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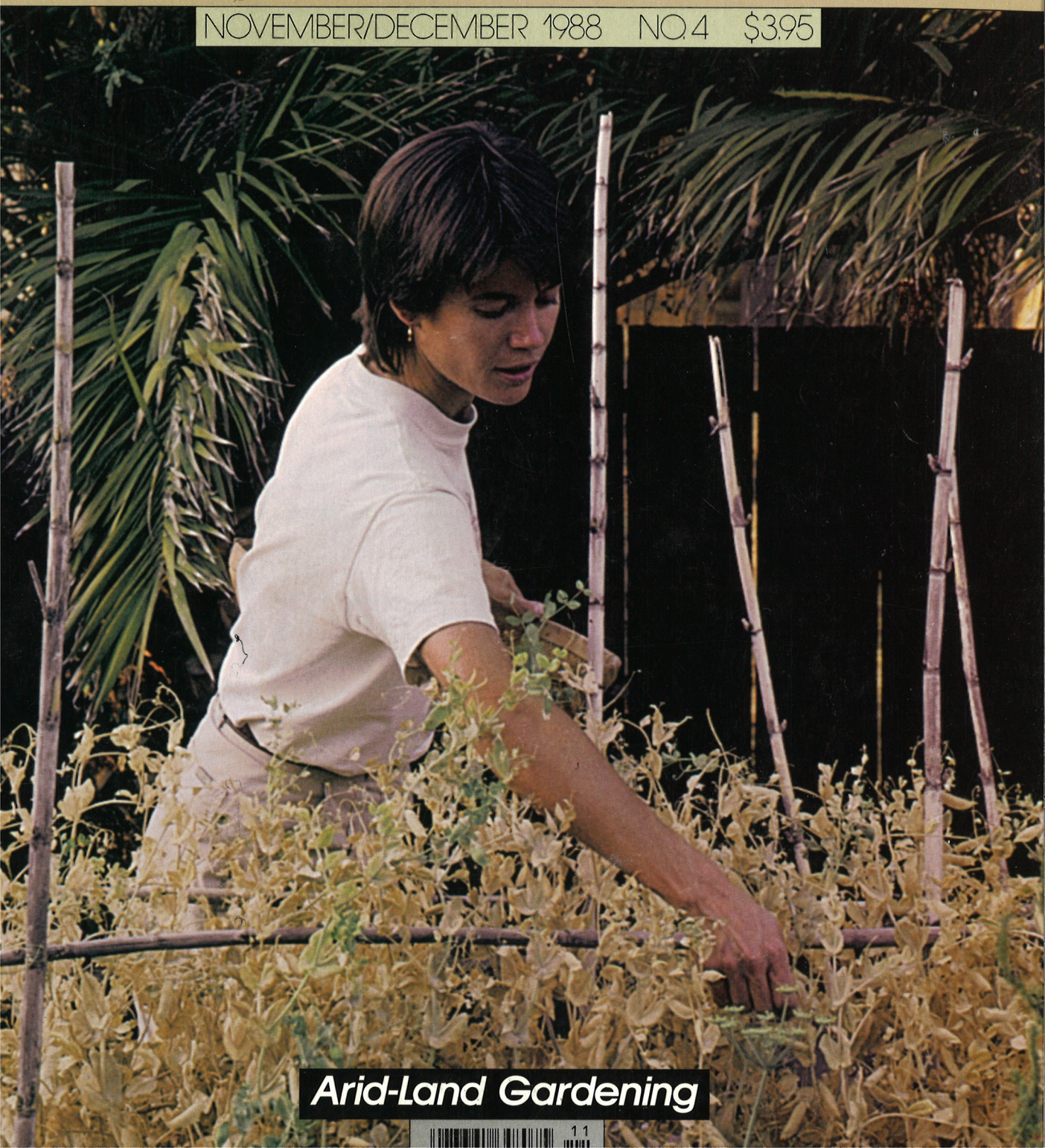

Arid-Land Gardening

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Managing Water in Arid Gardens

Simple, efficient, economical methods

by Daniela Soleri and David A. Cleveland

In some ways, we've got it easy gardening here in Tucson, Arizona. There's plenty of sun, the winters are mild, and we encounter very few weeds, insect pests or diseases. We garden throughout the year, although we plant different crops at different seasons (see sidebar, p. 17). By far our major concern is watering. Tucson lies in the Sonoran Desert. Our average annual rainfall is 11 in., with half falling during July, August and September. We usually get less than 5 in. from October through March, and less than 1 in. from April through June—our driest months.

To grow vegetables at all, we have to water, but that's not the easy solution people once thought it was. Tucson is the largest North American city that relies solely on groundwater for its municipal water supply. Water rates here are increasing, while our water table is dropping rapidly, so water conservation is a big issue for gardeners in this area.

During the hot season, gardeners may find their plants wilting in the afternoon after a morning watering. This is especially discouraging for newcomers who've recently moved to the desert from cooler, moister climates. The prospect of watering twice a day, combined with poor yields due to heat and other water stress, discourages many, who conclude that gardening in Tucson is not worth the money or the effort. Others persevere, only to be astounded by the amount of water they use.

It doesn't have to be that way. During the past 15 years, we've developed a way of gardening that uses water efficiently (returning about $8 worth of vegetables for each $1 spent on water), provides a steady supply of fresh vegetables and fruits, and looks like a peaceful oasis. We're both anthropologists, and our special interest is small-scale food production in dry areas, so many of our ideas come from our travels to study gardening methods in arid West Africa, Egypt and Mexico.

Only a minor fraction of the water supplied by rainfall or irrigation is absorbed by and stored in plants. Most of the water runs off the surface, percolates below the plants' roots, evaporates from the soil or evaporates from the plants' leaves. Our goal is to minimize the water that is wasted or lost from a garden, while supplying just enough for the plants to grow well.

Sunken beds—The most noticeable feature in our garden is the sunken beds. Each bed is surrounded by a berm, which serves as a walkway; the soil inside is at or slightly below ground level. We plant everything we grow—annual vegetables and flowers, trees, and perennials—

The authors grow vegetables, flowers and fruit year round in Tucson in a garden designed for efficient water use. The adobe-like walls of their sunken beds (above) channel rainfall or irrigation water into the planting area inside the bed. Windbreaks (like the one on the facing page) also help cut water loss.

The sunken beds are excavated to a depth of 18 in. to 24 in. to remove the heavy clay soil and the underlying caliche. Then they're refilled with a mixture of topsoil, compost and composted manure.

Soleri uses a hose with a bubbler attachment to flood the beds about 3 in. deep. This takes roughly five minutes, and supplies enough water to thoroughly wet the soil in the bed.

in these beds. The effect is a beautiful waffle pattern (covering about 600 sq. ft.) of earthen walkways transecting lush patches of garden crops.

Though strange to those accustomed to raised-bed or row gardening, these sunken or basin beds make sense for water conservation. In desert climates, the rate of water loss through direct evaporation from the soil to the air is very high. The drier and hotter the air, the more water vapor the air is able to hold and the greater the evaporation from garden soil. Wind increases the rate of evaporation by blowing away humid air near the soil surface and replacing it with drier air, which sucks more moisture from the soil. In the hot desert, a raised bed is like a wet sponge laid out on the bare ground. The soil heats up and water evaporates quickly because the sides as well as the top surface of the bed are exposed.

In sunken beds, only the top surface is exposed, and it's partly protected from drying winds by the raised berms. Inside our beds, we dig out the dense clay soil and replace it with at least 18 in. of topsoil, compost and composted manure. Water penetrates quickly into this mixture, and it's retained well by the organic matter. But the berms themselves are the real advantage of sunken beds: They contain rainfall and irrigation water, so none is lost to runoff.

We didn't invent sunken beds—they're common in many dryland areas. We remember seeing little nest-like gardens planted with onions, greens, okra or peppers in West Africa. Sometimes they were very small, just big enough to grow a few plants near the home. In Mexico, we saw bananas and other perennials planted in shallow basins in dooryard gardens. In New Mexico, the Zuni Indians aligned their series of small rectangular basins into "waffle" gardens.

We generally make rectangular beds, about 3½ ft. to 4 ft. wide by 5 ft. long. These are narrow enough that we can straddle them and reach down into the bed, or reach from either side out to the middle. To dig our garden beds, we first remove the topsoil (about 5 in. or so) from the bed and the surrounding area, and set it aside. The next layer of soil is a dense clay, which we dig out and make into firm, sturdy walkways, patting it into shape with our feet.

As we dig deeper into the beds, the clay soil becomes flecked with white bits of caliche (calcium carbonate), and often a rock-hard layer of caliche is not far below. Caliche is common in the soils of this region, and in our backyard it can start as shallow as 8 in. below the soil surface. We've never reached the bottom of the caliche layer, even when digging tree holes up to 5 ft. deep. Using picks and sometimes a heavy iron digging bar, ap-

Photo, top: David A. Cleveland

propriately called a caliche bar in this area, we dig each garden bed at least 18 in. deep.

Digging through caliche is hard work. Friends of ours have rented jackhammers or backhoes to do the job. (To dig those 5-ft.-deep planting holes for trees, we put on eye goggles and use cold chisels, like miners.) Deep digging is worth the effort, though—it really makes a difference in the hot season. We had some plants growing in beds less than 1 ft. deep that needed watering every couple of days in the summer, but 2-ft.-deep beds can go up to a week between waterings.

After removing and discarding the caliche, we refill each bed with a mixture of topsoil, compost and composted manure. Finally, we level the surface, normally by flooding the bed with water, then moving the soil around to fill in the low spots and take off the high spots. Sometimes we just straddle the bed and pull a straight board over the surface to rake it level.

Between crops, we usually add three or four 5-gal. bucketfuls of compost to each bed and mix it into the full depth of the bed. That's a generous amount, but organic matter breaks down quickly in the heat here. We make as much compost as we can, incorporating household trash, garden debris, mesquite leaves and pods, chopped prickly-pear cactus pads, and horse manure. We renew the beds each year or two, thoroughly remixing the soil with a shovel. It's an easy job compared to the initial digging. From time to time, we repair any erosion on the berms with fresh clay.

Watering the beds—By experimentation and observation, we've learned the best way to water the plants in our sunken beds. We keep the soil around newly planted seeds and seedlings moist by planting them in furrows or depressions within the bed and watering only the immediate area. Seedlings may need watering once a day in the hot season, but their roots penetrate only the top few inches of the soil. Wetting the soil deeper than that is a waste of water. For us, four gallons gives a whole bed of seedlings a good soaking.

By the time the seedlings are several inches tall, we fill the soil in around them, so the bed is level again, and begin to water the bed by flood irrigation. We use a hose and bubbler, opening the faucet as far as possible so the water fills the bed much faster than it soaks in. The bubbler breaks the force of the water to keep it from eroding the soil or mulch in the beds. Gardeners in West Africa achieve the same effect by pouring water onto their gardens through bunches of handheld leaves.

To check if we've added enough water, we take a long stick or an iron bar

In the authors' garden, vegetables and herbs for the cool season include collards, beets and dill.

The desert gardening year

The annual vegetable crops we grow are familiar to gardeners across the United States. During the cooler months from October to March, brassicas and root crops thrive, along with lettuce, peas, and herbs such as parsley, dill, cilantro and fennel. During the rest of the year, we grow corn, beans, squash, melons, tomatoes, peppers, okra, eggplants, amaranths and basil. Some of our crops were selected by Native American gardeners and farmers in this area over a period of hundreds of years. Others grow from seeds we brought back from our travels, and some are standard garden varieties.

Although we garden year round, seasonal differences are important. We follow a planting schedule that helps us make the most of the cool and warm seasons, while avoiding the most difficult gardening weather as much as possible. In early March, after the danger of frost is past, we plant some beds with short-season (60-90 days) corn, string beans and squash. In other beds, we plant long-season crops such as watermelon, and seedlings of chili peppers, eggplants, tomatoes, tomatilloes and basil that were started indoors in early February.

By late May or early June, the corn, beans and squash have produced a harvest, and their garden beds are fallowed. The few beds with long-season crops are heavily mulched, shaded and carefully maintained through the summer. During this time, fruit set stops in many plants because high temperatures disrupt pollen production. But these plants will start producing again after the rains begin, and often continue through November.

In mid-July, when the summer rains start, we plant more beds with corn, beans, cow peas, some squash and okra. The rise in humidity and some rainfall makes it much easier to start and maintain these crops at this time than it would have been if they were started one or two months earlier.

In October and November, when the temperatures begin to drop, we direct-sow seeds of lettuce, greens, peas, carrots and other cool-season crops. We have fun combining plants with different colors, textures and growth forms, such as ruby chard and carrots. The garden looks pretty in the winter, and it's a pleasant time of year to work outdoors.

There may be frosts anytime from the end of November to early March, but the days are sunny and mild. Occasional light rains mean we may not need to water for weeks at a time. The winter crops, and a variety of spring-flowering annual flowers, reach their peak in late March and early April, then decline in the hot, dry weeks that follow. *—D.S. and D.C.*

and insert it two or three places in a bed, feeling how it moves through the soil. With gentle pressure, the stick will move easily in wet soil, slowing or stopping when it reaches a dry zone. If we detect that the soil isn't moist to below the plants' root zones, we add more water and test again. We've learned that flooding with about 3 in. of water at each irrigation will wet the soil to the bottom of the bed. This takes about five minutes with the hose at full blast.

One technique we've experimented with is vertical mulching. A vertical mulch is a column or row of plant stalks buried a foot or so deep in the garden bed, creating a pathway for the water to follow down to the root zone. The idea is to direct the water below the surface layer, where most evaporation occurs. We've tried putting a row of vertical mulch down the middle of a bed, using stalks from last year's corn, Jerusalem artichokes, sunflowers or sorghum. It seems to help speed up water penetration, especially through heavy clay soils. It doesn't make as much difference in porous or open-textured soils, but may still be helpful.

It's important to catch what rainwater we do get, and not lose it as runoff. Our winter rains often are slow and gentle, but our summer rains, or "monsoons," tend to come as short, intense thunderstorms, and ½ in. or more of rain can fall in a sudden burst. A lot of the water runs right over the surface of hard, compacted soil without soaking in—this causes flash flooding in low-lying areas. Right after a rain, our yard is full of water, but it's a thin layer that quickly flows away.

To take advantage of the rainfall, we have to catch it and hold it so it can soak into the soil. We make channels that direct the runoff from the house roof toward basins around the jujube, lemon and pomegranate trees, and we go out with trowels during a rain to make sure that the water is flowing into these wells around the trees, and that the surrounding berms contain it there for a few hours until it can soak in. A heavy rainfall may also flood the sunken beds of our vegetable garden, but there the water sinks quickly into the deep, improved soil in the basins and never stands for more than an hour.

After the soil has been saturated by irrigation or rainfall, surface mulches help retain the moisture by reducing evaporation. They form a barrier to water vapor leaving the soil and they shade the surface, lowering soil temperatures. We use a 3-in.- to 5-in.-deep layer of coarsely textured compost, horse manure, leaf litter, palm fronds or other organic matter to mulch the soil in the planting basins. The mulch should shade the soil between the plants, but around seedlings we try to keep the mulch from touching the plants themselves. It's a haven for fungi and sow bugs, both of which prey on tender stems.

Tender young plants appreciate shading from the hot sun and drying winds. Soleri and Cleveland use carrizo (reed), palm fronds and corn stalks to build sunshades and windscreens.

Around our mesquites and grapefruit tree, we use a mulch made of closely spaced river cobbles, smoothly rounded stones about 6 in. to 8 in. in diameter. We decided to try this several years ago, when we observed that wildflower and grass seeds were most likely to germinate near bits of gravel, perhaps because the soil was slightly moister under the pebbles. About the same time, we read that stone surface mulches have been used for centuries in arid northwestern China.

Stone mulches are thought to work by capturing the water vapor released in the early morning, even by desert soils. The water condenses on the stones' lower surface and returns to the soil. The stones look nice around the trees—we laid them in pleasing patterns. We don't recommend stone mulches for annuals, however, because the stones absorb and then radiate too much heat for low, tender plants. Also, having to remove the stones each time the soil was prepared and planted would be a lot of work.

Shading—Most of the water plants take up in their roots evaporates from their leaves. This process, which is called transpiration, helps keep a plant cool and is essential for photosynthesis. Good growth and garden yields depend on sufficient water in the soil for high rates of transpiration and photosynthesis. High temperatures, wind and sun, however, can increase transpiration well beyond what is needed for maximum production.

Shading reduces leaf temperatures, so it cuts down on transpiration. When planting our summer garden, we choose beds that will have the best protection from the scorching midday and afternoon sun. Our garden is interplanted with trees that are relatively tolerant of heat and dryness. They shade the more vulnerable vegetable plants. For example, we grow squash and melons under a big mesquite tree, and train the vines back into the shelter under the tree, not out across the burning hot soil. Tall annuals such as corn, sorghum and sunflowers can give shade and protection to shorter plants. The sun is so intense here that vegetables get all the light they need even under partial shade.

Providing shade for small seedlings is especially important. We use the tips of palm fronds or make a tepee of corn stalks around tender young plants. We usually orient the shades to protect the plants on the south and west sides, shielding them from the worst of the midday and afternoon heat.

We also construct shades over the garden beds in the summer, using the woody stems of carrizo (*Phragmites australis*), a native reed, and palm fronds. These building materials are attractive and easy to grow or find in this area. They make excellent, lightweight, flexible shades that won't break or blow over with the winds of late summer. For vining varieties of tomatoes, beans and tomatilloes, these shades also serve as trellises. We stick the poles about a foot deep into the soil (this is easiest to do after watering), then tie on crossbars, tops or sides as needed. We often line the structures with palm fronds, so they serve as windbreaks as well as sunshades.

No matter how adapted the crop or how carefully managed the garden, when there is no rain the summer desert garden needs to be watered to ensure that the plants will survive. In the summertime, we always try to water our garden in the evening. During the night, as the air cools (and with the absence of sunlight), evaporation and transpiration rates drop, so less water is lost to the air. Warm desert evenings are wonderful, the most pleasant time of the day, and we relax and enjoy the garden while avoiding the heat and sun. □

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