TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

CoolBot provides inexpensive, effective cooling

In many developing countries, the rate of postharvest loss for fruits and vegetables exceeds 50 percent. Cool storage can greatly reduce these losses, increasing income for farmers. Cool storage is virtually non-existent due to the high cost of equipment and lack of knowledge about the benefits of cooling produce. Temperature control alone can extend shelf life by weeks or even months. Farmers who can store their produce longer can take advantage of better prices, as market prices can fluctuate dramatically over time.

How the CoolBot works

The CoolBot was developed by Store It Cold as an affordable way for small-scale producers to cool products on their farms. The Horticulture Innovation Lab has tested cool rooms equipped with the CoolBot on three continents.

The equipment:

- Overrides an air conditioner's temperature gauge, tricking it into working harder while preventing components from freezing.
- Converts an insulated room and an inexpensive, readily available, window air conditioner into a cool room.
- Substantially reduces the cost of a cool storage environment for fruits, vegetables, flowers and other products.
- Makes cool storage a viable option for farmers, cooperatives and market groups in the developing world.

Neeru Dubey, of Amity University, shows a CoolBot working in India during a Horticulture Innovation Lab project testing local installation in multiple countries, including India, Honduras and Uganda.

Benefits

- Farmers can store produce to sell in the off-season when prices are higher.
- Improved cold storage possibilities will stabilize fruit and vegetable prices, giving consumers access to nutritious fresh produce all year.
- Farmers are better protected from erratic market prices.

Basic costs

- $299 CoolBot
- $700 Air conditioner
- $2,000 Insulated room
- $200 Electricity costs/month

These costs are subject to local variation. Identifying local, effective options for insulated rooms is one objective of a related Horticulture Innovation Lab project.

What's next? Scaling up

- **Education:** Increase postharvest training and direct farmer outreach.
- **Adoption:** Work with industry, farmer cooperatives, local and regional markets, and bulk purchasers to adopt the CoolBot.
- **Investment:** Research innovative investment options for farmers and groups. Identify entrepreneurs eager to promote the CoolBot.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Solar drying adds value to crop surplus

Fruits and vegetables are highly profitable commodities for both small- and large-scale farmers. These crops are often harvested in high volume over a short period of time, when quality is high but prices are low. Rates of loss and waste in fresh produce can be quite high, especially in developing countries. Solar drying of fresh fruits and vegetables is a simple processing technique that adds value to crop surpluses, preserves and extends food supplies, empowers smallholders and creates rural employment.

Designed by UC Davis researchers for the Horticulture Innovation Lab, the chimney solar dryer combines solar heat collection with rapid air flow for efficient drying of fresh produce.

Chimney solar dryer design

From Horticulture Innovation Lab researchers at UC Davis, the chimney solar dryer is designed to provide efficient drying even in hazy or partially cloudy conditions, using inexpensive and readily available materials. Other features of this design include:

- The chimney ensures continuous air flow around the product, thus increasing the speed of drying compared to other designs.
- This design's large heat-collection area ensures high temperatures and rapid water removal.
- Flexible design allows users to modify tray depth and size to fit consumer demands.

Benefits

- Cost-effective, small-scale processing option for smallholder farmers
- Easily modified to suit specific requirements of different products and climates
- Provides benefits of solar drying even in hazy or partially cloudy conditions
- Dries produce twice as fast as cabinet dryer designs

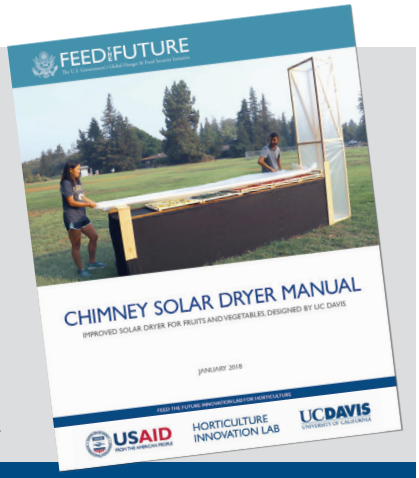
Basic costs

- Clear plastic, 2-4 mm thick
- Dark-colored row cover fabric or black plastic
- Food-grade plastic mesh or galvanized screen
- Plywood
- Basic carpentry materials

Materials can be purchased for less than $150; however, costs are subject to local variation.

Helping build more chimney solar dryers

- **Manual for building, using and troubleshooting:** The Horticulture Innovation Lab has created a manual with a detailed materials list, isometric illustrations, photos, directions for how to build, troubleshooting tips and other user support.
- **Video series:** Short videos show how to build and use a chimney solar dryer. Find videos and manuals at: https://horticulture.ucdavis.edu/chimney-solar-dryer
- **Further testing, adapting and adoption:** Researchers with the Horticulture Innovation Lab have used chimney solar dryers with farmers in the United States, Ghana, Guinea, Kenya, Tanzania, Bangladesh, Thailand, Guatemala and Honduras.



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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Drying beads save high quality seeds

In tropical climates, high humidity causes rapid seed deterioration, resulting in poor stand establishment, lower productivity, reduced market value and a disincentive to invest in improved seeds. Under humid conditions, drying under the sun and other traditional methods cannot reduce seed moisture sufficiently to maintain seed quality. For every 1 percent increase in seed moisture content, seed longevity is reduced by approximately half.

How drying beads work

Drying beads are a desiccant product developed by Rhino Research using zeolite. When used with airtight containers, the drying beads provide a widely adaptable method for drying high-value horticultural seeds and maintaining seed quality during storage. The beads can be reused indefinitely by heating between uses.

Reusable drying beads improve germination and plant vigor if used to dry horticultural seeds. The beads are being rapidly adopted by Bangladesh seed companies.

Benefits

- Drying beads enable seed producers to dry seeds to very low moisture content without the use of heat, thus preserving seed quality.
- Keeping seeds dry during storage can increase seed longevity, germination rates and plant vigor — ultimately increasing yield capacity for farmers.
- Drying beads can be integrated into local seed systems to improve markets for local and improved cultivars. With increased confidence in seed quality, farmers have greater incentive to invest in seed and can begin their seasons without the penalty of poor seed.
- Drying beads cost $8-15/kilogram and require only an airtight container to keep seed dry. The beads can be recharged in an oven to be used repeatedly.

ACHIEVEMENTS

200 tons of vegetable seed

dried and stored with drying beads in Bangladesh so far in 2016-2017, which provides an estimated

100,000 farmers with better seed

Scaling success so far

- **Identifying motivated beneficiaries:** By connecting with seed companies that can immediately recognize and recoup benefits of improved seed quality, the team has successfully deployed drying beads into the marketplace, with seed farmers using them and vegetable farmers accessing higher quality vegetable seed.
- **Effective training and engagement:** The team provided week-long trainings to 14 seed leaders repeating 3-7 times over several months, with a possibility of certification. Those leaders have already trained more than 70 staff members, who trained more than 500 seed production farmers.
- **Growing interest:** Success can breed interest, and demand for drying beads is growing. In the wake of this USAID-funded research and **public-private partnership**, seed companies in India are discussing their own training series, product distributors are lining up, and organizations such as Winrock International, the Bill and Melinda Gates Foundation and the Rockefeller Foundation have started to mobilize.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

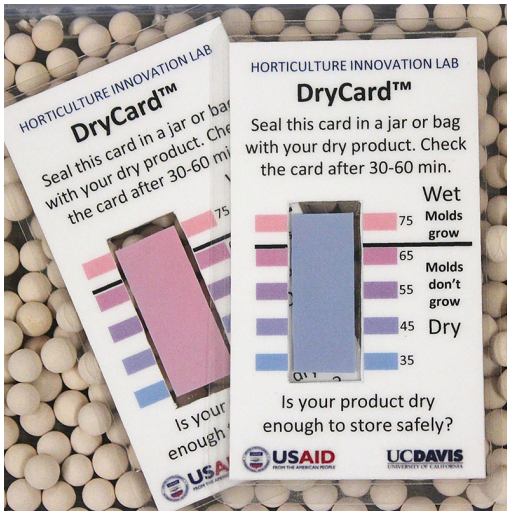
New, low-cost indicator of food dryness: DryCard

In developing countries, mold growth on dried foods can result in postharvest losses for farmers and unsafe foods for consumers. Food will not mold if it is properly dried, but smallholder farmers do not have access to a cost-effective way of assessing food dryness. Farmers who are able to assess dryness before storing can reduce postharvest losses and better provide consumers and their families with safe, higher quality foods.

How the DryCard™ works

The DryCard incorporates a cobalt chloride humidity indicator strip that changes color depending on the level of relative humidity. In an airtight container, the relative humidity of air around a product reflects the dryness of the product (this concept is called equilibrium relative humidity).

To use, place the DryCard and a sample of the dried product in an airtight container, such as a sealed plastic bag or a jar. After a brief wait, the card indicator will display a measure of the equilibrium relative humidity. Match the color of the strip with the scale on the card. If the indicator strip turns pink, then the product is too wet for safe storage. If the strip turns blue or grey, then the product is adequately dried. Store the card in a plastic bag to prevent contact with water. If cared for properly, the DryCard can be reused many times.



The indicator strip on a DryCard turns pink if product is too wet for safe storage. Blue or grey indicates product is adequately dry (shown here with drying beads).

Benefits

- All participants in the dry chain can more confidently store, exchange, and consume dried products.
- Farmers maintain quality and quantity of goods, allowing them to sell more product at higher prices.
- Consumers have increased access to safer, better tasting dried foods.

Basic costs to manufacture

- Cobalt chloride strips (approximately $4 for 100 strips)
- Printed paper
- Plastic lamination (about $12 for 500 cards)

The DryCard is inexpensive to make and is currently available in sample quantities from the Horticulture Innovation Lab. Visit http://drycard.ucdavis.edu for details.

What's next? Scaling up

- **Partnership:** The Horticulture Innovation Lab is working with researchers and development organizations to test usability and perceived value of the DryCard.
- **Education:** Increase awareness about relationship between equilibrium relative humidity and food safety. Train farmers and traders on how to use the DryCard. Collaborate with local organizations to raise awareness of the DryCard.
- **Scaling:** Identify local entrepreneurs interested in manufacturing and marketing the DryCard.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Vegetable grafting increases yield, business opportunities

In many tropical countries, the production of vegetables such as tomato can be dramatically reduced by diseases in the soil, impacting the livelihoods of rural families. One of the biggest such problems affecting tomatoes in the tropics is bacterial wilt (*Ralstonia solanacearum*). Grafting is a proven technology being increasingly adopted worldwide to reduce the risk of soilborne diseases.

How vegetable grafting works

Grafting begins with two types of seedlings that are cut and then physically joined together to grow into one plant. The two parts are:

- the scion, the part of the plant above the ground, which is chosen based on fruit quality for the market
- the rootstock, below ground, which is chosen for its ability to resist soilborne diseases

Immediately after the seedlings are grafted together, plants are placed in a grafting chamber for about one week with high humidity and reduced light intensity for the graft union to heal. The grafted seedlings are further "hardened" in a screenhouse to prepare for transplanting in the field. Depending on growing conditions, the grafting process typically takes about 30-33 days.

A recently grafted tomato plant, with scion above the union (held together temporarily with a plastic tie) and rootstock below. This grafted seedling would next spend a week in a grafting chamber and additional time in a screenhouse before being transplanted in a field.

Benefits

- Grafted plants can reduce the incidence of plant disease, thus increasing potential yields.
- With reduced plant disease pressures, farmers can reduce their use of pesticides and may be more likely to be able to grow organically.
- Entrepreneurs can specialize in the production of grafted vegetable seedlings, earning income while selling improved seedlings to farmers.

Basic costs to implement

- Potting mix and trays for seedlings
- Clean blade, gloves and plastic for grafting
- Screenhouse
- Grafting chamber
- Labor to graft and care for seedlings

These costs are subject to local variation. Identifying sources of appropriate rootstock and scion is a critical activity.

What's next? Scaling up

- **Education:** Train farmers and extension workers through field trials and demonstration plots. Work with input supplier able to produce the needed plants.
- **Adoption:** Work with non-governmental organizations and extension for promotion and awareness.
- **Investment:** Identify partners and entrepreneurs to establish grafting facilities and distribution channels to deliver plants safely to farmers. Ongoing local research to monitor disease pressures and resistant varieties.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Growing vegetables with conservation agriculture

Farmers who grow vegetables on small plots of land often face challenges related to land preparation, weed control and irrigation. At the same time, both their land preparation (because of possible erosion) and pesticide applications (to control weeds) can cause environmental problems. Conservation agriculture is a set of practices that reduces farmer labor and helps the environment while improving soil quality.

How conservation agriculture works

Conservation agriculture typically involves three practices:

- limited soil disturbance (reduced tillage or no-till)
- a layer of vegetative cover on the soil (known as mulch)
- diverse crop rotation

Combined with drip irrigation

Combining these practices with drip irrigation improves water use efficiency, delivering water more directly to the crop roots and decreasing surface evaporation. Drip irrigation works well with conservation agriculture because the mulch layer reduces the need for weeding, thus reducing potential inconvenience and damage to the irrigation equipment. Field trials have found that the combination of conservation agriculture and drip irrigation can mitigate the temporary yield reductions which are often seen upon first adopting conservation agriculture practices.

When combining drip irrigation with conservation agriculture to grow vegetables such as these tomatoes on small plots, the drip irrigation tape is installed beneath the mulch layer.

Benefits of the combination

- Reduce strenuous labor needed for land preparation, irrigation and weeding
- Increase soil organic matter which improves soil structure, moisture infiltration and soil moisture holding capacity
- Reduce soil erosion and herbicide use
- Improve water efficiency, thus reducing the amount of water to pump or cart to the field

Basic costs to implement

- Mulch, including labor to collect and transport
- Drip irrigation tape and connectors
- Water filters for irrigation (depending on local water quality)
- Water container and/or pump for irrigation

These costs are subject to local variation. Identifying appropriate sources of mulch is an ongoing activity.

What's next? Scaling up

- **Education:** Train farmers and extension workers through field trials and demonstration plots.
- **Adoption:** Work with non-governmental organizations and extension for promotion and awareness.
- **Investment:** Identify partners and entrepreneurs to make water containers and irrigation equipment available.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Pest-exclusion nets protect crops to boost yield

Insect pests reduce crop yield by attacking crops and by transmitting diseases. Access to training and information on effective use of pesticides can be rare for many smallholder farmers. As a result, farmers often sell damaged produce or use high levels of pesticides, which can be dangerous to both farmers and consumers and can increase insect resistance to pesticides. Pest-exclusion nets can have a major impact in addressing many of these problems.

How the nets work

Pest-exclusion nets create a barrier that protects vegetables against pests and associated diseases. The nets are easy to use and can also serve as floating row covers to control temperature, light, relative humidity and soil moisture for plant production. The nets are low-cost and can be reused for 3–5 years. Pest-exclusion nets are made and marketed locally by mosquito net manufacturers.

Pest-exclusion nets are being used in Kenya and Benin to increase yield and quality in crops such as cabbage, with research and support from a Horticulture Innovation Lab project.

Benefits

- Improve yields and vegetable quality
- Provide an inexpensive and safe method of managing insect pests
- Improve ambient growing conditions and water-use efficiency, enhancing yield and produce quality
- Reduce reliance on toxic and expensive pesticides that impact environmental and human health
- Increase market opportunities for domestically produced textiles

Basic costs

- Netting $60-99 per 150 m^2

Costs are subject to local variation and depend on whether nets are impregnated with insecticide or not, lightweight or heavyweight.

What's next? Scaling up

- **Education:** Train farmers through field trials and demonstration plots.
- **Adoption:** Highlight production and income gains. Increase product availability within the region.
- **Investment:** Work with industry and entrepreneurs to promote the nets.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Facilitated solarization reduces weeds, pests in a week

In developing countries women often carry out the time- and labor-intensive work of hand-weeding, and pests are often controlled with chemicals by small-scale farmers with little knowledge of proper handling or application. Misuse of pesticides and herbicides can result in water contamination, pest resurgence and unsafe produce. Soil solarization is a well-studied technique that can reduce heat-sensitive weeds, pests, and diseases without chemicals. But this process typically requires a minimum of six weeks of sunny skies and high temperatures, which can be difficult and costly for smallholder farmers with a continuous rotation of crops. Instead, facilitated soil solarization is a technique that has shown promise for control of heat-sensitive weeds and soil-borne pests and diseases, in only one week.

How facilitated solarization works

Facilitated solarization reduces the time needed by covering the clear solarizing plastic with an insulating layer at night to reduce the heat lost during cool nights. First, prepare beds and irrigate soil down to about 30 cm, as wet soil better conducts and holds heat. Then place clear plastic directly over the soil, and secure by burying the edges in a trench around the beds. Just after the hottest time of the day, apply insulation materials, such as wool, fiberglass, old blankets, bags packed with rice hulls or chicken feathers. Remove the insulation in the morning as the sun is rising and store in a safe location for re-applying in the late afternoon.

Facilitated solarization can speed up the standard soil solarization process with the addition of insulation to reduce heat loss at night.

Benefits

- Reduces need for hand-weeding
- Reduces soil-borne pests and diseases without using chemicals
- Simple and cost effective, using only clean solar energy, clear plastic and reusable insulation
- Reduces the time a field needs to remain unplanted for traditional solarization

Basic costs

- **Clear plastic**: 1.5–2 mm thick, optimal to provide greatest heat transfer while reducing tearing
- **Insulation materials**: Industrial insulation, blankets, packed rice hulls or chicken feathers

The costs of these items are subject to local variation.

What's next? Scaling up

- **Further research:** Conduct adaptive research in different climate zones to fine-tune recommended exposure time, identify a more complete spectrum of weeds and soil-borne pests that are affected, and identify affordable, effective insulation options for small-scale growers in resource-poor areas.
- **Adoption:** Work with NGOs, extension agencies, farmer groups and other trainers to demonstrate the efficacy of facilitated soil solarization.

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TECHNOLOGIES FOR HORTICULTURAL DEVELOPMENT

Solar pumps improve irrigation options for farmers

Rain-fed agriculture can be a high-risk venture, particularly with changing rainfall patterns and high-value crops such as fruits and vegetables. Irrigated cropland is twice as productive as rain-fed agriculture (World Development Report 2008), but many farmers do not have access to irrigation infrastructure, including a nearby water source and power to move the water to and through their fields. Combining drip irrigation kits, newly affordable photovoltaic panels and off-the-shelf, 12-volt pumps can result in a cost-effective system for supplying water for irrigation. Solar-powered irrigation has the potential to increase incomes dramatically, particularly for the most remote producers.

How the solar pump system works

A 50-watt photovoltaic solar panel can power a 12-volt pump, which can move 1,300–2,600 liters per hour (or 350–700 gallons). Standard plastic fittings and half-inch piping connect these elements to a water saving tank of 500–1,000 liters. A sturdy stand should be built for the water tank to provide gravity flow, and a frame should also be constructed to provide the best angle for the solar panels. Multiple filters are needed to protect the life of the pump and minimize clogging in sprinkler emitters and tubes. A solar pump combined with affordable drip irrigation kits can be used with a wide variety of high-value crops to increase water efficiency, minimize fertilizer loss, and irrigate hilly terrains.

A solar-powered pump — shown here at the Horticulture Innovation Lab's Regional Center at Kasetsart University— can enable drip irrigation in remote locations, where access to electricity, high costs of securing fuel, and distance from a water source can make irrigation prohibitively difficult for smallholder farmers.

Benefits

- Solar irrigation can increase incomes dramatically, particularly for remote producers with inconsistent access to electricity or fuel.
- Pump irrigation reduces labor for water delivery.
- By targeting water at a crop's roots, drip irrigation can reduce weed and disease pressures, and increase efficiency of chemical applications.
- Drip irrigation significantly increases water use efficiency.

Basic costs

- Solar panels and frame
- 12V water pump and electric wire
- Water level switches
- PVC piping, connectors, valve
- 500L water storage tank and stand
- Filters
- PVC cutter
- Irrigation tape or tubing

These basic materials are available from local suppliers at low costs.

What's next? Scaling up

- **Education:** Continue to provide training through the Horticulture Innovation Lab Regional Centers and our network of partners.
- **Research:** Test components available in partner countries to find the most effective and affordable combinations.
- **Partnerships:** Work with the Horticulture Innovation Lab's network of partners to provide training, consulting and extension services to small-scale fruit and vegetable growers.

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