AVRDC

International Cooperators' Guide

November 1999
AVRDC pub # 99-497

Suggested Cultural Practices for Field Cultivation of Sweet Peppers

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These suggestions were developed for the specific conditions at the Asian Vegetable Research and Development Center (AVRDC) in the Taiwan lowlands (latitude 23° 7' N, elevation 8 m above sea level). You might need to revise these cultural practices to fit your local environment.

Climate and soil requirements

Sweet peppers grow best between 21 and 24°C. When temperatures fall below 18°C or exceed 27°C for extended periods, growth and yield are usually decreased. Sweet peppers can tolerate daytime temperatures over 30°C, as long as night temperatures are within 21–24°C. Sweet peppers are photoperiod- and humidity-insensitive (day length and relative humidity do not affect flowering or fruit set). They grow best in a loam or silty-loam soil with good water-holding capacity. But they can grow on many soil types, as long as the soil is well drained. Soil pH should be between 5.5 and 6.8.

Choosing a variety

Sweet pepper yields vary widely depending on variety. So begin by comparing the yield potential of currently grown varieties with the yield potential of the best new varieties. Make sure, however, that the test plots were handled the way you intend to grow your crop.

Compare the total agronomic package. On clay soils, for instance, Phytophthora blight might be more yield limiting than potato virus Y (PVY), so a PVY-resistant variety lacking blight resistance would likely be a poor choice.

Growing peppers in a different season or under a different rotation system might provide higher yields and/or higher prices. Relay or intercropping might provide extra income from the same piece of land, and reduce insect and disease problems. Calculate potential returns, and choose the variety and cropping system that serve you best.

Seed treatment

The primary seed-borne fungal pathogens are *Colletotrichum* spp., the causal agents of anthracnose. To minimize seed transmission, soak seeds in warm water (50°C) for 30 min or soak them in 1.25% (v/v) Clorox for 30 min, and rinse in cold water. Apply a fungicide seed coating, such as 1 g of Benomyl 20% active ingredient (AI) wettable powder (WP) and 1 g Thiram 20% AI WP (or 0.8 g of Benlate [a mixture of Benomyl and Thiram] 50% AI WP) in 400 ml of water, so that the final concentration is 0.1% AI. Coat the seeds thoroughly by mixing 1 g of seeds with 1 ml of the fungicide mixture. Seeds may be dried at 20°C and 40% relative humidity or sown immediately. The fungicide protects young seedlings from damping off pathogens, such as Rhizoctonia, Pythium, and Fusarium spp. Captan can be substituted for Benomyl.

The primary seed-borne viral pathogens are tobamoviruses, including tobacco mosaic virus (TMV), tomato mosaic virus (ToMV), and pepper mild mottle virus (PMMV). To minimize seed transmission, soak 2 g of seeds in 10% (w/v) trisodium phosphate (TSP) ($Na_3PO_4 \cdot 12\ H_2O$) for 30 min, transfer them to a fresh 10% TSP solution for 2 hours, then rinse in running water for 45 min. This treatment can be done on freshly harvested or dry seeds. Or soak seeds for 4–6 hours in 5% (v/v) hydrochloric acid, then rinse in running water for 1 hour.

The primary seed-borne bacterial pathogen is *Xanthomonas campestris* pv. *vesicatoria* (Xcv), the causal agent of bacterial spot. To minimize Xcv infection, soak 2 g of seeds in 10 ml of 1.3% (v/v) acetic acid (shake occasionally) for 4 hours, rinse the seeds with water three times, soak the seeds in 1.25% (v/v) Clorox for 5 min, and rinse under running water for 15 min. Or soak seeds in warm water (50°C) for 30 min, then dry them or sow immediately.

If you don't know what pathogens, if any, are on your seeds, then soaking in TSP followed by coating with Benlate (see instructions for application above) is a good general-purpose seed treatment. This should not affect germination. Pathogen-free seeds sown in sterile soil require no treatment.

Seedling production

Times from sowing to plant emergence at different soil temperatures are shown in Table 1. Germination varies depending on variety, seed quality, and soil mixture. For optimum germination, sow seeds in well-drained, sterile vermiculite at 28°C. Water daily.

Table 1. Influence of soil temperature on length of time to plant emergence

Temperature (°C)	Days after sowing
<15	No germination
15	25
20	13
25–35	8
>35	No germination

Source: Knott's Handbook for Vegetable Growers, 1997, p. 96.

One gram contains approximately 160 seeds. Approximately 206 g are needed to plant 1 ha at a density of 26,670 plants/ha, assuming 90% germination and 90% survival after transplanting. Fill the seedling tray with sowing medium, such as peat moss, commercial potting soil, or a potting mix prepared from soil, compost, rice hulls, vermiculite, peat moss, and/or sand. The potting mix should have good water-holding capacity and good drainage. We recommend a mixture of 66% peat moss and 34% coarse vermiculite. If you use non-sterile components, we recommend that you sterilize your potting mixture by autoclaving or baking at 150°C for 2 hours. If seedlings are started in a raised soil bed, the soil should be sterilized by burning a 3- to 5-cm thick layer of rice straw or other dry organic matter on the bed. This also adds minor amounts of P and K to the soil, which helps establish the seedlings.

Sow one seed per cell (or broadcast the seeds lightly in a seedbed) and cover 1 cm deep. Cover the seedlings with an insect-proof net, or sow them inside a greenhouse or screenhouse. This provides shade and protects seedlings from heavy rain and pests, such as aphids, which transmit viruses. Water the seedlings thoroughly every morning or as needed (not too wet, not too dry), using a fine sprinkler. Irrigate with a 0.25% (w/v) solution of water-soluble or liquid fertilizer (10-10-10) when two true leaves appear. If damping-off occurs, irrigate with a 0.25% (w/v) solution of Benlate or a similar fungicide.

If the seedlings have been grown in shade, harden them off by gradually exposing them to direct sunlight over 4–5 days prior to transplanting. On day one, expose them to 3–4 hours of direct sunlight. Increase the duration until they receive full sun on day four.

Transplanting

Recommended spacing varies depending on cropping system, soil type, and variety. AVRDC uses 1.5-m wide beds (furrow to furrow), 30 cm high. We transplant two rows per bed. Rows are 50 cm apart, with 50 cm between plants within rows, for a plant population density of 26,670 plants/ha. Place three or four granules of carbofuran (Furadan 5G) in each hole just prior to transplanting, to guard against insect attack. Solarizing or flooding the soil prior to transplanting can reduce the number of harmful organisms.

Under good conditions, seedlings are ready for transplanting four weeks after sowing. The ideal seedling has 4–5 true leaves, is disease-free, stocky, and has no flowers. Transplant in the late afternoon or on a cloudy day to minimize transplant shock. Bury each plant to half its total height (root to tip), and irrigate immediately after transplanting to establish good root-to-soil contact. Transplanting can be done manually or by machine. AVRDC uses a Blue Line 2000 transplanter from Kennco Mfg., Florida. A five-person team can transplant 2500 plants/hr.

Fertilization

Nutrient requirements for a target yield of 28 t/ha (fresh weight) are listed in Table 2. Forty percent of the N should be applied as basal fertilizer before transplanting. The remaining 60% should be side-dressed in three equal amounts at 2, 4, and 6 weeks after transplanting (WAT). Fifty percent of the P and K should be applied as basal fertilizer, and the remaining 50% should be side-dressed at 4 WAT.

The amount of fertilizer to apply depends on soil fertility, fertilizer recovery rate, soil organic matter, soil mineralization of N, and soil leaching of N. A soil test is highly recommended to determine the available N, P, and K. The amount to be applied can then be calculated based on your target yield and adjusted for residual nutrients. For example, if the target yield is 14 t/ha and the soil test indicates that 50 kg each of N, P, and K are available, you would need to apply about 38 kg N and 30 kg K. Fifteen kilograms N and 15 kg K would be applied as basal fertilizer, and the remaining N would be side-dressed at the rate of about 7.5 kg/ha at 2, 4, and 6 WAT; the remaining 15 kg/ha K would be side-dressed at 4 WAT.

Compost and/or green manure crops help increase soil organic matter content, which increases the soil's buffering capacity. Applying fertilizer through a drip irrigation system is beneficial because it helps sweet peppers maintain constant growth.

Fertilizer recommendations depend heavily on local conditions, so consult your fertility management specialist for recommendations. Or conduct your own fertilizer trials to determine optimum rate. Refer to “Determining Fertilizer Rates for Crops in Cropping Systems" in *A Methodology for On-farm Cropping Systems Research*, published by the International Rice Research Institute (IRRI), Los Baños, Philippines (Web site: http://www.cgiar.org/irri/).

Field management

Mulching is recommended to reduce weed competition, soil compaction, and soil erosion, and to maintain a uniform root environment and conserve soil moisture. Use rice straw (5 t/ha) or other organic material, polyethylene plastic, or a combination of materials. Plastic mulch must be laid down before transplanting; organic mulches can be laid down before or after transplanting. If plastic mulch is used, holes are cut in the plastic and plants are set directly into the holes. During hot weather (>25°C nighttime temperature), cover plastic mulch with straw to reduce temperature in the root zone. Or irrigate and drain the field frequently to keep temperatures down.

Most sweet pepper varieties require staking to prevent lodging, particularly when they have a heavy load of fruits.

Table 2. N, P, and K requirements, expected recovery rate, and total amount to apply for a target yield of 28 t/ha (fresh weight) of sweet pepper

	Nutrient requirement (kg/ha)	Nutrient recovery (%)	Amount needed* (kg/ha)
N	70	40	175
P	10	10	100
K	80	50	160

* Assuming no nutrients are available in the soil; the actual amount of fertilizer applied should be adjusted downward based on the soil test results.

Sweet peppers are fairly shallow-rooted and have low tolerance to drought or flooding. They will generally wilt and die if they stand in water for very long, so drain fields quickly after heavy rain.

Crop water use will be relatively high when evaporation is high and when the crop is flowering and setting fruit. If rainfall does not provide sufficient moisture, irrigate when the field reaches 40–50% available soil moisture. (To gauge soil moisture content, take a handful of soil from the bottom of a six-inch deep hole. Squeeze the soil. If it holds together when you release your grip, then there is sufficient soil moisture. If the soil crumbles, then it's time to irrigate.) Thorough irrigation provides uniform soil moisture, essential for optimum plant and fruit growth. Over-irrigation stimulates the growth of Phytophthora blight. Furrow or drip irrigation are recommended; sprinkler irrigation should be avoided as wet leaves and fruits promote disease development. If overhead irrigation must be used, avoid late evening irrigation. Leaves should be dry before nightfall.

If mulch is not available, or does not provide adequate weed control, several herbicides are available, such as Lasso (alachlor 43EC), Amex (butralin 47EC), Devrinol (napropamide 2E or 10G), and Dual (metolachlor 8E or 25G). Hand or hoe weeding can be performed as needed. At AVRDC, we spray 0.4% (v/v) Lasso 43EC around the base of the plants 2–3 days after transplanting, and then we spray Roundup (glyphosate) to control weeds in the furrows later in the season. Care must be taken that Roundup does not drift to the pepper plants. The best type of herbicide, rate, and method and date of application will vary depending on weed species, soil type, and temperature at time of application.

Integrated pest management (IPM) should be followed as much as possible. IPM can have many components, including good hygiene, field scouting, mechanical control, cultural practices, biological control, and chemical control. See Table 3 for recommended IPM options for common diseases and insects.

Use high quality, pathogen-free seeds and/or seedlings, and remove diseased/dead leaves and plants promptly. Practice good weed control and be careful not to damage the crop. If you have a disease outbreak in one part of the field, work in other areas of the field before working in the diseased area. To restrict the spread of tobamoviruses, dip your hands and tools in milk before handling pepper plants. Be aware that irrigation water can carry pathogens, such as *Phytophthora capsici*. Mechanical control measures include the use of nets, polyethylene mulch, and other barriers to keep insects away from plants. Yellow and/or blue sticky traps can be used to catch aphids, thrips, and other insects.

Scout your fields at least twice a week, checking for pests and diseases. Count the incidence of pests and diseases on 60 plants chosen randomly in 0.1 ha. Decisions about spraying should be based on the economic threshold (ET) of damage, but such ET values are generally not available for the major pests and diseases that affect peppers. Consult your local entomologist and/or pathologist for specific pest control recommendations for your area.

Planting resistant varieties is the best way to control pests. Many commercial varieties carry resistance to one or more pests, but if no resistant variety is available, try sowing the crop when pest pressure is lowest, and use the proper plant density. High plant densities lead to thin, weak plants, which are more susceptible to diseases and insects. Prevent plants from being overloaded with fruits. Remove routinely all fruits that set at the first bifurcation node, and all leaves and branches below the first bifurcation node. This will promote vigorous plant growth and reduce the spread of foliar diseases. Crop rotation, particularly a rice–pepper rotation, helps reduce disease and insect problems. Sweet peppers should never follow other Solanaceous crops, such as potato (*Solanum tuberosum*) or tomato (*Lycopersicon esculentum*), because these crops share many common soil-borne diseases. Do not plant sweet peppers after sweet potatoes (*Ipomea batatas*), due to allelopathic effects.

Biological control is the control of pests and diseases by their natural enemies. Four groups of biological control organisms are commonly recognized: predators, parasites, microorganisms, and plant extracts and minerals. For more information on biological control of pepper pests and diseases, contact Koppert Biological Systems at http://www.koppert.nl/english/pest.htm. Plant extracts, such as neem seed extract and hot pepper extract, can be sprayed on young seedlings to help protect them from insects.

Chemical control of pests should be used mainly as a corrective measure. If possible, choose a pesticide that targets the specific insect that is causing the damage, and try to avoid pesticides that kill or inhibit the development or reproduction of beneficial organisms. And further safeguard beneficial insects by using selective application techniques, such as seed coating or application of systemic pesticides in the seedling nursery. Dusting any pesticide generally inhibits beneficial organisms, as does the addition of a wetter or spreader to a pesticide sprayer. Choose pesticides that have short persistence, i.e., the effects of which last only a few days. Chemical pesticides should be applied in the evening, and workers should not be allowed into the field until the recommended waiting period (usually 12 or 24 hours) has passed. Wear protective clothing and follow all label directions when applying pesticides. If multiple applications are needed to control a disease or insect problem, follow a pesticide rotation that includes at least three different modes-of-action.

Harvesting

Sweet peppers should be harvested when fruits reach full size (depending on variety, market, and environment) and become firm, but before turning color (unless they are intended for mature color: yellow, orange, or red). The fruits at the first and second nodes will be larger than subsequent fruits. It usually takes 35–40 days from flowering to optimum harvest stage, but the environment can affect this. Stems of pepper plants are very fragile, so use a knife to harvest fruits. To avoid mechanical transmission of tobamoviruses, dip knives routinely in a 3% (w/v) solution of TSP, or in milk.

For most sweet pepper varieties, production usually lasts 6–8 weeks (3–4 harvests as fruits ripen). In temperate regions, sweet pepper production is usually halted by frost at the end of the season. In tropical and subtropical regions, pepper production is usually halted by biotic and/or abiotic stresses.

Table 3. Common diseases and insects of sweet peppers in Asia with their Latin names along with mode of transmission, symptoms, and some suggested IPM methods

Transfer mode	Symptoms	Suggested IPM methods
Phytophthora blight: *Phytophthora capsici*		
Soil-borne; rain splash. Not transmitted by seed.	Damping off of young seedlings; root and crown rot; blight on leaves	Resistant varieties; raised beds; crop rotation; fungicides, such as metalaxyl and fixed copper
Anthracnose: *Colletotrichum* spp. (*acutatum, capsici, connoides, gloeosporioides*)		
Rain splash in warm, wet weather. Transmitted in and on seeds.	Water-soaked spots (on fruits) expand to become dark and depressed concentric rings	Pathogen-free seed; rotation; fungicides, such as chlorothalonil or mancozeb; furrow irrigation
Bacterial spot: *Xanthomonas campestris* pv. *vesicatoria*		
Rain splash; dew condensation. Transmitted in and on seeds.	Irregular, light-brown, water-soaked lesions (on leaves) with thin white borders; defoliation	Resistant varieties; pathogen-free seeds/seedlings; spray mixture of mancozeb and fixed copper
Bacterial wilt: *Ralstonia solanacearum*		
Soil-borne. Not transmitted by seeds.	Leaves turn yellow, wilt, and drop off. (When put in water, cut stems ooze milky streams of bacteria.)	Resistant varieties; good soil drainage and raised beds; rotation with non-host crops, such as rice
Chili veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), potato virus Y (PVY)		
Aphids. Not transmitted by seeds.	Mosaic and mottled leaves; leaf deformation (Symptoms vary.)	Resistant varieties; weed control; pesticides to control aphids; nets to protect seedlings
Tobamoviruses		
Contact. Transmitted in and on seeds.	Leaf mosaic; stunted plants; systemic bleaching of leaves	Resistant varieties; pathogen-free seeds; dip tools and hands in milk or TSP prior to handling plants
Aphids: *Aphis gossypii, Myzus persicae*		
Flight; wind	Leaf distortion and mottling; chlorotic leaf spots; black sooty mold	Reflective mulches; rotation; predators and parasites; pesticide sprays, such as pirimicarb 50DP
Thrips: *Scirtothrips dorsalis, Thrips palmi*		
Flight; wind	Young leaves curl upwards; fruits netted with cork-like streaks	Weed control; crop rotation; predators and parasites; rotate insecticides
Mites: *Polyphagotarsonemus latus*		
Flight; wind	Leaves curl downwards; growing point and young leaves are bronzed and stunted; cork-like fruits	Tolerant varieties; weed control; crop rotation; miticide sprays, such as abamectin and dicofol

For more information see "Pepper Diseases: A Field Guide" by LL Black, SK Green, L Hartman, and JM Poulos, published by AVRDC in 1991