MECHANICAL HARVESTING

for green asparagus

U.C. nonselective asparagus harvester. A hand-cut row is at the immediate right of the harvester and a selective machine row is adjacent on the left, both of which were disked 26 days earlier. The second row to the left is a nonselective row just before harvesting.

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RESULTS OF 1968 TESTS INDICATE THAT SUBSTANTIAL REDUCTIONS IN YIELD OF GREEN ASPARAGUS CAN BE EXPECTED WITH SELECTIVE MECHANICAL HARVESTING, AS WELL AS WITH NONSELECTIVE HARVESTING. UNDER PRESENT CONDITIONS A GROWER'S NET PROFIT WOULD BE REDUCED IF HE CHANGED FROM HAND CUTTING TO EITHER SYSTEM OF MECHANICAL HARVESTING. A MORE DETAILED REPORT ON THESE TESTS IS AVAILABLE, UPON REQUEST, FROM THE DEPARTMENT OF AGRICULTURAL ENGINEERING, UNIVERSITY OF CALIFORNIA, DAVIS.

THE COST OF HARVESTING California asparagus by hand currently amounts to about 45 per cent of the gross income. During recent years, labor for hand cutting has become less efficient and more difficult to obtain, resulting in renewed interest in mechanical harvesting.

Two approaches, selective and nonselective, have been used in the development of mechanical harvesters for green asparagus. A selective mechanical harvester attempts to duplicate the hand-cutting operation, cutting all spears taller than a preselected height and leaving the shorter spears for subsequent harvests. A nonselective harvester cuts all spears, regardless of length, each time the field is gone over. Although a nonselective harvester was developed at Davis by the Department of Agricultural Engineering in the 1950's, it is only within the last two or three years that any selective harvesters have progressed to the point of field-worthiness.

To permit an economic evaluation of selective-versus-nonselective harvesting, plot tests were conducted during the 1968 canning and freezing season to compare yields from a commercially available selective harvester, the University of California's nonselective harvester, and hand cutting.

Selective harvester

The selective harvester used in these tests was a Hart-Carter Model 39, updated with current modifications. A limited number of these machines was manufactured for sale in 1967. At the time of these tests the Hart-Carter was the only selective asparagus harvester known to be commercially available. It is a pull-type machine with 11 selection channels, each covering a 2¾-inch width of row. Each channel has a trailing knife attached to a pair of flexible cables (similar to a speedometer cable) that is dragged along the ground surface. Horizontal leaf-type springs attached to the bottom portions of the dividers hold the two cables of each pair together at the front. A spear that is tall enough to be contacted by the leaf springs is guided between the two knife cables for that channel and is subsequently cut by the knife. Because shorter spears are not guided between the two cables of any unit, they are bypassed by the knives.

The selection height is adjusted by raising or lowering the entire harvester. Spears tall enough to be selected are gripped between pickup belts that hold the spears during cutting and then lift them and drop them onto an inclined draper belt. In a commercial operation the asparagus is discharged into a pallet bin carried on the rear of the machine. In these tests, however, the asparagus was collected in a shallow pan just below the discharge point.

Nonselective harvester

The U.C. nonselective harvester was built in 1956 and tested in 1957 and 1958. It is a self-propelled unit built onto a modified small tractor. Sheet-metal dividers with their bottoms about 2 inches above the flat-top beds guide the standing spears into a series of 14 rotating gripper units, each covering a 2½-inch width of row. A bandsaw type of blade, passing around the four large pulleys visible in the photograph, cuts all spears at or just below the ground surface immediately after they have been gripped. The cut spears are elevated by the grippers, dropped onto a grooved cross-conveyor belt, and ultimately deposited in a box at the left front of the machine. Spears shorter than about 3½ inches are cut but not recovered, since the gripping level is 3½ inches above the blade. A gage roller on top of the bed, at the rear, maintains a constant height relation between the harvesting unit and the bed surface by actuating a valve in the hydraulic lift system.

Test procedure

The tests were conducted in a seven-year-old planting of Variety 500W located 3 miles east of Courtland on a Columbia silty loam soil. Rows were spaced at 6-ft intervals. A randomized block design was used, with eight replications of each of the three treatments. Each replication consisted of 220 ft of row.

To initiate the tests, all beds were disked in the conventional manner on April 9. Rows to be harvested mechanically were then gone over with a special crowder-type shaper that produced flat-top beds. The hand-cut and selective machine rows were reworked once during the tests. The nonselective rows did not need to be reworked because cutting at or just below the ground surface, as was done during these tests, effectively controls weeds on top of the beds. However, a rotary-hoe arrangement was used on the nonselective beds immediately after the sixth cutting to break a firm crust that developed after a rain a few days earlier. The crust-breaking operation had no noticeable effect on the yield.

The selective harvester was set for a selection height of 6 to 7 inches. It was operated at 1.7 miles per hour except on two rows that were cut at 2.6 miles per hour during the last half of the season. The nonselective harvester was operated at 2.5 miles per hour, except that four rows were cut at 3.25 miles per hour during the last half of the season.

Ten nonselective cuttings were made during the 58-day test period at intervals of four to seven days, the objective being to make each cutting when about 5 per cent of all spears over 3¾ inches tall were taller than 12 inches. The selective machine rows were harvested daily during warm weather and every other day during cool periods. Hand-cut rows were harvested daily by University of California personnel.

Results

Spear length distributions for the machine treatments are shown in table 1. The spears from selective harvesting that were shorter than about 6 inches were a result of machine performance characteristics (spear breakage, high cuts, knife cables spreading and engaging short spears, etc.). In counts made on the selective machine rows twice during the season, 15 per cent of the stumps on the beds were over 2 inches tall and 6 per cent of all the stumps were "brushed out."

As indicated in table 2, the percentage of spears with open heads (culls) was more than twice as great for both machine-harvested treatments as for hand cutting. Mechanical damage (side plus tip) amounted to 9.2 per cent of the total trimmed weight for the selective harvester and 4.2 per cent for the non-selective harvester. The 1.7 per cent tip damage in the hand-cut treatment is much less than would be expected in a commercial operation.

Hart-Carter selective harvester in asparagus test plot.

Yields and ratios of machine yields to U.C. hand-cut yields are compared in table 3. Yields for the machine treatments were based on the 4½-inch trimmed weight of spears initially 4¾ to 16 inches long plus the 3½-inch trimmed weight of spears initially 3¾ to 4¾ inches long. Hand-cut yields were based on 4½-inch trimmed weights.

The weight of good 3½-inch trimmed spears amounted to 18 per cent of the total good trimmed weight for nonselective harvesting and 3 per cent for selective mechanical harvesting. Yield ratios in relation to *commercial* hand cutting probably would be somewhat higher than indicated in table 3. Factors contributing to the yield differences are summarized in table 4.

With the selective harvester, percentages of mechanical damage and missed spears were both greater at 2.6 miles per hour than at 1.7 miles per hour, as reflected in the yield ratios shown in table 3.

When there was no crust on top of the beds, the performance of the nonselective harvester at 3.25 miles per hour was fully as good as at 2.5 miles per hour. In the one cutting where there was a firm ¼-inch crust, the nonselective harvester missed 8 per cent of all spears over 3¾ inches at 2.5 miles per hour and 10 per cent at 3.25 miles per hour (as compared with 3.6 per cent when there was no crust).

Other tests

Three other organizations conducted plot tests during the 1967 and 1968 seasons to compare yields from selective mechanical harvesting and hand cutting, and Rutgers University conducted tests with a nonselective harvester in 1960. These tests by others included the Hart-Carter machine and three different kinds of selective harvesters with power-actuated knives instead of trailing knives.

The results from the several sources are reasonably consistent and indicate that yield losses of current selective harvesters with power-actuated knives are comparable with those from the Hart-Carter harvester. Yield ratios from these tests are included in the detailed report. In general, it appears that if yields are based on 3½-inch plus 4½-inch trimmed weights, a nonselective harvester such as the U.C. machine might recover 50 to 60 per cent as much good yield as from *commercial* hand cutting, and the better selective harvesters might recover 55 to 65 per cent of the hand-cut yield.

Economic analysis

Capacities and labor requirements for selective and nonselective harvesters are compared in table 5. Labor requirements (man-hours per acre for machine operator) are about five times as great for selective mechanical harvesting as for nonselective harvesting, and machine overhead plus operating costs are three to four times as great as for nonselective harvesting. Thus, a selective harvester must recover a higher percentage of the potential yield than a nonselective harvester to be economically comparable.

The accompanying graph shows calculated harvesting costs for one-row and three-row harvesters in relation to crop acres per machine. A 55-day harvest season was assumed, with 10 nonselective cuttings or 45 selective cuttings during this period. Values assumed for the various cost factors involved are included in the detailed report. A useful harvester life of seven years was assumed. New prices for self-propelled nonselective harvesters were estimated at $6,000 for one-row, and about $12,000 for three-row machines.

The new prices of $4,500 and $12,000 indicated on the graph for pull-type selective harvesters could represent models with power-actuated knives. New prices and annual costs per acre probably would be a little lower for trailing-knife harvesters such as the Hart-Carter. In comparison with the values shown for the $12,000 pull-type harvester, the annual cost per acre for a three-row self-propelled selective harvester used on 100 acres would be about $5 greater if the new price were $16,000 and $40 per acre greater if the new price were $25,000.

The curves in the lower half of the graph show machine-plus-labor costs. The upper group of curves includes charges for assumed yield losses of 40 per cent for selective mechanical harvesting and 50 per cent for nonselective harvesting. Note that with these loss percentages the cost per acre with any of the harvesters is substantially greater than shown for hand harvesting.

Break-even yield ratios can be determined from the grid in the lower right-hand portion of the graph. At the break-even ratio, which is applied only to good spears, the machine-plus-labor cost per acre, plus the value of the yield loss, is equal to the hand harvesting cost. The graph indicates that as the potential yield is increased, a higher percentage of yield reduction can be tolerated with no decrease of net profit, in comparison with hand harvesting (i.e., break-even ratios become smaller).

Although the costs shown in the graph are based largely on estimates for the various factors, the following generalizations probably would not be invalidated by any likely changes in cost factors:

(a) A one-row selective harvester does not appear to be economically feasible, even if operated 20 hours per day.

(b) A three-row selective harvester needs to be operated on a two-shift basis to minimize costs per acre.

(c) With nonselective harvesters the total cost per acre for 10 hours operation per day is very little greater than for 20 hours per day.

(d) Even if break-even yield ratios can be achieved for large acreages, the economic feasibility of mechanical harvesting is questionable for fewer than 30 to 50 acres.

Design improvements on some of the current selective harvesters could substantially reduce losses and thereby improve their economic feasibility. Yields from nonselective harvesting would be significantly increased if an asparagus variety were developed that would cycle after each cutting. Using plant populations several times greater than are now considered normal, with the possibility of greatly increasing the potential yield per acre, is a promising approach now being investigated by many of the plant breeders.

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ESTIMATED COMPARATIVE MECHANICAL HARVESTING COSTS FOR ASPARAGUS IN RELATION TO ACREAGE PER MACHINE—6-FOOT ROW SPACING

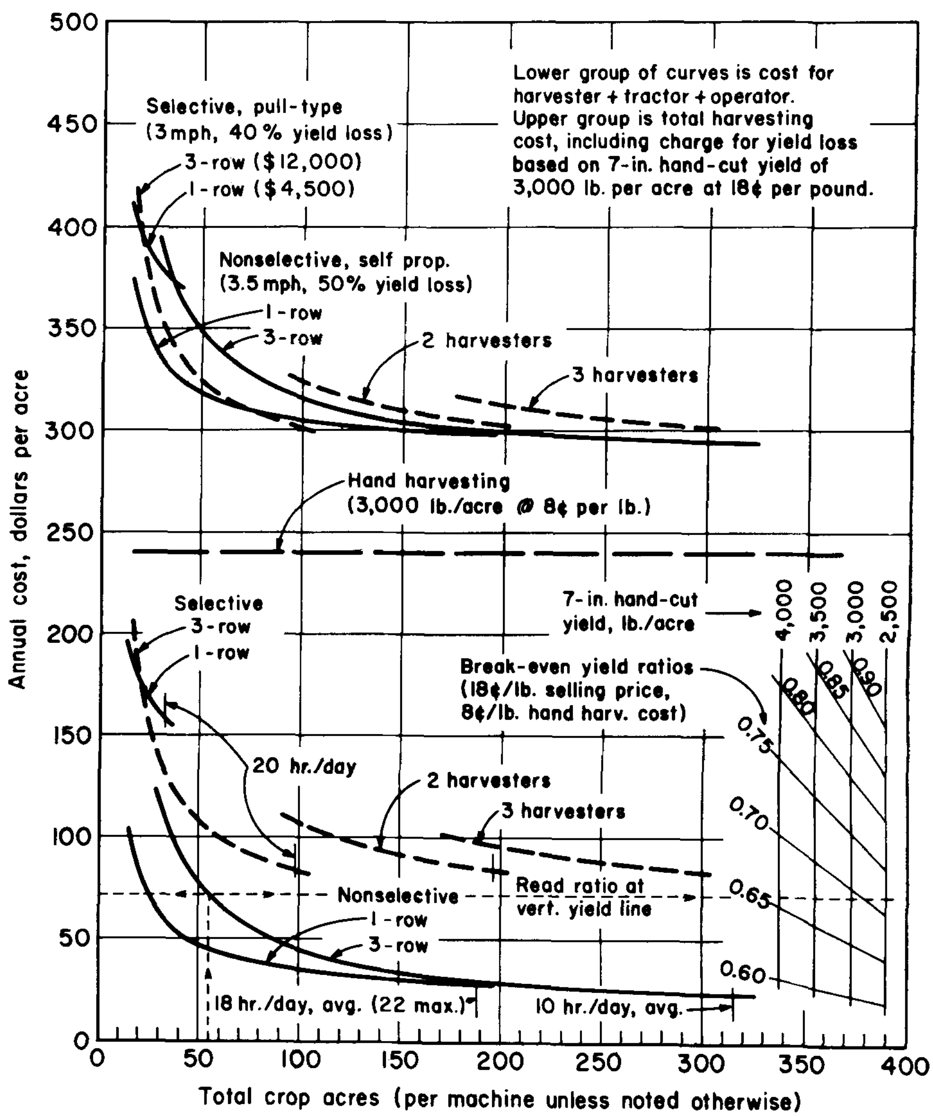

TABLE 1. LENGTH DISTRIBUTION FOR ASPARAGUS SPEARS OVER 3/8-INCH DIAMETER PRODUCED ON MACHINE-HARVESTED BEDS

	Nonsel. on-time cuttings	Selective One-day cuttings	Selective Two-day cuttings
Number of cuttings	6	21	13
Total No. of spears*	16,950	9,950	10,500
Percentage of total number of spears			
0–3¾" length	52.8†	12.0	11.7
3¾–4¾" length	8.4	5.5	5.5
4–6¾" length	10.3	16.2	13.5
6–8" length	12.0	35.6	30.2
8–10" length	9.1		
10–12" length	5.0	30.7	39.1
12–16" length	2.3		
Over 16" length	0.1		

* Totals for nonselective cuttings obtained by counting all emerged spears over 3/8-inch diameter just prior to each cutting. Selective totals are recovered plus missed spears.

† Determined by subtraction. All other percentages are based on counts made after harvesting and include recovered plus missed spears.

TABLE 2. CULL PERCENTAGES IN ASPARAGUS HARVEST TESTS

	Percentage of total trimmed weight: Hand	Selective (1.7 mph)	Nonselective (2.5 mph)
Tip damage	1.7	7.5	3.5
Side damage	0.0	1.7	0.7
Open heads	5.1	12.6	11.2
Crooks and misc.	5.1	3.8	6.4
All culls	11.9	25.6	21.8

TABLE 3. COMPARISON OF ASPARAGUS YIELDS FROM MACHINE AND HAND HARVESTING

	Good Spears	Good + culls
Total yields, lbs. per acre*		
Hand-cut	2,030†	2,310†
Selective machine (1.7 mph)	1,080	1,445
Nonselective machine	925	1,185
LSD, 1% level		126
Yield ratios, machine ÷ hand		
Selective, 1.7 miles per hour	0.53	0.63
Selective, 2.6 miles per hour	0.50	0.61
Nonselective, 2.5 or 3.25 Miles per hour	0.46	0.51

* Yields are based on 3½-inch + 4½-inch trimmed weights of spears over 3/8-inch diameter and are for a period of 58 days.

† Equivalent to about 4,000 and 4,600 lbs. per acre on a 7-inch length basis.

TABLE 4. ANALYSIS OF ASPARAGUS YIELD DIFFERENCES FOR GOOD SPEARS PLUS CULLS*

	Selective	Nonselective
Number of spears produced, per cent of hand-cut	90	129†
Number of spears shorter than 3¾", per cent of total spears produced	12	53
Missed spears over 3¾" long, per cent of total over 3¾"	12.5	3.6
Weight per trimmed spear (3½" + 4½"), per cent of 4½" hand-cut	90	88

* All percentages based on spears over 3/8-inch diameter.

† Averaged 112 per cent for periods not affected by disking of hand-cut beds.

TABLE 5. MACHINE CAPACITIES FOR 6-FOOT ROW SPACING IN ASPARAGUS

	Selective 1-row	Selective 3-row	Nonselective 1-row	Nonselective 3-row
Assumed speed, miles per hour	3.0	3.0	3.5	3.5
Average acres per hour (25% lost time)	1.6	4.9	1.9	5.7
Days between cuttings	1	1	4–7	4–7
Assumed hours per day	20	20	10*	10*
Crop acres per machine	33	100	105	315
Man-hours per acre per year (independent of acres per machine)	28	9	5	1.7

* For average time of 5½ days between cuttings. Would be 12 hours per day at minimum interval of 4½ days in warm weather.

Wood processing RESIDUES *—disposal and use in Shasta County*

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WOOD PRODUCTS MANUFACTURE is a vital segment of the economy of Shasta County; however, as with most industry, it is not an unmixed blessing. Wood products manufacture is essentially a reduction process and residues generated at each stage have become increasingly acute in recent years. Operators are faced with the necessity of increasing the percentage of raw material converted to marketable products in order to maintain a competitive position. On the other hand, they are faced with increasing pressure from the community to reduce or eliminate the smoke and ash problems caused by common residue disposal methods.

Industry efforts

Industry efforts to reduce the problem through increased use of residues have been conducted sporadically by individual companies—not only in the Shasta area, but throughout the West. End glued lumber, pulp chips, particleboard, boiler fuel from waste wood, and horticultural products from bark are examples of the improved use of residues by Shasta County. Complete utilization is a difficult goal to achieve, however, even by the most efficient mills.

Paradoxically, increasing use of residues has made residue disposal more of a community nuisance. A properly operated teepee burner of the right size is relatively smoke and cinder free when burning the residues from a mill without by-product recovery. However, even the best burner operating techniques are not adequate to prevent smoke and cinders when the usable slabs, edgings and other large chunks have been removed. The sawdust, shavings and bark remaining tend to settle in a compact mass on the burner floor—making it virtually impossible to attain the temperature necessary for a nuisance-free operation.

Few solutions

Very few operators have been able to completely eliminate the problem. The Shasta County wood processing industry, recognizing a common interest in residue disposal progress, formed the Shasta County Forest Products Council with the specific task of coordinating the activities of its members and conducting research leading to reduction of the problem.

At the present time most mills have taken advantage of the obviously profitable uses for wood residues. What remains are, in general, a series of economically unattractive alternatives. Industry management must select the least undesirable of these options. The Forest Products Council's request to the University of California for a study of the amount of residues developed at individual mills in the County was made to give industry an informed approach to the problem. The study was undertaken as a cooperative project with the University's Agricultural Extension Service and Forest Products Laboratory, supported in part by a grant from the Council. Only member firms of the Council were included and basic data were supplied by the cooperating firms. This information was supplemented by data collected in field studies, when it was necessary.

In 1966, the cooperating mills processed more than 391 million board feet of logs containing an estimated 60 million cu ft of wood and an estimated 12 million cu ft of bark. Lumber processed in planing mills and by other secondary manufacturers totaled more than 458 million board ft. The amount of residue generated in the processing of wood is dependent on the size, soundness and species of the logs, the efficiency of the operation, and the products produced. The estimated totals for the cooperating firms are given in tables 1 and 2.