fails to meet the stem diameter requirement of the spear grade or bead quality is not quite good enough for the spear grade. Heads, or portions of heads, having over-mature beads are "culls." The term "chop" comes from the practice of chopping this material into small pieces before packaging and freezing.

Graph 1 shows yield trends of spears, chop, culls, and a combination of spears and chop. "Zero" day on the graph is the day of highest yield of spears. The yield curve for spears shows that there was a five-day period when yield of spears exceeded 5,200 lbs per acre. During this time the yield of spears and chop combined was increasing at the rate of 464 lbs per acre per day. Five thousand pounds per acre of spear grade broccoli exceeds the average yield in Ventura County.

In the harvest five days before the peak yield of spears, most of the chop material was made up of heads too small to be graded as spears. In harvests two days prior to the peak yield of spears, or later, most of the chop material consisted of branches trimmed from large heads that were too mature for the spear grade.

In computing the graph line to show the yield trend of spears and chop, the data for the harvest five days before the peak yield of spears were omitted because yield increase during the first three-day interval was at a lower rate than later on. No heads were graded "cull" until four days after the peak yield of spears.

For a crop in which both yield and quality are changing rapidly from day to day, a simple objective means of predicting the best days to harvest is highly desirable. Graph 2 does little more than show that sampling a field to determine the percentage of the crop making spear grade cannot be used to predict a good harvest date. The reason is that, at the same time the percentage of heads making spear grade is being increased by heads reaching the required stem diameter, it is also being decreased by heads becoming over-mature. Until an objective method based on field sampling is developed, the time for harvesting will have to be based on good judgment of farmers and field men.

Cooling trials with

PLASTIC TRAY PACK NECTARINES IN VARIOUS CONTAINERS

F. G. MITCHELL • R. A. PARSONS • GENE MAYER

Studies were conducted on the effect of side venting patterns on the cooling rate of nectarines in several commercial containers, and in a container with a new experimental design. The location of vents had some effect on cooling rate, but the differences did not appear to be commercially important. Dividing the vent area into a large number of small openings substantially slowed room cooling (the cooling of containers by placing them in a cold room) without improving uniformity. Room cooling was speeded considerably when the side vent area was increased to about 6 per cent. However, further increases in the vent area only slightly speeded room cooling. The value of vent areas greater than 6 per cent, especially when located along top or bottom score lines, must be weighed against their potential weakening effect on the container. When forced-air cooling was used (the forcing of cold air through the container and around the fruit) the cooling time was directly related to vent area regardless of size and location. The design of the experimental container facilitated air circulation, resulting in only small differences in cooling time between the 3.8 and 5.6 per cent side vent openings. The use of this container design and the choice of container venting may depend upon the results of static stacking tests which were not included in these studies.

SOME CALIFORNIA peach and nectarine shippers used corrugated paperboard containers during the 1970 season as an alternative to wooden lugs for tray-packed fruit. The tray pack consists of two layers of fruit in light-weight plastic trays. To be successful such containers must permit the fruit to be promptly and thoroughly cooled. The tests reported here were made to compare the cooling rate of nectarines in several types of corrugated containers and in wood lugs, and to evaluate the venting needs for satisfactory cooling.
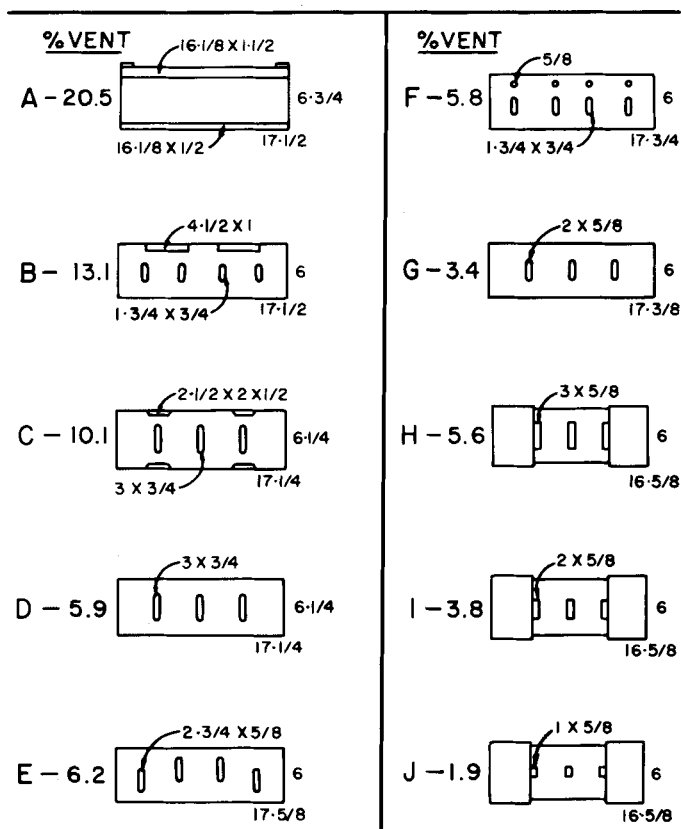
Test procedures

Tests were conducted in a cooling tunnel that had been demonstrated capable of duplicating full pallet cooling results. Refrigeration was supplied by placing the tunnel in a cold room. Air was drawn through the tunnel by a centrifugal blower and was controlled by a calibrated, sharp-edged orifice plate.

Each type of container was tested under both room cooling and forced-air cooling. Room cooling is accomplished by circulating cold air past containers which are placed in the cooling room. Cooling depends upon the conduction of heat through container walls, and upon some turbulence and mixing as cold air moves past container vents. Forced-air cooling is a University-developed system whereby the air supply is forced to pass through the containers and around the fruit for recirculation. The intimate contact between the product and the coolant air substantially reduces the cooling time. In these forced-air cooling tests the ratio of air volume to fruit weight was similar to that recommended for room cooling.

Six packed containers of known weight were placed in the tunnel two layers deep and three packages long as shown in

%VENT

A – 20.5   16-1/8 X 1-1/2   6-3/4
16-1/8 X 1/2   17-1/2

B – 13.1   4-1/2 X 1   0 0 0 0   6
1-3/4 X 3/4   17-1/2

C – 10.1   2-1/2 X 2 X 1/2   0 0 0   6-1/4
3 X 3/4   17-1/4

D – 5.9   3 X 3/4   0 0 0   6-1/4
17-1/4

E – 6.2   2-3/4 X 5/8   0 0 0 0   6
17-5/8

%VENT

F – 5.8   5/8   0 0 0 0   6
1-3/4 X 3/4   17-3/4

G – 3.4   2 X 5/8   0 0 0   6
17-3/8

H – 5.6   3 X 5/8   6
16-5/8

I – 3.8   2 X 5/8   6
16-5/8

J – 1.9   1 X 5/8   6
16-5/8

sketch. The top, sides and bottom of the tunnel were insulated to simulate a "core" through a loaded pallet. Periodic temperature measurements were obtained with a multipoint recording potentiometer and copper-constantin thermocouples placed 7/8-inch deep into size 70 (2 5/8-inch diameter) nectarines. The initial fruit temperature was 70 to 72°F and the coolant air was 33°F.

Through a series of tests, a curve was developed for both forced-air and room cooling of the plastic tray-packed wood lug (container A, diagram 2). Following this, containers B through G (see diagram) were spaced 1 inch apart and room cooled. Air flow was adjusted to create a 0.01-inch (water gauge) pressure drop across the test fruit in the simulated pallet "core." This provided an air velocity of 350 to 400 ft per minute past the containers. Room cooling measurements were thus collected under conditions of speed and uniformity which would be achieved only under ideal commercial cooling conditions.

Each of these containers was also forced-air cooled by eliminating spacing and adjusting air flow to create a 0.40-inch pressure drop across the fruit.

Venting patterns shown in H, I and J (see diagram) were developed for an ex-perimental container (provided by the International Paper Company) on the basis of results obtained from containers B through G and evaluated as in the previous tests.

All data are presented as times required to cool the slowest cooling fruit in a container 7/8 of the distance between its initial temperature and the temperature of the cooling medium. For example, fruit with an initial temperature of 70°F, placed in 33°F air, would be 7/8 cooled when it reached 38°F (38 is 7/8 of the distance between 70 and 33). Even 90°F fruit placed in 33°F air would be 7/8 cooled when it reached 40°F. Thus wide variations in initial fruit temperatures have little effect on the 7/8 cooling temperature.

Cooling times compared

Cooling times for all tests are shown in the table. Among the commercial corrugated containers—B through G—there was a wide range of venting positions, areas and patterns. These variations had little effect on uniformity of cooling between the top and bottom layers of fruit in the container. While there is a general relationship between side venting percentage and the time required for cooling, there are some discrepancies which

appear to be due to the venting pattern used.

Room cooling was speeded only slightly when containers had vent areas greater than 6 per cent, such as provided by scoreline vents in containers B and C. The value of the added venting is questionable in view of its minor benefit in cooling and its potential effect on container strength. For example, containers C and D were identical except that the top and bottom scoreline vents were eliminated from container D. This 42 per cent reduction in side area venting slowed room cooling by only 5 per cent. However, reductions below 6 per cent in side venting can greatly slow room cooling, as shown by container G, with 3.4 per cent venting—requiring 62 per cent longer to room cool than container E with 6.2 per cent venting.

The room cooling rate of container F was 30 per cent slower than would be anticipated by its venting area. This slow cooling was apparently caused by a restrictive effect resulting from dividing the vent area into a large number of small openings. This venting pattern did not improve cooling uniformity.

The forced-air cooling time, in contrast to room cooling time, was more closely related to venting area. With the exception of container D, the cooling time among containers A through F was very uniform. When air pressure across the containers was 0.4-inch (water gauge) the fruit was cooled within 3.3 to 4.2 hours.

Experimental container

The experimental container (H, I and J in diagram) was constructed with wrap-around end panels which projected beyond the outside dimensions of the top, bottom and sides. All vents were placed in the inset section of the side panels to avoid blockage during stacking and to allow contact with circulating cold air during room cooling. The vent sizes that were selected provided 5.6, 3.8 and 1.9 per cent of side vent area open. The results of these tests are shown in the table.

Air flow (cubic ft per minute per pound of fruit) required to maintain the same static pressure difference during forced-air cooling is increased by this design because some air sweeps between containers rather than going through side vents. Data in the table show that the amount of side venting is less important with this design. Only an 11 per cent difference occurred in cooling time between containers H and I which had 5.6 and 3.8 per cent side venting, respectively.

Cooling curves (see graph) for these experimental containers were estimated from the curve developed for the wood lug. Under forced-air, the difference in cooling time between fruit in containers H and I and other comparably vented containers is small, and of questionable commercial importance. Cooling was considerably slower in container J, with 1.9 per cent side vent area. This venting is not recommended.

One advantage of the experimental container that could not be evaluated in these tests was the possibility of maintaining open side vents despite gross stacking errors. This could be an important consideration in commercial practice, since containers are seldom stacked with sufficient accuracy to assure side vent alignment. Commercial variations in air velocity, air movement patterns, and pallet placement in the cold room might cause the experimental containers to perform better than indicated in these tests. The results with the experimental container indicate that the design feature that allows air to circulate around the container can augment side venting in improving room cooling efficiency.

Fruit in the standard wood lug cooled faster in a room cooler than all but one of the tested containers. However, fruit in containers with a side vent area of 6 per cent or more cooled in 16½ hours or less as compared with the 12½ hour cooling time for fruit in wood lugs. A side vent area smaller than 6 per cent is not recommended. Score line vents decrease cooling time only slightly and, because they may weaken the container substantially, are not recommended. Three or four large side vents allow the fruit to cool faster in a room than many smaller vents with the same total area. Fruit can be cooled two to three times faster if air is forced through the containers. Containers should have about 5 to 6 per cent side area for rapid forced-air cooling. Greater vent area may be used, but does not substantially decrease the cooling time. This test evaluated only the effect of these various containers on fruit cooling. These containers were not evaluated for static stacking strength or for their ability to successfully transport fruit.

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Cooling test tunnel used to simulate cooling in the "core" area of a pallet. Cutaway diagram shows positioning of the six tray pack containers and air flow pattern during a typical test. Air passes through an orifice plate in plenum (air) chamber to allow measurement.
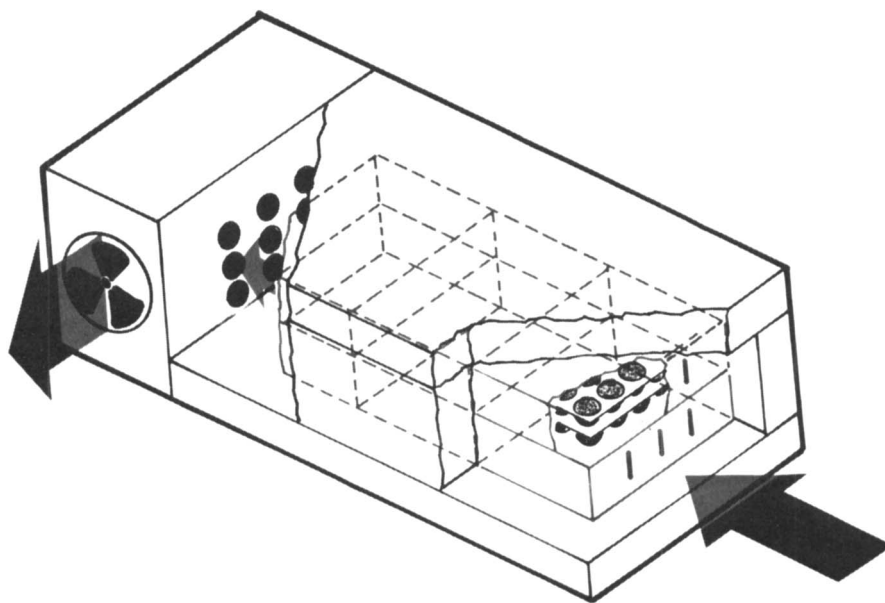
COOLING RATES OF PLASTIC TRAY PACK NECTARINES IN VARIOUS CONTAINERS
Slowest 7/8 cooling times

Container Type*	Side area vented	Room cooling top	Room cooling bottom	Forced-air (0.40" H₂O) volume	Forced-air (0.40" H₂O) top	Forced-air (0.40" H₂O) bottom
	%	hrs.	hrs.	cfm/lb	hrs.	hrs.
A	20.5	12.5	12.2	1.76	3.0	3.6
B	13.1	10.7	11.0	.77	3.1	3.3
C	10.1	12.4	13.8	.75	3.7	3.6
D	5.9	14.5	14.5	.58	5.4	4.7
E	6.2	16.5	16.5	.48	4.2	4.2
F	5.8	18.0	20.0	.48	4.1	4.1
G	3.4	26.8	26.8	.49	7.2	6.2
H	5.6	15.8	13.5	1.30	4.8	4.4
I	3.8	17.5	16.2	1.04	5.3	5.0
J	1.9	27.8	27.8	.98	7.9	8.5

* For container and vent patterns, see diagram (opposite page).
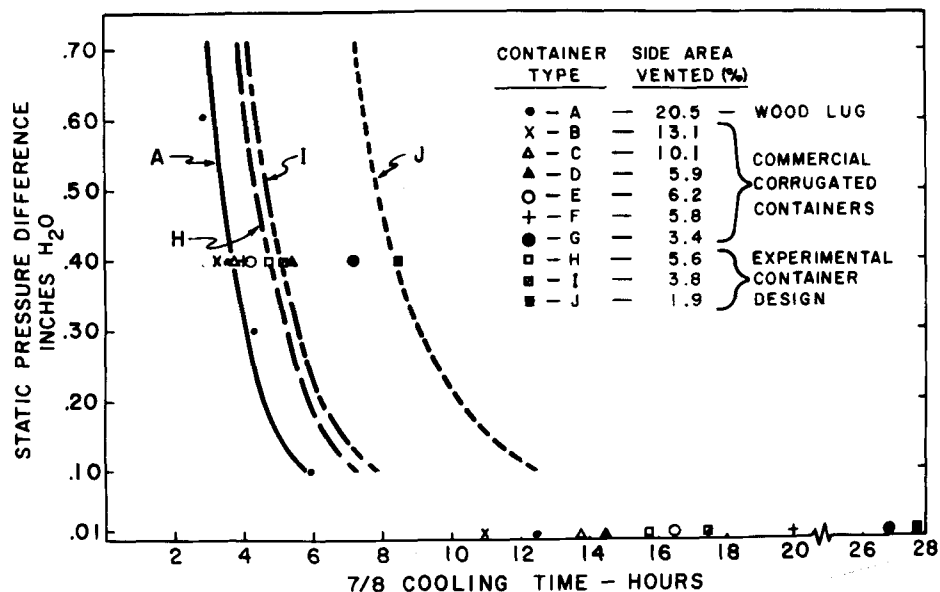
The effect of static pressure on the time required to cool plastic tray pack nectarines in various containers. The cooling curve for container A (diagram) is plotted from test results. Data for all other containers (B through J) are plotted at static pressure differences of 0.01-inch and 0.40-inch water. From these data, cooling curves are estimated for the experimental container with venting patterns, H, I and J. The static pressure difference is the measure of the pressure drop between the air entering and leaving the column of fruit in the test chamber.