobin); destruction of infected plant debris; some tolerant varieties are available.
Gray leaf spot: *Stemphylium solani*		
Promoted by warm, wet weather and heavy dews.	Small, brownish-black foliar specks often found first on lower leaves; lesions become grayish-brown and often surrounded by yellow ring.	Resistant varieties available; fungicides such as Bravo (chlorothalonil) or Dithane (mancozeb).
Bacterial wilt: *Ralstonia* [formerly *Pseudomonas*] *solanacearum*		
Soil-borne; promoted by warm weather and wet soils.	Wilting of lower leaves and eventually entire plant; no foliar yellowing; sliced stems placed in water produce a milky ooze.	No effective chemical control; choose tolerant varieties; good soil drainage; soil pH of 5.5 and above; avoid nematode-infested fields; grow tomato after paddy rice.

Transmission	Appearance	Control
Southern blight: *Sclerotium rolfsii*		
Soil-borne; promoted by warm, wet conditions.	Rapid plant wilting with no foliar yellowing; white fungal growth often present on stem at soil line.	Delay planting until green manure has decomposed; fungicides such as Terraclor F (PCNB); good soil drainage; keep bed surface dry; grow tomato after paddy rice or corn.
Fusarium wilt: *Fusarium oxysporum* f. sp. *lycopersici*		
Soil-borne; promoted by warm conditions; three races of the pathogen reported.	Foliar yellowing usually starting on lower leaves, often on one side of the branch; vascular discoloration; wilted plants.	No effective chemical control; use resistant varieties; good soil drainage; keep bed surface as dry as possible; grow tomato after paddy rice.
Tomato Yellow Leaf Curl Virus (TYLCV)		
Spread by whiteflies *(Bemisia tabaci)*.	Stunting, yellowing, and cupping of leaflets; erect branching.	Tolerant varieties; 60-day crop-free period between old infected crop and new crop; before transplanting, cover seedlings with 60-mesh nets to keep whiteflies off plants; insecticides such as Confidor/Admire (imidacloprid) or Asana (esfenvalerate); rotate insecticides to reduce build-up of insecticide-tolerant whiteflies.
Tomato fruitworm: *Helicoverpa armigera*		
Young caterpillars have prominent rows of dark bumps on back; older caterpillars are dark gray to light brown and have lengthwise stripes on the body.	Small, darkened holes at base of fruit pedicel, often under the calyx.	Insecticides such as Guthion (azinphos-methyl), Javelin *(Bacillus thuringiensis)*, Lannate (methomyl), Asana (esfenvalerate), or pyrethrins; insecticides are effective against eggs and young caterpillars before fruit entry.
Root-knot nematodes: *Meloidogyne incognita, M. javanica, M. arenaria*		
Root-knot nematodes live in soil and attack roots of many kinds of plants; promoted by sandy soils and warm temperatures.	Aboveground symptoms include stunting, wilting, and yellowing; roots develop large knots (galls).	Resistant varieties; fallow plowing; rotation with paddy rice.

For more information on tomato diseases, please refer to: Blancard, D. 1994. A Colour Atlas of Tomato Diseases: Observation, Identification, and Control. Manson Publishing, London, U.K.; Jones, J.B., Jones, J.P., Stall, R.E., and Zitter, T.A. 1993. Compendium of Tomato Diseases. APS Press, USA.

Figure 4. Treating flower cluster with CPA

enough to enclose the flower cluster. Clusters are treated when 3–5 flowers have opened (Figure 4). Fit the cup over the cluster and apply one squirt. Direct the spray toward the calyx, not inside the flowers.

Treat each cluster only once; multiple applications to the same cluster can cause fruit deformities. Avoid spray drift to the foliage. Once diluted, the growth regulator lasts a maximum of four weeks if refrigerated, but it is best to use it within one week.

Harvest

Tomato can be harvested at different stages, depending upon the time needed to market the fruit. For long distance transport, fruit can be harvested at the *breaker stage* (not more than 10% of the surface is tannish-yellow, pink, or red). Fruit for local sale can be harvested at later ripening stages.

Poor care of fruit after harvest will lead to poor fruit quality. Avoid fruit injury and do not mix damaged and undamaged fruit. Harvest during cool periods, such as late afternoon or early morning. Shade the harvested fruit and avoid exposing fruit to temperatures above 25°C. If possible, store the fruit in a ventilated place with a relative humidity of 85–90% to slow water loss.

Table 2. Preparation of CPA solution

1. Purchase CPA from Sigma or another chemical supply company.

2. Dissolve 1.5 g CPA in 100 ml of distilled water and shake until dissolved.

3. Add more distilled water until the total solution is 1000 ml. This results in 0.15% or 1500 parts per million (ppm) CPA "stock solution." The stock solution should be refrigerated until use.

4. CPA concentration can range from 15 to 75 ppm. Optimal CPA concentrations depend on variety, growing environment, and cultural practices. Generally, extreme temperatures require higher concentrations of CPA.

5. Just before CPA application to flowers, dilute the stock solution as follows:

   For 15 ppm CPA, dilute 10 ml of the stock solution with 990 ml of distilled water. Add 0.2 ml of Tween 20 (surfactant that helps CPA adhere to the flower).

   For 30 ppm CPA, dilute 20 ml of the stock solution with 980 ml of distilled water. Add 0.2 ml of Tween 20.

   For 75 ppm CPA, dilute 50 ml of the stock solution with 950 ml of distilled water. Add 0.2 ml of Tween 20.