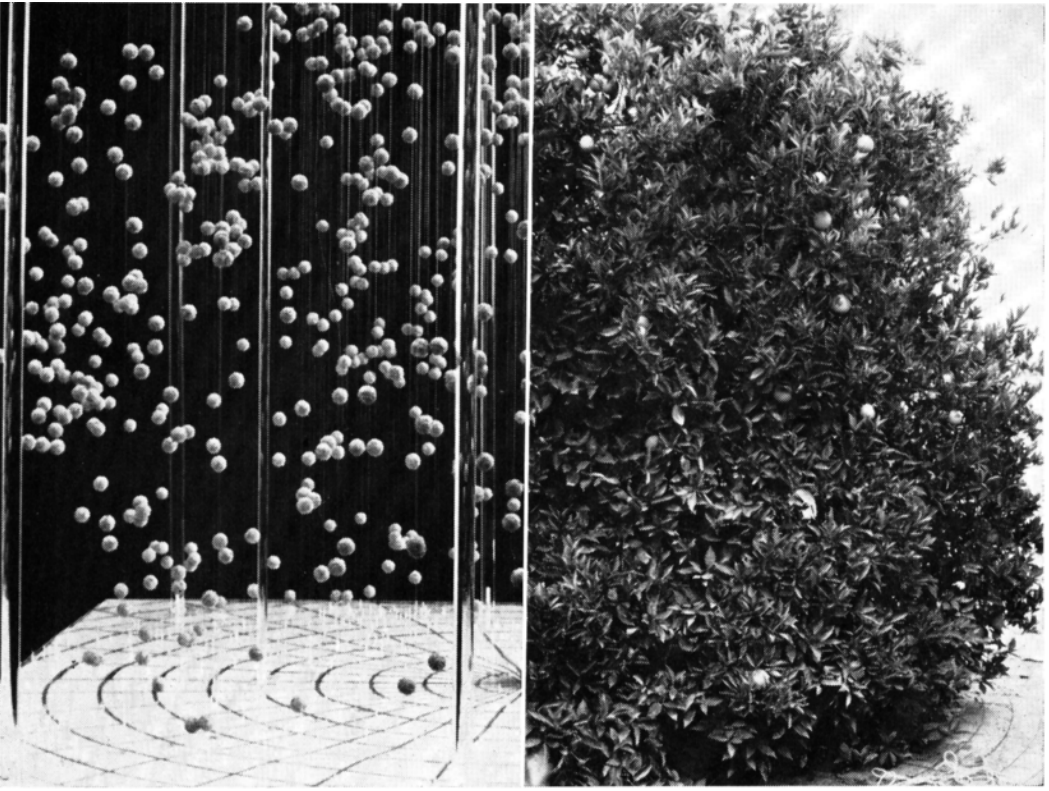

C. E. SCHERTZ · G. K. BROWN

Complexity of fruit removal problem in citrus is indicated in composite photo above (and cover) showing three-dimensional model of location of oranges on half a tree, to left, and actual photograph of the opposite half of the tree, to right.

THE LOSS OF the bracero labor supply has stimulated interest in the status of harvest mechanization of California's many crops. Solutions to the many unsolved problems of citrus harvesting are made even more difficult because approximately 75% of California citrus is shipped for fresh marketing.

Short-range solutions

It appears that short-range solutions involving (1) picker aids (in terms of improved clippers and man positioners) and (2) fruit handling systems, hold the greatest promise for the near future. Research and development work on man positioners is being actively continued by the University of California and many industrial organizations. The U.C. machine developed by R. J. Smith, Agricultural Economist, U.C., Riverside, was demonstrated, along with six other man-positioning machines, at a recent exhibit.

As with many other agricultural operations, a series of economic-political pressures have left mechanization as the only alternative. Pressures for mechanization of citrus harvesting will most likely increase, and it appears necessary to anticipate changes and consider possibilities for total mechanical harvesting of the citrus crop.

The general trend in mechanization of crop harvesting has been for the systems to evolve, at least in part, from equipment successfully used with other crops. This has been the case for small grain and forage crops as well as certain deciduous fruits. A harvesting system for citrus may develop from successful mechanization of some other tree crops, including shake-and-catch equipment. While such adaptation has been questionable in the past, it may appear more realistic as new research develops.

Research toward total-harvest has been underway for 2½ years by U.C. and USDA agricultural engineers in cooperation with the Departments of Biochemistry and Horticultural Sciences at the Davis and Riverside campuses. The University of California research project, "Development of Mechanized Citrus Fruit Harvesting Systems," and the USDA research project, "Equipment and Methods for Harvesting and Field Handling of Citrus Fruits," include studies ranging from basic research on the formation of the abscission layer and on the fruit-bearing habits of a tree, to applied research including the design and testing of specific harvesting components. The tree and fruit must be understood before development work can proceed with assurance.

Tree characteristics

Characteristics of the tree and fruit are being studied to determine those which lend themselves to effective harvesting. For example, the removal force when pulling perpendicular to the core axis for oranges is one-sixth of that when pulling colinear with the core axis. However, pulling perpendicular to the core axis gives a more favorable separation. Other findings indicate that the application of torque about the core axis tends to separate the orange from the tree with some stem. Removal by this latter method may require a destemming operation on the harvester, or a means of protecting fruit from stem punctures if the destemming operation is located remotely.

Bearing zones

Studies are being made to determine fruit-bearing zones within the tree. This knowledge is important both to the development of mechanical harvesting systems and to the development of man-positioning machines. Zones of heavy fruit concentration must be penetrated in both cases; whereas, economics must be considered in zones of extremely light fruit set. Tree training by pruning, shaping, shading, or other methods may be effective in forcing the tree to give an optimum combination of quality fruit in zones compatible with removal and collection systems. Various training methods are being investigated.

The limits of tree injury and leaf removal, without adversely affecting the tree's future production, are also being studied. It is essential that the allowable

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MECHANIZATION OF CITRUS HARVESTING

This article briefly describes the various areas of research presently underway, by University of California and U. S. Department of Agriculture, aimed specifically toward total citrus harvest mechanization. The article considers: (1) the phases of work being performed, (2) the relationships of the phases to the overall objective, and (3) the coordination of the work among the research disciplines. It also points out that at the present stage of research, the total mechanization of California citrus harvesting is not imminent.

limits be known to avoid being overly restrictive in the design of practical harvest components. The mechanical limitations in handling the fruit are also being studied.

Basic studies are in progress on the formation of the abscission layer to determine if a chemical, electric potential, or other means can be used in reducing the bonding force of the abscission layer. If the strength of the abscission layer can be reduced, the chances for success with a mass removal system are improved. Such a system might include limb or trunk shaking methods (which are successful with some deciduous fruits), oscillating air blasts, oscillating tines, stripping tines, canopy shaking, or maybe explosives. The feasibility of these methods is being investigated.

Removal methods

If mass removal is effective in releasing the fruits, the fruit must travel some distance unprotected through the tree, which can result in fruit injury. Research indicates that tree training influences the extent of this injury. If injury from falling through the tree cannot be tolerated, an intermediate catching device may be necessary. Such a device with troughs that enter the tree to collect the fruit is being developed.

An individual removal system may penetrate the tree canopy in a preset pattern and remove those fruits within its picking zone, or it may have a sensor to limit the penetrations to the points where fruit is located. An approach between these two in complexity would be to have the removal device penetrate the canopy in a preset pattern, with sensors to activate the device only when it is near a fruit. This would permit the use of a removal device that did some damage to the tree during activation; whereas, the damage might be intolerable if such a device were to be activated continuously.

Selectivity

Investigations are being made of selective criteria suitable for differentiation between mature fruit, leaves, and other plant portions. Of the methods investigated, those of light reflectance, electrical capacitance, and gamma-ray back scatter indicate greatest promise. Methods involving electrical resistance and temperature appear nonselective.

While some of the research being conducted in several areas of this problem at present has been encouraging, other results have been negative, and the mechanization of California citrus harvesting does not appear imminent. The outline included here contains a breakdown of research areas being pursued and lists the names of the personnel conducting the work in each phase:

OUTLINE OF RESEARCH UNDERWAY ON CITRUS HARVEST MECHANIZATION

I. Fruiting Habits
- A. Fruit bearing zones in trees (C. E. Schertz, G. K. Brown)

II. Removal Forces
- A. Pull force (C. E. Schertz)
- B. Torque (C. E. Schertz)

III. Effects on Tree
- A. Effects on tree from mechanical injury to stems and branches (L. N. Lewis, C. D. McCarty)
- B. Effects on tree from leaf and/or stem removal (L. N. Lewis, C. D. McCarty)
- C. Effects on tree from application of chemicals to promote formation of abscission layer (L. N. Lewis, C. D. McCarty)
- D. Effects on tree from pruning and tree shaping (L. N. Lewis, C. D. McCarty)
- E. Effects on tree from application of externally applied voltage (J. Molitorisz)
- F. Effects on the environment of the tree from artificial shade (C. E. Schertz, G. K. Brown)

IV. Effects on Fruit
- A. Effects on fruit from drop through tree (I. L. Eaks, G. L. Rygg, C. D. McCarty, C. E. Schertz, P. A. Adrian)
- B. Limitations of mechanical loading (I. L. Eaks, G. L. Rygg, R. L. Perry, R. B. Fridley, C. E. Schertz)
- C. Effects on fruit from various methods of application of removal force (C. E. Schertz)
- D. Effects on fruit from freezing the zone of the abscission layer (C. E. Schertz)

V. Picking Aids
- A. Single clip lemon clipper (G. K. Brown)
- B. Vacuum fruit remover (J. Molitorisz)
- C. Fruit conveyance from picker to container (G. K. Brown)
- D. Man-positioners (R. L. Perry, R. M. Perkins [with R. J. Smith]; J. Molitorisz)

VI. Selection Criteria
- A. Light reflectance for selection (G. L. Zachariah, P. A. Adrian, C. E. Schertz)
- B. Electrical capacitance (G. L. Zachariah, C. E. Schertz)
- C. Electrical resistance (C. E. Schertz)
- D. Gamma-ray back scatter (C. E. Schertz)
- E. Temperature (C. E. Schertz)

VII. Fruit Removal Devices
- A. Oscillating tines (C. E. Schertz, G. K. Brown)
- B. Rotating stripping tines (C. E. Schertz)
- C. Vertical oscillating air (J. Molitorisz)
- D. Explosives (C. E. Schertz, P. A. Adrian)
- E. Canopy shaking (C. E. Schertz, G. K. Brown)
- F. Limb and trunk shaking (P. A. Adrian, R. B. Fridley)
- G. Vacuum twist remover (C. E. Schertz, G. K. Brown)
- H. Rotating cutoff cylinder (C. E. Schertz)

VIII. Fruit Collection Devices
- A. Intermediate catching troughs (C. E. Schertz)

C. E. Schertz is Assistant Professor, Department of Agricultural Engineering, University of California, Davis; C. K. Brown and P. A. Adrian are Agricultural Engineers, AERD, USDA, Davis; R. B. Fridley and G. L. Zachariah are Assistant Professors, Department of Agricultural Engineering, U.C., Davis; R. L. Perry is Professor and R. M. Perkins is Assistant Specialist, Department of Agricultural Engineering, U.C., Riverside; J. Molitorisz is Agricultural Engineer, AERD, USDA, Riverside; I. L. Eaks is Plant Physiologist, Department of Biochemistry; L. N. Lewis is Assistant Horticulturist, Department of Horticultural Sciences; C. D. McCarty is Extension Horticulture Technologist, U.C., Riverside; and G. L. Rygg is Research Plant Physiologist, ARS, USDA, Pomona.