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My Introduction to Chinese Greenhouses

In March 2014, I visited a small commercial aquaponics facility, Today's Green Acres, in southern Tennessee with a couple friends. The owner of the facility gave me and 20 other attendees a free tour of his aquaponics greenhouses and an hour-long talk about the science and art of aquaponics—growing vegetables in nutrient-rich water from fish tanks.

The first aquaponics greenhouse we toured blew me away. It was a verdant profusion of spinach, lettuce, basil, and other greens, looking absolutely delicious (Figure 1.1). And, what is more, there wasn't a weed in sight! Our host discussed care of fish, planting, and a number of other topics, including the energy requirements of aquaponics growing compared to conventional agriculture.

One of the chief advantages of growing aquaponically, he noted, is that this system uses much less energy than conventional farming operations. Modern agriculture relies heavily on large machines to grow and harvest produce, and semi-trucks to ship it long distances to markets throughout the nation. In the process, it consumes an inordinate amount of energy. In fact, way more calories of fossil fuel are used to produce and distribute food than is actually in the final product.

Out of curiosity, I asked how much it cost to heat the tiny greenhouse in which we were standing. His answer: It had cost $700 to $800 a month over the winter (Figure 1.2).

I was shocked by his answer. What made my shock even greater was that we'd experienced an extremely mild winter.

Thinking that I'd like to try aquaponics, but totally turned off by the high energy costs, I immediately began to think how I could set up an aquaponics greenhouse in an even colder environment—east central Missouri—but greatly reduce, perhaps even eliminate, costly energy bills. Doing so would, of course, help improve the profitability of such an operation. The way I see it, you have to sell a heck of a lot of lettuce and spinach to pay an $800 per month heating bill. If you want to pay for labor, materials, taxes, etc., making a profit would be next to impossible.

FIGURE 1.1. Luscious greens growing in March in an aquaponics greenhouse at Today's Green Acres in Elora, Tennessee, in the extreme southern part of the state.

FIGURE 1.2. Conventional greenhouses such as this one at Today's Green Acres can cost a fortune to heat and cool, making it difficult to generate a profit and to run an environmentally sustainable business.

Several novel ways to heat and cool greenhouses, ideas that I'd been thinking about for many years and some of which I'd been experimenting with, immediately came to mind. Let me start with some of my successful endeavors.

Early Experiences with Greenhouse Growing

I began experimenting with more sustainable and affordable ways to grow in greenhouses in the mid-1990s. In 1996, for instance, I built a small greenhouse over my raised-bed garden at my home in Evergreen, Colorado. This home is nestled in the foothills of the Rocky Mountains, at 8,000 feet above sea level (Figure 1.3). The growing season at this elevation was short. Extremely short. It commenced on June 1 and ended August 31.

The mini greenhouse I built, however, allowed me to extend the ridiculously short growing season by two to four months. This simple structure created a slightly warmer microenvironment that enabled me to plant cold-weather veggies like spinach, peas, and lettuce one to two months *before* the last frost in the spring (which usually occurred around

June 1) and then continue to grow a month or two *after* the first frost in the fall (which usually occurred around September 15).

A couple of years later, I started experimenting in Colorado with Eliot Coleman's four-season harvest technique. If you don't already know, this is an elegantly simple technique that allows one to grow "cold-footed vegetables" such as lettuce, kale, certain varieties of spinach, and bok choi (Chinese cabbage) *throughout* the winter in many cold climates *without* supplemental heat—even in some rather unpleasantly cold places.

FIGURE 1.3. This mini greenhouse in front of my home in Evergreen, Colorado, in the foothills of the Rockies 8,000 feet above sea level allowed me to stretch the growing season in this rather chilly region by three to four months each year.

The secret to the four-season harvest lies in creating a microclimate suitable to growing such vegetables throughout the winter. In this technique, spinach, kale, and other cold-weather vegetables are grown in the ground or in raised beds, either in a large greenhouse or in a large hoop house. Those structures create a slightly warmer microenvironment, like the one I'd been previously using. However, that's not all. Raised beds or portions of the greenhouse garden are "encased" in smaller mini hoop houses as shown in Figure 1.4. These create an even warmer microclimate.

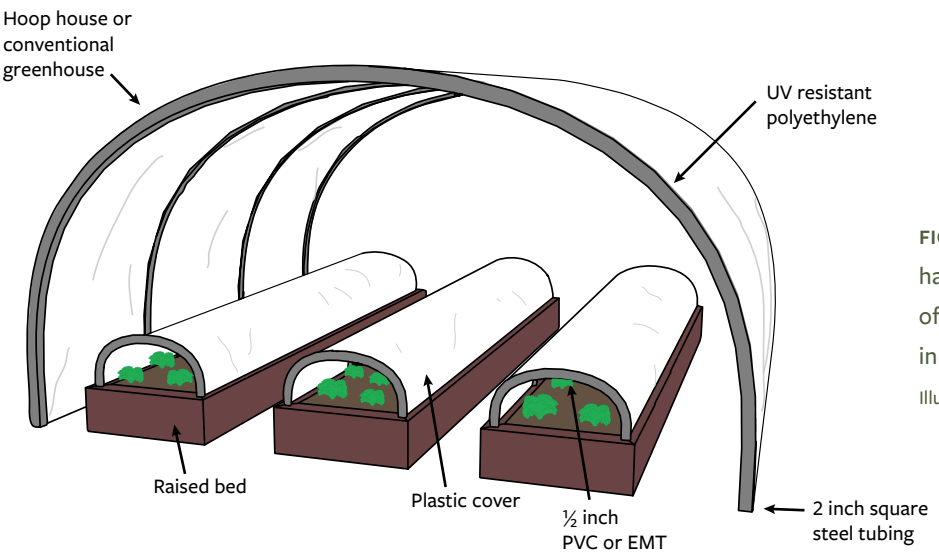

FIGURE 1.4. The four-season harvest hoop house consists of small hoop houses housed in a larger hoop house.

Illustration by Forrest Chiras.

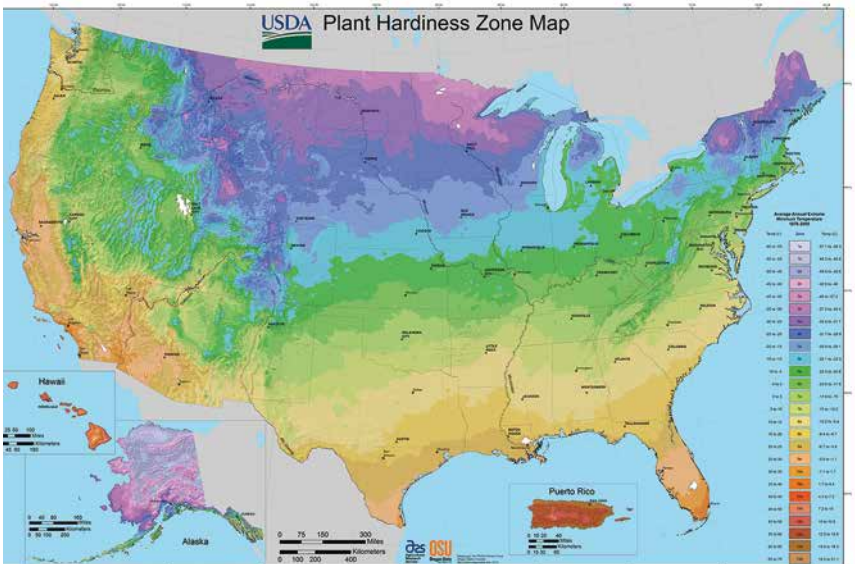

FIGURE 1.5. USDA hardiness zones. The four-season greenhouse allows us to alter growing conditions within a hoop house.

FIGURE 1.6. I used square steel tubing to build my hoop house in Missouri, which I used to grow year-round for many years. I placed smaller hoop houses over the raised beds to create a warmer microclimate, allowing me to grow cold-footed veggies throughout the coldest of winters.

The four-season harvest technique works, according to Coleman, because one layer of protection—that is, the plastic covering of the large hoop house—effectively raises the average daily temperature during the winter inside the structure the equivalent of moving one hardiness zone south (Figure 1.5). The mini hoop houses form a second layer and, he asserts, shift the conditions inside a four-season greenhouse another zone farther south. That's sufficient in many locations to grow cold-tolerant vegetables throughout the winter.

When my wife Linda and I moved to the much warmer farm in east-central Missouri, I set up another four-season hoop house, which operated extremely well (Figures 1.6 and 1.7). Many a day, I've waded through a foot of snow to harvest lettuce or spinach for a mid-winter garden-fresh salad! It is important to note that, while this technique works well with cold-weather veggies, it won't work for their warmer-weather cousins. For instance, you can't grow beans, tomatoes, peppers, or squash in the

Building a Four-Season Greenhouse

I build mini hoop houses with either half-inch (1.25 cm) white PVC pipe or half-inch EMT metal conduit. Both can be easily bent to create two- to three-foot high mini hoop houses inside a larger hoop house or greenhouse. You'll probably need a pipe bender, though, to bend EMT. (If you are worried about vinyl chloride outgassing from PVC, don't. Vinyl chloride is not released from the finished product.)

To secure PVC hoops, I drive an 18-inch (46 cm) long half-inch (2.5 cm) diameter piece of rebar in the ground with a small handheld sledge. I slip one end of the PVC pipe over the rebar anchor. I then bend the pipe and slip the other end over the rebar on the other side of the bed. This creates a fairly strong and stable support structure.

EMT is galvanized metal conduit for electrical wiring and resists rusting, so it can be driven directly into the ground after you've bent it. Or, it can be attached to the wood frame of your raised-bed garden by metal two-hole straps.

With the hoops in place, I drape clear or translucent 6-mil polyethylene sheeting over the hoops, being sure to use enough to seal both ends. Polyethylene sheeting can be purchased at hardware stores and also at major home improvement centers.

FIGURE 1.7. The middle raised bed in my hoop house. I built a smaller hoop house over this bed. One cool thing about this is that moisture that evaporates from the soil and leaves tends to condense on the plastic and rain down on the veggies. Very little watering was required over the winter. Notice the luxuriant growth of various greens in the dead of winter. One secret to this success is that we bury well composted humanure in the beds, which creates a remarkably rich soil.

FIGURE 1.8. An above-ground (Americanized) Chinese greenhouse in southern Tennessee. Don't be deceived by this design. True Chinese greenhouses are earth-sheltered to permit wintertime production without costly fossil fuels. I'd be very leery about above-ground constructions. I'll explain why in the next chapter.

winter in a four-season greenhouse in most locations in North America. These lilly-livered vegetables cannot survive the cold and occasional freezing temperatures that occur inside the greenhouse.

Four-season greenhouses are designed to rely entirely on solar energy. And, like many simple ideas in self-sufficiency, they work—if they are designed, built, and operated correctly.

Even though my early experience with four-season harvest had proved successful, I still yearned for a way to grow more vegetables—specifically, warm-weather veggies—in a greenhouse throughout the winter and to do so naturally—that is, using only solar energy. I had designed a few systems that would allow me to capture heat naturally generated by solar energy in a greenhouse on sunny winter days, then pump the heat into the floor or directly into soil in raised beds. Placing mini hoop houses over solar-heated raised beds, I hypothesized, would allow me to create an even warmer microclimate. But would it be enough to enable me to grow warm weather vegetables in –10°F (–23°C) weather? Probably not.

I also thought about partially earth-sheltering a greenhouse to see if that would help maintain favorable interior temperatures. My earth-sheltered passive solar home in Colorado proved that it might work. I grew all kinds of warm weather fruits and vegetables—including bananas—in the winter in an indoor planter in that house. But a solar home is much better insulated than a greenhouse. Still, I thought, if I combined some of my other techniques, like the ones I just mentioned, I might be able to grow tomatoes in winter in a greenhouse.

My thinking on the subject crystallized when I was introduced to the Chinese style greenhouse. My

first introduction, albeit brief, came during my tour of Today's Green Acres. That's when I encountered my first Chinese greenhouse, which I soon learned was designed for growing cold and warm-weather vegetables during the late fall, winter, and spring *using only solar energy* (Figure 1.8). Chinese greenhouses are unlike conventional greenhouses in many ways, as you shall soon see. One of the key features, however, is that they have much less light-admitting cover, as you can see in Figure 1.8.

The Chinese Greenhouse

During our tour of Today's Green Acres, we visited an odd-shaped, highly unconventional greenhouse. It was called a Chinese greenhouse. This greenhouse, we were told, was designed to grow warm-weather vegetables throughout the winter without supplemental heating. No propane or gas heaters were required. It was the first time I'd heard of such a thing.

Enthused by the concept, I was still a bit skeptical whether this particular structure could live up to its promises. As you can see from Figure 1.8, this greenhouse was built above-ground. To me, that would undoubtedly result in rather wide interior temperature swings in winter months. (Earth-sheltered buildings tend to stay much warmer in the winter.) It was difficult for me to imagine how the temperatures inside this greenhouse would remain warm enough for sissy tomatoes and green peppers when ambient temperatures dropped below freezing.

My skepticism was bolstered by another missing element: This greenhouse was lacking in another essential component that would ensure plant-friendly temperatures, notably internal thermal mass (built-in heat-absorbing materials). In solar heated homes, something I'm really familiar with, thermal mass is strategically added to soak up heat from solar energy during the day, even on cold sunny winter days, and radiate that heat into the building at night, helping to keep the interior temperature higher and more stable. Without it, I doubted this little knock-off of a true Chinese greenhouse would work. So, even though this "Chinese greenhouse" looked cool, it seemed unlikely that this particular design would actually work.

Adding thermal mass and earth-sheltering the structure could, I suspected, result in a greenhouse that would allow me to grow all kinds of

vegetables, even warm-weather crops like peppers and tomatoes, through the winter and without costly fossil fuels. When I began to research Chinese greenhouses, that's what I found. True Chinese greenhouses were often earth-sheltered and contained lots of thermal mass. As you will learn in the next two chapters, these aren't the only design features that enable Chinese greenhouses to perform their winter miracles.

Meeting Dr. Sanjun Gu and The Real Chinese Greenhouse

In the Fall of 2014, just a few months later, I received a valuable lesson in the design and construction of Chinese greenhouses. I was teaching a course titled Applied Ecology, through the Sustainable Living program at Maharishi University in Fairfield, Iowa. That's when I met Dr. Sanjun Gu, a world authority on Chinese greenhouses. This meeting would change my life and start me off on yet another path toward self-sufficiency and sustainability.

FIGURE 1.9. Chinese greenhouse. The greenhouse shown in the photo is earth-sheltered on the north side. Also note that there is no glazing (glass or plastic) on the east side. Compare it to the above-ground greenhouse shown in Figure 1.8. Courtesy of Dr. Sanjun Gu.

Dr. Gu was visiting the campus for the day and was eating lunch in the faculty dining room with some of my colleagues. He sat across from me and soon we found ourselves engaged in a conversation about Chinese greenhouses (see Figures 1.9 and 1.10). Because of the course I was teaching and my unbridled enthusiasm, he generously agreed to make a surprise visit to my class to give a talk. That's when I realized how important this idea was and how it could help revolutionize greenhouse growing in North America.

Inspired by his talk, I began to read everything I could on the subject. Regrettably, that was not much. There was very little information on Chinese greenhouses on the Internet or in magazines at that time! At this writing (April 2020), there is more information, but

FIGURE 1.10. The inside of a large Chinese greenhouse showing luxuriant growth of squash in March.
Courtesy of Dr. Sanjun Gu.

there aren't any books on the subject. What is more, magazine articles devoted to Chinese greenhouses, and books that include sections on them, tend to be misinformed and lead readers to wrong conclusions.

Eager to spread the word, I put together a one-hour slide show on Chinese greenhouses using many of Dr. Gu's slides—with his permission, of course. The presentation covered what I had learned online and what I had learned from Dr. Gu. It also included some of my ideas on improving their performance, for example, incorporating active solar heating, active and passive cooling measures, energy efficiency, and solar electricity. If successful, these efforts would help growers like me create an even more hospitable environment, one that allows homeowners and commercial growers to produce all kinds of vegetables year-round, even in very cold climates, using only solar energy. That slide show, which I began offering at Mother Earth News Fairs in 2015, and a two-day workshop I put together on off-grid aquaponics served as the inspiration for this book.

What's this Book about?

This book describes the design, construction, and operation of Chinese greenhouses and ways to "supercharge" these amazing structures, so they perform even better. Keep in mind that many of these ideas can be applied to conventional greenhouses as well.

In the following pages, I'll discuss

- how to design and build a Chinese greenhouse
- the importance of earth-sheltering, proper orientation, thermal mass, and insulation to creating a successful Chinese greenhouse—and products you can use to achieve your goals
- how solar hot water systems can be used to provide supplemental heat
- how solar hot air systems can be used to provide additional heat and how to build one
- how to store heat both for the short term and long term
- how to actively and passively cool a Chinese greenhouse
- how to successfully operate and grow crops in a Chinese greenhouse

Two novel and very exciting ideas that may further fire up your enthusiasm are short-term heat storage and long-term heat storage. I'll show you how to collect and store excess heat generated on sunny, winter days in a greenhouse for nighttime use. This technique will help you maintain evening temperatures suitable for warm-weather plants, even citrus trees. I'll also show you how to store heat generated both inside the greenhouse and in solar hot water systems, throughout the summer and early fall, to help heat your greenhouse in the winter.

So, let's say we get started.