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Suggested Cultural Practices for Chili Pepper

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Introduction

Chili pepper (*Capsicum annuum*) is a popular vegetable valued around the world for the color, flavor, spice, and nutritional value it contributes to many meals (Fig. 1). Pepper varieties display a wide range of plant and fruit traits, and production practices vary greatly from region to region.

The following recommendations were developed at AVRDC in the Taiwan lowlands. Modifications may be needed to take into account different soils, weather, pests and diseases.

Fig. 1. Chili pepper

Climate and soil requirements

Chili pepper is better adapted to hot weather than is sweet pepper, but it does not set fruit well when night temperatures are greater than 24°C. Optimum day temperatures for chili pepper growth range from 20 to 30°C. When the temperature falls below 15°C or exceeds 32°C for extended periods, growth and yield are usually reduced. Peppers are photoperiod-insensitive (daylength does not affect flowering or fruit set).

Chili pepper grows best in a loam or silt loam soil with good water-holding capacity, but 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 cultivar

Chili pepper yields vary widely depending on cultivar and season. It's important to consider fruit quality, especially consumer preferences for the shape, color and degree of pungency of fruits. Also consider local pest and disease pressures, genetic resistance to these local diseases, heat and drought tolerance, vine vigor, and seed costs.

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. Growers should calculate potential returns, and choose the cultivar and cropping system that serves them best.

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Treating seed

The primary seed-borne fungal pathogens are surface saprophytes such as *Fusarium* spp., *Pythium* spp., *Rhizoctonia solani, and Colletotrichum* spp. To minimize seed transmission, soak seeds in warm water (50°C) for 30 minutes, rinse them in cold water, and dry them before sowing. Apply a fungicide seed coating, such as 1 g of Benomyl 20% active ingredient (a.i.) wettable powder (WP) and 1 g Thiram 20% a.i. WP (or 0.8 g of Benlate [a mixture of Benomyl and Thiram] 50% a.i. WP) in 400 ml of water, so that the final concentration is 0.1% a.i.. Coat the seeds thoroughly by mixing 1 g of seeds with 1 ml of the fungicide suspension. Seeds may be dried at 20°C and 40% relative humidity or sown immediately.

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 ml of 10% (w/v) trisodium phosphate (TSP) ($Na_3PO_4 \bullet 12\ H_2O$) for 30 min, transfer them to a fresh 10% TSP solution for 2 hours, then rinse in running water for 45 minutes. 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. Dry them for storage, or sow immediately.

The primary seed-borne bacterial pathogen is *Xanthomonas campestris* pv. *vesicatoria* (Xcv). 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 minutes, and rinse under running water for 15 minutes. Or soak seeds in warm water (50°C) for 30 minutes, then dry or sow immediately. Pathogen-free seeds sown in sterile soil require no treatment.

Raising transplants

Germination varies depending on variety, seed quality, and soil mixture. For optimum germination, sow seeds in a well-drained, sterile soilless mix at 25–28°C, and water daily. Under these conditions, seeds will germinate in about eight days. Seeds will germinate in 13 days at 20°C and 25 days at 15°C; they may not germinate at all if temperatures are below 15 or above 35°C.

One gram contains approximately 220 seeds. Approximately 150 g may be needed to transplant 1 ha at a density of 30,000 plants/ha, assuming 90% germination and 90% of seedlings are of good quality.

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 67% peat moss and 33% 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 sanitized by burning a 5-cm thick layer of rice straw or other dry organic matter on the bed. This also adds small amounts of P and K to the soil for 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 (Fig. 2), 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. Upon emergence, 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 similar fungicide.

Fig. 2. Seedlings growing under mesh net

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

Field preparation

The soil where chili peppers are to be grown should be carefully selected and prepared for the crop. Crop rotations should avoid sequences in which peppers are planted immediately following another Solanaceous crop such as tomato, eggplant, or potato. A preceding paddy rice crop is often helpful in that the flooded soil is depleted of many soil-borne pathogens and weed seeds. Addition of compost, animal manures, or green manures can boost the soil's organic matter content and improve the soil's nutrient buffering capacity. The soil should be loosened as deeply as practical, and fitted into beds according to local practices. Raised bed plantings are especially useful during raining periods; they improve the aeration of the pepper's roots and minimize losses due to root diseases and flooding.

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 55 cm apart, with 45 cm between plants within rows, for a plant population density of 29,630 plants/ha. Place three or four granules of carbofuran (Furadan 5G) in each hole just prior to transplanting to guard against the attack of cutworms and other insects. Under good conditions, seedlings are ready for transplanting four to five weeks after sowing. The ideal seedling has 4–5 true leaves, is disease-free, stocky, and has no flowers.

Bare-root seedlings are lifted from the seedbed by loosening the soil with a spading fork, and carefully separating the roots from the surrounding soil, discarding damaged or inferior plants, and binding into convenient bundles for transport to the field (Fig. 3). The seedlings should be kept cool, moist, and shaded between the lifting and transplanting tasks.

Fig. 3. Growers carefully remove bare root seedlings for transplanting (above); close-up of seedlings (right)

Transplant in the late afternoon or on a cloudy day to minimize transplant shock. Bury each plant to the level of the cotyledons or first true leaves and irrigate immediately to establish good root-to-soil contact. Transplanting can be done manually or by machine.

Fertilizing

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 2.5 t/ha and the soil test indicates that 100 kg each of N, P, and K are available, you would need to apply about 125 kg N, 10 kg P, and 10 kg K.

Nutrient requirements for a target yield of 5 t/ha (dry matter basis) are listed in Table 1. 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). Half of the P and K should be applied as basal fertilizer, and the remainder should be sidedressed at 4 WAT.

Fertilizer recommendations depend heavily on local conditions. Minor nutrient deficiencies, e.g. zinc, iron and calcium may also be factors in some localities. Consult your fertility management specialist for recommendations or conduct your own fertilizer trials to determine optimum rates.

Table 1. N,P, and K requirements, expected recovery rate, and total amount to apply for a target yield of 5 t/ha of dried chili peppers

Nutrient	Nutrient requirement (kg/ha)	Nutrient recovery (%)	Amount needed[z] (kg/ha)
N	180	40	450
P	22	10	220
K	200	50	400

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

Mulching

Mulching is recommended to reduce weed competition, soil compaction, and soil erosion. Mulching also maintains a uniform root environment and conserves 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 (Fig. 4); 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. Reflective mulches will build up less heat in the soil than black plastic mulch and also provide some protection from aphids. 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.

Fig. 4. Raised beds are formed and plastic mulch is laid in preparation for planting

Irrigating

Pepper plants are fairly shallow-rooted and have low tolerance to drought or flooding. Fields should be irrigated if there are signs of wilting at midday. Thorough irrigation provides uniform soil moisture, essential for optimum plant and fruit growth. Furrow or drip irrigation are recommended; overhead irrigation should be avoided as wet leaves and fruits promote disease development. If overhead irrigation must be used, apply early in the day so that leaves are dry before nightfall.

Pepper plants cannot tolerate flooding and fields should be drained quickly after heavy rain. Pepper plants will generally wilt and die if they stand in water for more than 48 hours. Phytophthora blight and bacterial wilt may cause total crop loss following prolonged flooding.

Controlling weeds

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).

Manual weeding can be performed as needed. At AVRDC, we spray 0.4% (v/v) Lasso 43EC at the base of the plants 2–3 days after transplanting, and then 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 herbicide, rate, and method of application will vary depending on weed species, soil type, and temperature at time of application. Consult with your local extension office for their recommendations.

Staking

Plants may be staked to prevent lodging, particularly when they have a heavy load of fruits. Each plant is individually staked before flowering stage (Fig. 5). Yields are generally higher with staking. Other staking and training techniques may be used based on local experience.

Fig. 5. Staked planting

Controlling diseases

General recommendations

Use high quality, pathogen-free seeds and/or seedlings, and remove diseased leaves and seedlings promptly. Control weeds regularly. 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*.

Use resistant cultivars, if available. If no resistant cultivar is available, try sowing the crop when pathogen pressure is lowest, and use the proper plant density, both in seedling production beds and in the transplanted field. High plant densities lead to weak plants, which are more susceptible to diseases.

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. Peppers should never follow other Solanaceous crops, such as potato (*Solanum tuberosum*) or tomato (*Lycopersicon esculentum*), because these crops share many soil-borne diseases. Do not plant peppers after sweet potatoes (*Ipomea batatas*), due to allelopathic effects. The following are some of the most common diseases on chili pepper:

Anthracnose (*Collectotrichum* spp.)

Anthracnose may occur in the field or develop as a post-harvest decay of pepper fruits. Typically, symptoms first appear on mature fruits as small, watersoaked, sunken lesions that rapidly expand. The lesions may increase to 3–4 cm in diameter on large fruits (Fig. 6). Fully expanded lesions are sunken and range from dark red to light tan. The disease may occur wherever pepper is grown under overhead irrigation or rainfed conditions. The pathogens can be seed-borne in pepper and persist in crop debris. They have a wide host range.

To control anthracnose, use pathogen-free seed and rotate crops. Fungicides can reduce losses. Since symptoms usually occur on mature fruit, harvest and utilize fruit in the immature green stage, or harvest mature fruit frequently and process quickly.

Fig. 6. Anthracnose lesions on mature fruit

Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*)

Small watersoaked spots on leaves become necrotic with yellow borders (Fig. 7a). The lesions may be sunken on the upper surface and raised on the lower surface. Heavily infected leaves may turn yellow and drop, resulting in severe defoliation. Dark, raised lesions have a corky or wart-like appearance on fruits (Fig. 7b). Elongated necrotic spots or streaks appear on stems and petioles. This disease is seedborne and can survive in crop debris from infected plants. Many strains attack both tomato and pepper. The disease is enhanced by overhead watering, heavy dew formation, and high temperatures.

To control this disease, rotate pepper with cereals and other non-susceptible crops. Use pathogen-free seed and transplants. Resistant cultivars are becoming available, but may not be resistant to all strains of the disease. Sprays of copper or copper + maneb will reduce damage. Rain shelters may reduce the severity of disease during rainy periods.

Fig.7. Bacterial spot lesions on leaf and fruit

Bacterial wilt (*Ralstonia solanacearum*)

The initial symptom is wilting of lower leaves (or upper leaves of seedlings) followed by a sudden and permanent wilt of the entire plant without yellowing (Fig. 8a). Vascular browning occurs (Fig. 8b) and cortical decay is sometimes evident near the soil line. Bacterial streaming from vascular elements occurs when cross sections of the lower stem are suspended in water. The disease affects over 200 different plant species. It is more severe on tomato, tobacco, potato and eggplant, but it can be very damaging to pepper. The bacterium survives in the soil for long periods. It gains entry through natural root wounds or wounds created by insects, nematodes or cultivation. High temperature and high soil moisture favor disease development.

To control bacterial wilt, use pathogen-free seedbeds to produce disease-free transplants. Fumigate seedbeds and pasteurize the planting medium for container-grown plants. Rotate with flooded rice; rotation with non-susceptible crops provides limited value. Avoid cultivation that damages roots. Use raised beds to facilitate drainage. Resistant cultivars are being developed.

Fig. 8. Healthy and bacterial wilt-infected plant; browning of inner vascular tissue

Cercospora leaf spot (*Cercospora capsici*)

Fig. 9. Cercospora "frog eye" lesions

Its "frog eye" leaf lesions are circular, about 1-cm in diameter, with brown borders and light gray centers (Fig. 9). Severe infection can cause leaf drop, with or without leaf yellowing. Lesions also appear on stems, petioles and peduncles; fruit do not become infected. The fungus survives from one season to another on crop debris. Extended rainy periods and close plant spacing enhance development. Fungicides are usually only necessary during conditions highly favorable to the disease.

Phytophthora blight (*Phytophthora capsici*)

This disease can occur on pepper grown anywhere in the world, at any stage of growth, and on all plant parts. The most common symptom is a stem or collar rot followed by sudden wilting without foliar yellowing (Fig. 10a). Other symptoms include damping-off and tip blight of young seedlings (Fig. 10b), dried tan-colored lesions on foliage, as well as softened fruit.

This soil-borne disease is controlled through the use of resistant cultivars, raised beds, crop rotation, and fungicides such as mefenoxan, metalayxl, potassium phosphate, copper alone, or copper-containing products. To avoid soil splash, the use of mulch and furrow irrigation, rather than overhead irrigation, are preferred.

Fig. 10. Phytophthora *lesion; healthy and blight-infested seedlings*

Aphid-transmitted viruses: Chili veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), potato virus Y (PVY)

Symptoms vary, but generally these diseases show mosaic, mottled and/or deformed leaves (Fig. 11). Plants are stunted and the loss of marketable yield can be dramatic. To control, use resistant cultivars. Reduce the number of aphid vectors by controlling weeds, using insecticides, and using mesh netting to exclude aphids from seedlings.

Fig.11. Mottling of leaves caused by PVY and ChiVMV, respectively.

Tobamoviruses: Tobacco mosaic virus (TMV), tomato mosaic virus (ToMV); and potato mild mottle virus (PMMV)

Fig. 12. Leaf crinkling caused by PMMV

These diseases are transmitted in and on seeds, as well as through contact of plants. Symptoms include stunting, leaf mosaic and crinkling (Fig. 12), and systemic bleaching of leaves. To minimize problems, use resistant varieties and pathogen-free seeds. Dip tools in milk or TSP before handling plants.

Controlling insect pests

General recommendations

Seedlings in the nursery can be protected using mesh netting or yellow sticky traps. After plants are in the field, scout plants at least twice a week, looking for damage. Plant extracts, such as neem seed or hot pepper extract, can be sprayed on seedlings to help protect them.

Chemical pesticides should be used mainly as a corrective measure. If possible, choose a pesticide that targets the specific pest that is causing the damage, and avoid pesticides that kill beneficial organisms. 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 label directions. If multiple applications are needed, rotate pesticides that have different modes-of-action.

Aphids (*Aphis gossypii, Myzus persicae*)

These are small, succulent, pear-shaped insects that vary in color from yellow to green to black (Fig. 13). Aphids pierce leaves and suck the sap, causing foliage to become distorted and often curled under. Aphids exude a sticky substance that attracts ants and leads to the development of a sooty mold on plants. Aphids are vectors to many viruses, including ChiVMV, CMV and PVY. Control aphids by using reflective mulches, rotating crops, spraying with pesticides, or introducing predators and parasites.

Fig. 13. Aphids (inset right) cause sooty mold and leaf distortion

Broad mite (*Polyphagotarsonemus latus*)

This tiny, crab-like pest (Fig. 14) causes leaves to curl *downwards* and become narrow. Most damage occurs between veins of young leaves. Corky tissue develops on fruits. Mites are yellow or white, tiny (about the size of a grain of sand), and found near the mid-vein on the undersides of the leaves.

This pest is controlled through the use of tolerant cultivars, weed control, crop rotation, and miticides such as abamectin and dicofol.

Fig. 14. Mites (inset right) cause leaves to curl downwards and corky tissue to develop on fruits

Thrips (*Scirtothrips dorsalis, Thrips palmi*)

Thrips cause young leaves to curl *upwards* (Fig. 15a). Brown areas develop between veins of both young and old leaves. Corky tissue develops on infested fruits. Thrips are very small and group together along the mid-vein (Fig. 15b) or along borders of damaged leaf tissues.

Reduce thrip damage by controlling weeds, rotating crops, using predators and parasites, and rotating insecticides.

Fig. 15. Thrips cause leaves to curl upwards; they are often found near the mid-vein of leaves.

Tomato fruitworm (*Helicoverpa armigera*)

Tomato fruitworm feeds on flowers, pods and fruits of pepper (Fig. 16). Larvae move from one fruit to the next, destroying only small portions of each fruit. Damaged fruits may drop, ripen prematurely, or become infected with disease. The entrance hole near the pedicel develops a dark scar. Monitor closely, looking for the larvae on plants; older larvae can be found by cutting into fruits. Young larvae are light yellow and spotted. Mature larvae are brown to gray in color with lengthwise stripes along the body.

Fig. 16. Fruitworm larva boring inside pepper

To control, spray insecticides to kill exposed larvae. Remove infested fruits to reduce pest populations.

Other disorder

Root-knot nematode (*Meloidogyne incognita* and other *Meloidogyne* spp.)

This nematode damages the root system. Infested plants become stunted and yellowed. Severely affected plants may wilt. A careful look at the root system will reveal small galls (Fig. 17). This nematode has a very wide host range. Its eggs can remain dormant for a few months. Warm temperatures and light sandy soils are conducive for its development.

Fig. 17. Knotted, galled pepper root system

To control, use crop rotation; flooded rice in particular greatly reduces nematode populations. A few resistant cultivars are available. Soil fumigants or nematicides may be used. Plowing during the fallow season will expose nematodes to drying and eliminate weeds that host the pest.

Harvesting

For fresh use, chili peppers can be harvested either at the green immature or red mature stage. It takes about 55–60 days after flowering for fruits to fully ripen, depending on temperature, soil fertility, and cultivar. Warmer temperatures will hasten ripening, and cooler temperatures will delay ripening. If conditions are favorable, chili production can continue for several months. Fruits can be harvested weekly.

Fresh chili fruits should not be washed unless they will be kept cool (10°C) until sold. Fruits should be stored in a cool, shaded, dry place until they are sold. At typical tropical ambient temperature and humidity (28°C and 60% RH), fruits will last unspoiled for 1–2 weeks. Anthracnose is the major cause of fresh fruit spoilage.

For dry chili, it's important to preserve the red color of the mature fruits. Drying them in the sun is a common practice (Fig. 18), but this tends to bleach the fruits, and rainfall and dew promote fruit rot. Solar dryers have been developed, but they require fairly constant sunshine. Cloudy weather increases the drying time and the risk of post-harvest spoilage. Blanching the fruits in hot water (65°C) for 3 minutes and removing the pedicel and calyx can decrease drying time, increase color retention, and reduce post-harvest losses. In general, cultivars with low dry matter content and/or thick flesh are difficult to dry and are generally sold fresh. If ovens are available, dry fruits for 8 hours at 60°C, then reduce the temperature to 50°C and continue until fruits are completely dry (about 10 more hours).

Fig. 18. Peppers drying in the sun

In temperate regions, harvesting is usually halted by frost. In tropical and subtropical regions, production declines due to disease or other stresses. ⌘