An evaporative cooler for vegetable crops

The low cost of this cooling system makes it especially suitable for small farmers and roadside merchants. It also can be used for short-term storage.

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Some vegetable crops are harvested with pulp temperatures too high and under humidity conditions too low for maximum shelf life. Present facilities for cooling produce and providing proper humidity usually consist of a system for rapid cooling as the commodity arrives from the field and a cold room for subsequent storage. Both are expensive to install, and the mechanical refrigeration system for the cooler requires large amounts of energy. The goal of this project was to develop a simple, low-cost, energy-efficient alternative that would be applicable to both large-scale and small-scale operations.

Evaporative cooling is an effective means of providing low air temperature and high relative humidity for cooling produce. Its limitation is that a well-designed system provides air at one to two degrees above the wet-bulb temperature of the ambient air, outside the cooling unit. The mean wet-bulb temperature in California ranges from 50° to 70° F during the harvest season and drops to slightly below 40° F during the winter. These temperatures are acceptable for cooling the chilling-sensitive crops listed in table 1. Crops not listed in the table require a storage temperature near 32° F and would not be suitable for this system.

A small unit was constructed to verify the effectiveness of evaporative cooling (see drawing). The fan was selected to provide about 400 to 600 cubic feet per minute (cfm) at 0.75 to 0.10 inch watergage static pressure. This is enough air flow to cool at least 600 pounds of produce in 1 to 2 hours.

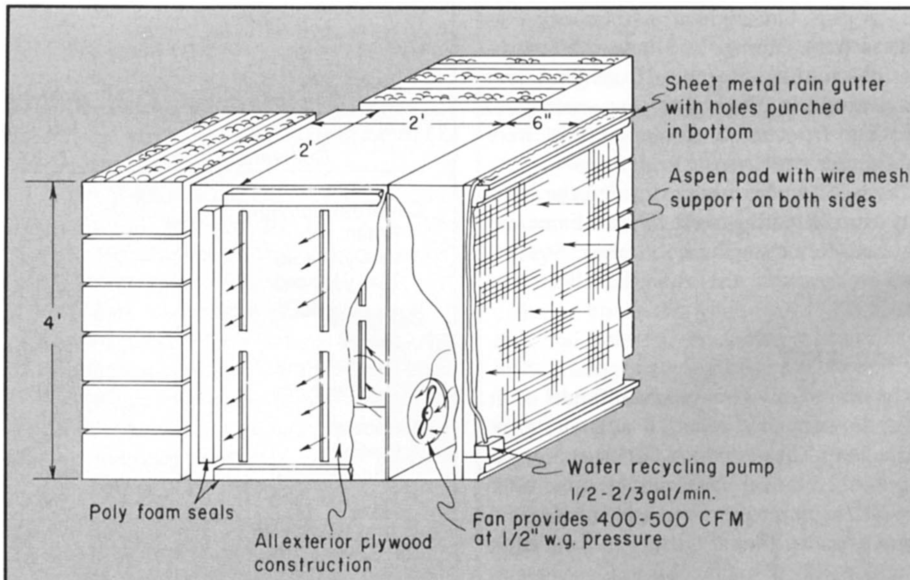
The cooling pad was a commercially available aspen fiber pad designed for evaporative cooling. The total pad area was 8 square feet, which resulted in an average air velocity through the pad of 50 to 75 feet per minute (fpm). The velocity recommended for most evaporative cooling systems is in the range of 100 to 300 fpm. The low velocity was selected to ensure nearly complete saturation of the air, resulting in lowest possible cooling air temperature and a high relative humidity. Also, the large pad area fitted the size of the air plenum required for distributing the cooled air to the vegetable boxes.

A small pump was used to recirculate water from the bottom to the top gutter. The rate of water flow through the pad was 0.42 gallon per minute. The unit consumed less than 0.03 gallon per minute of water through evaporation, and an additional small amount of water was continuously drained away to prevent salt buildup. The unit was built primarily of ½-inch exterior grade plywood. If new materials were purchased, the total unit would cost about $150 to $200.

Table 2 summarizes the data obtained in five cooling experiments. All commodities were packed in commonly used containers. The air flow varied with the amount of produce placed on the cooler, because fan output varies with air flow resistance. The cooling rate for each commodity is primarily a factor of the rate of air flow per weight of produce. The lower air flows of about 1 cfm per pound resulted in ⅞ cooling time of about two hours. (⅞ cooling time is the time required to cool the produce ⅞ of the difference between the initial product temperature and the temperature of the cooling air.) Air-flow rates over 3 cfm per pound provided ⅞ cooling times of 1¼ hours. These cooling rates are rapid enough for most operations.

The graph illustrates the cooling air temperature produced by the unit during a 24-hour period. The fan was producing about 500 cfm. The maximum air temperature produced by the unit was 70° F during the afternoon with a minimum during the early morning of 57° F. In general, the air temperature produced by the unit was about 2° F higher than the wet-bulb temperature. This resulted in a relative humidity of about 90 percent in the air leaving the unit. The temperature of the air through the cooling pad was ½ to 1° F higher than the wet-bulb temperature, and the remainder of the increase was caused by heat from the fan and motor. The test was conducted during August, which typically has the highest wet-bulb temperatures of the year.

The cooling unit was powered by a ⅓ horsepower (hp) fan motor and 1/60-hp recirculation pump motor. This energy input produces nearly 11,000 BTUs of cooling (nearly 1 ton of refrigeration) when 500 cfm of air is cooled 20° F. For each unit of energy input, 14 energy units of cooling are produced. A mechanical refrigeration system produces



Evaporative cooler for small lots of produce.

about 3 energy units of cooling for each unit input (but it produces lower temperatures than evaporative cooling can).

The test unit provided optimum relative humidity and acceptable temperature conditions for cooling most types of chilling-sensitive produce. The maximum temperature produced by the unit exceeded recommended temperatures by about 10° F because of high ambient wet-bulb temperatures. During the cooler harvest months and cooler times of the day, the unit can provide nearly optimum temperatures. In any case, most refrigerated transit vehicles or cold storage facilities, if properly utilized, can provide the small amount of additional cooling needed to bring the produce to optimum temperature.

Minimum produce temperature can be obtained by allowing the commodity to remain on the cooler until the wet bulb drops. For example, when the afternoon peak wet-bulb temperature is 10° F above the desired commodity temperature, the product will need to remain on the cooler until early morning. This may require additional cooler capacity, but considering how inexpensive the equipment is, this should not be a problem. When wet-bulb temperature is not high, the commodity can be removed from the cooler within a few hours.

Another advantage of this system is that the cooler can also be used for short-term storage in place of a relatively expensive mechanically cooled storage room. The system produces cool, high-humidity air that can be forced past the produce, even after it has cooled, without damaging it. To reduce energy use during storage, it would probably be desirable to have a two-speed fan in the unit and use the low speed during storage. With this modification and some temporary shading, any field location with water and electricity could be used for short-term storage.

The small investment needed to set up an evaporative cooling system and its low energy requirements make it especially suitable for farmers and roadside merchants who do not have the financial resources to invest in a mechanically cooled storage room or cooling facility. Many of these producers have either ignored product temperature management or depended on a custom cooling and storage facility some distance from their operations. The technology described is inexpensive enough to allow almost any grower to use it to help ensure produce quality.

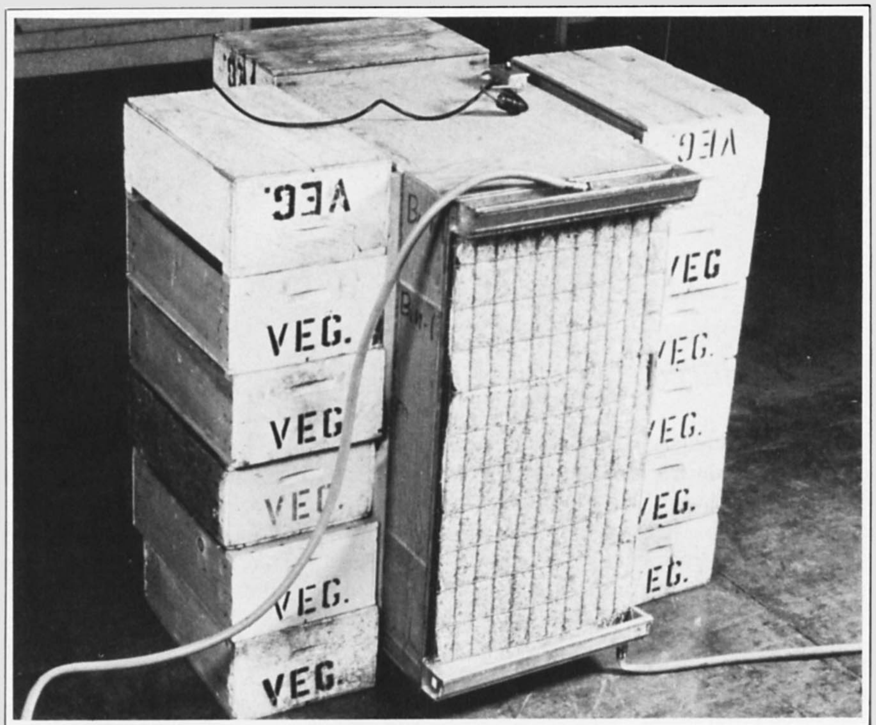
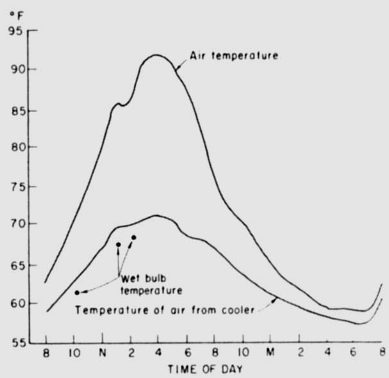


TABLE 1. Recommended Storage Temperatures and Humidities for Selected Crops

Commodity	Temperature	Relative humidity
	°F	%
Avocados	40-55°	85-90
Snap beans	40-45°	90-95
Cucumbers	45-50°	90-95
Eggplant	45-50°	90
Most melons	45-50°	85-95
Okra	45-50°	90-95
Sweet peppers	45-50°	90-95
Firm ripe tomatoes	45-50°	85-90
Pumpkins, winter squash	50-55°	70-75
Sweet potatoes	55-60°	85-90
Mature green tomatoes	55-70°	85-90
California grapefruit	60°	85-90
Lemons	32-60°	85-90



Air temperature produced by cooler.

TABLE 2. Summary of Evaporative Cooling Trials

	Tomato	Sweet pepper	Zucchini squash Test #1	Zucchini squash Test #2	Crooked-neck squash
Weight cooled (lb)	540	100	588	168	168
Airflow (cfm)	580	385	502	510	510
Airflow/wt (cfm/lb)	1.1	3.9	0.85	3.0	3.0
7/8 cooling time (min)	120	75	100*	75	75
Average initial pulp temp (°F)	74	90	87	84	85
Average pulp temp at 7/8 cool (°F)	61	63	—	69	69
Average dry bulb temp (°F)	65	72	98	80	80
Average wet bulb temp (°F)	52	56	71	64	64
Average temp of cooled air (°F)	55	60	74	67	67

*Calculated from 1/2 cooling time data.

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