Asparagus harvester in peat field. A cut row of schedule A (mixed green and white) is shown at left, with hand-cut bed immediately to its right. Note the dust cloud behind the harvester.

Mechanical Harvesting Feasible

THE IMPENDING SHORTAGE of labor for harvesting asparagus has caused renewed interest in mechanical harvesting. Because California produces virtually all the white asparagus grown in the United States, and because the percentage of California production harvested as white asparagus has increased during the last few years, current emphasis is on the development of a harvester for this product. Results obtained with an experimental harvester for green asparagus were reported about seven years ago in *California Agriculture*.

White asparagus is cut at a depth of 8 to 10 inches below the ground surface, because the exposed portions of the spears turn green after emergence above the top of the bed. In hand-cutting, each spear is cut within a day after the tip becomes visible above the ground.

Tractor-mounted machine

The mechanical harvester used in tests reported here was similar to one built by Magnuson Engineers, San Jose, California, in 1951, under contract with the California Asparagus Advisory Board. This machine, which is mounted on a high-clearance tractor, cuts all spears at a depth of 8 to 9 inches with a bandsaw-type unit. Behind the blade is a series of three rolls that successively lift the cut spears (more or less vertically) so a mesh-type conveyor can get beneath them. The conveyor elevates the spears as most of the fine soil falls through the mesh openings. In these tests, spears, trash, and clods were discharged onto the top of the bed and the spears were then picked up by hand.

Test plots

One test plot was in a 6-year-old planting of variety U. C. 711 on a peaty muck soil, on Staten Island. A second plot was in a 16-year-old planting of variety U. C. 500 on a fairly heavy clay loam soil just west of Thornton. Row spacings were 7 ft in the peat field and 7½ ft in the clay loam.

In each of the two test plots, four 400-ft rows distributed across the plot were hand-cut daily by University personnel, as white asparagus. Four rows (identified as schedule A) were machine-cut at a depth of 8 to 9 inches when a few spears were taller than 8 inches above the top of the bed, thus producing some spears that were all green after trimming to 4½ inches. Four other rows (identified as schedule B) were machine-cut at a depth of 8 to 9 inches when just a few spears showed more than 1½ inches of green tip. (Present cannery standards for white asparagus allow up to 1½ inches of green tip.)

The tests were initiated on April 21 in the peat plot and April 24 in the clay loam plot, when all beds were split out and reshaped with a ridging disk. A special, crowder-type bed shaper was then used on the machine-cut rows to form beds 11½ to 12 inches high in the peat plot and 13 inches high in the clay loam plot and having flat tops 16 to 18 inches wide. In the peat plot the tops of most crowns were then 2 to 4 inches below the cutting level. The crowns in the 16-year-old clay loam plot, however, were so high that even with the higher beds the cutting level was barely above the crowns.

Bed preparation

Because the beds in the clay loam plot were extremely cloddy, all rows were gone over several times with combinations of a tandem disk harrow, rotary hoe, and cultipacker, before the final ridging. The

Comparative yields for hand cutting and nonselective mechanical harvesting of white asparagus were determined during the 1964 cannery season, using an experimental harvester. In the tests, the machine-harvested all-white treatment on a peat soil produced 72% as much weight of good, white asparagus as did the hand-cut rows. A rough cost analysis indicates that, under these conditions, nonselective mechanical harvesting may be economically feasible. Results were less favorable in a 16-year-old planting on a clay loam soil. Mechanical harvesting caused the beds to dry out more than hand cutting and increased the tendency for the peat soil to blow.

R. A. KEPNER

GRAPH 1, AVERAGE DAILY YIELDS OF AS-PARAGUS AND WEATHER DATA FOR THREE TREATMENTS IN THE PEAT PLOT.
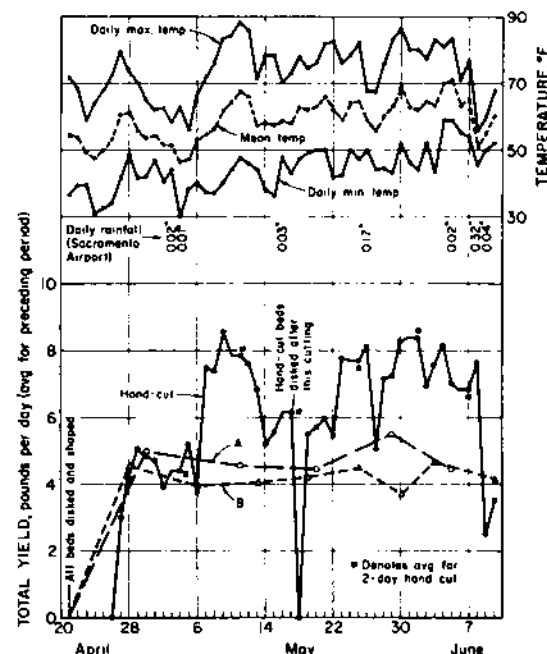
for White Asparagus

machine-cut beds were also rototilled down almost to the tops of the crowns (some were hit) to provide loose soil for the bandsaw blade. The rototilling treatment may have been so severe as to affect yields.

Machine-cut beds were reshaped with the special crowder after each cutting. Hand-cut beds were disked once during the tests (but not split out), in accordance with usual grower practice. The tests in the peat plot covered a seven-week period corresponding approximately to the cannery season. The tests in the clay loam plot were discontinued after a month because the yields were low and erratic and considered not typical, partly because of the age of the beds.

The beds of the peat machine-white treatment were cut and reshaped seven times during a six-week period in which there was no rain. The repeated stirring up and reshaping caused the top and outer layers of soil in these beds to become quite powdery and increased their susceptibility to being blown by wind. The peat beds dried out down to the cutting level but, perhaps because of a high water table, remained moist below this level.

Machine performance

The combination of elevating rolls and wire-mesh-type conveyor with 1½-inch hex openings did an excellent job of getting the cut spears out onto the tops of the beds. Occasional checks made by hand digging over distances of 5 to 10 ft revealed very few missed spears longer than 1 to 2 inches. The performance of the conveyor in separating clods and trash from the spears was unsatisfactory, however. In the clay loam plot, clods discharged from the rear of the conveyor broke many cut spears on top of the beds. Further development is needed to improve separation and to provide an acceptable system for getting the spears into a container.

Bandsaw blades were made from wood-cutting blade material 0.022 inch thick and ¾ inch wide and had four teeth

GRAPH 2, DISTRIBUTION OF MACHINE-CUT ASPARAGUS SPEARS IN RELATION TO HARVESTED LENGTH IN PEAT TEST PLOT, 1964.

Cutting schedule	Cutting numbers	Total no. of spears
A	2-5	6,600
B	2-8	7,700
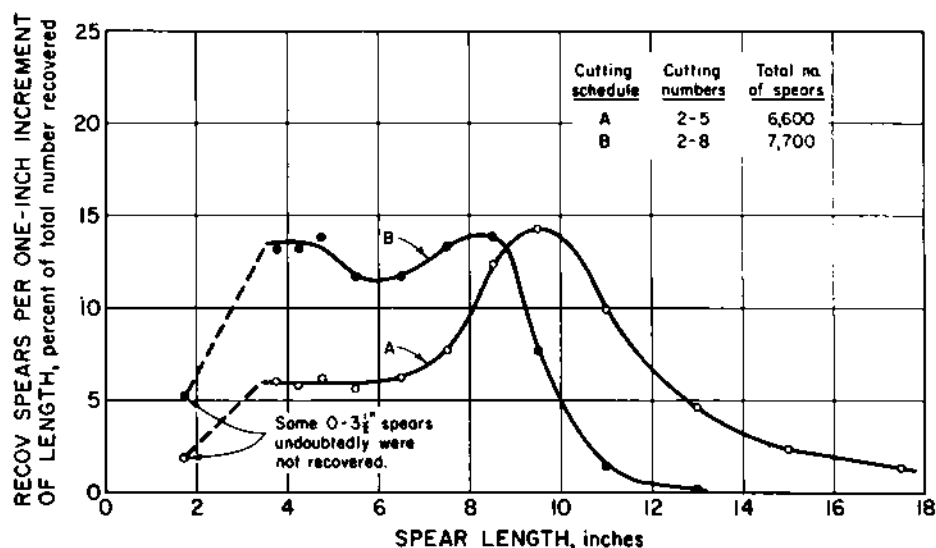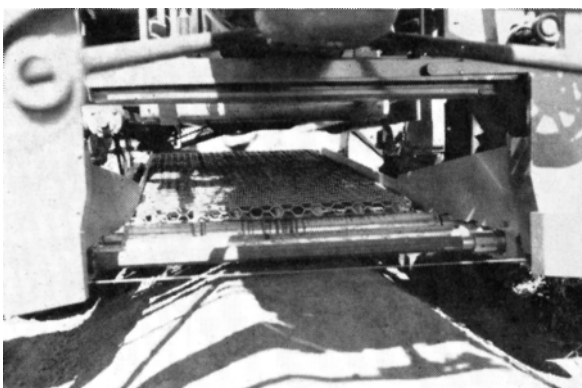
Close-up front view of asparagus harvester showing band-saw blade, series of three rolls that initially lift spears, and mesh-type elevator-separator behind rolls.
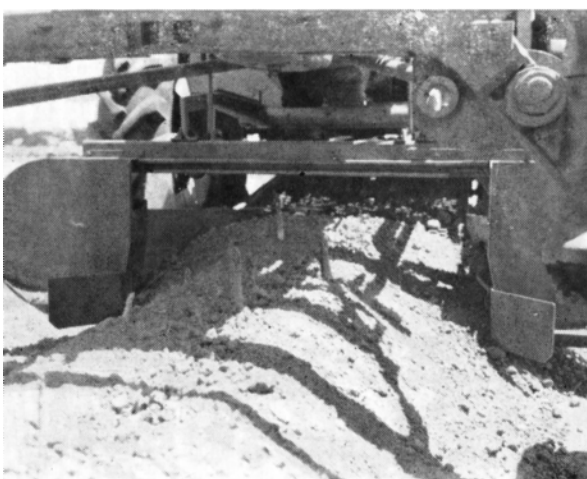
Close-up front view in operating position on a row of schedule A in clay loam field.

Bed shaper used on machine-cut rows, shown in peat field.

per inch. The linear speed of the blade was 2,400 ft per minute. This unit did an excellent job of cutting in the peat at the forward speed of $2\frac{1}{4}$ miles per hour used in all the tests. Although the rate of wear was rather high, a blade should last for perhaps 5 to 10 hours. Only one blade was broken in the peat plot and that was because it cut into a crown.

In the clay loam plot, the teeth would wear off in less than $\frac{1}{2}$ mile of row. Blades broke frequently, usually from hitting either a crown or a firm section in the bed. It is probable that some other type of cutting unit will be needed for sedimentary soils.

Growth characteristics

Time intervals between cuttings for the peat plot ranged from 5 to 8 days for schedule B (white) and from 7 to 11 days for schedule A (green-and-white). The interval decreased as the average daily temperature increased. Minimum intervals might have been at least half a day shorter if there had been any hot weather during the tests.

The distribution of machine-cut spears in relation to harvested length is shown for the peat plot on graph 2. Each curve is the average for all cuttings except the first one. The graph shows that the distribution for schedule B was rather uniform between $3\frac{1}{2}$ and 9 inches, whereas schedule A produced the greatest concentration of spears in the 8- to 11-inch range. Schedule A averaged only one-third as many 0 to $3\frac{1}{2}$-inch spears per day as did schedule B. In both plots schedule A seemed to show more of a cycling tendency than did schedule B.

Omitting the period of the first machine cutting because of the influence of the original disking, the average number of spears recovered per day from each machine treatment in the peat plot, including 0 to $3\frac{1}{2}$-inch lengths, was only 85% as great as the number from the hand-cut treatment. Some of the 15% difference undoubtedly was due to short spear tips that were not recovered by the harvester. Considering the entire period of the tests, there was no difference in the average number of spears per day from the machine-cut treatments and the hand-cut treatment in the peat plot.

There was no appreciable difference between hand-cut and machine-cut white spears in regard to average weight per spear after trimming to $4\frac{1}{2}$ inches, but the weight of the top $4\frac{1}{2}$ inches decreases as the spear grows taller after emerging from the bed.

Yields

All hand-cut spears and all machine-cut spears longer than $4\frac{1}{2}$ inches were trimmed to a final length of $4\frac{1}{2}$ inches. Machine-cut spears in the as-harvested length range of $3\frac{1}{2}$ to $4\frac{1}{2}$ inches were trimmed to $3\frac{1}{2}$ inches. For comparative purposes, yields were based on weights of these trimmed lengths, excluding spears with butt diameters less than $\frac{3}{8}$ inch. These lengths represent the final canned product. As an intermediate step, spears longer than 7 inches were trimmed to 7 inches and weighed, this representing the present basis for payment to growers.

Average daily yields for each of the three treatments in the peat plot are shown in graph 1. Cumulative yields are shown in graph 4, where each point represents the total production to that date. Culls are included in both hand-cut and machine-cut yields to provide a comparison between the potential yields without regard to the amount of damage caused by a particular machine. Yield curves for the clay loam plot (not shown) are similar to those for the peat plot except that yields were lower.

The distribution of machine-cut asparagus, in regard to culls and various color combinations, is shown in the table. Percentages given are averages for all cuttings and are based on weights of spears over $\frac{3}{8}$-inch diameter. Culls from the hand-cut beds averaged 7.7% of the total weight for the peat plot and 9.0% for the clay loam plot.

Graph 3 shows diagrammatically the differences between average daily yields from the three treatments and the division of total production into culls and various color combinations of good spears. Note

DISTRIBUTION OF MACHINE-CUT SPEARS BY CLASSIFICATION

Classification	Per cent of total 3½" + 4½" trimmed weight			
	Peat		Clay loam	
	A	B	A	B
3½" good (all-white)	4.7	10.4	7.4	14.4
4½" good, white or green-tipped (not over 1½" green)	45.0	68.8	37.5	56.3
4½" good, all-green	11.2	0.6	15.8	3.6
4½" good, part green (over 1½" green)	25.0	8.5	23.0	12.8
Culls (total, 3½" + 4½")	14.1*	11.7	16.3	12.9

* Includes 4.2% all-green culls (mostly seedy or open heads) and 9.9% white or part white culls.

that in both fields the *total* production was substantially greater for the machine A schedule (green-and-white) than for the machine B schedule (white). This relation still exists if culls are eliminated, although the difference is smaller. If the good spears that are part white but have over 1½ inches of green are considered unmarketable, then the B yield was greater than the schedule A yield. The tops of the dotted sections of the bars indicate the comparative yields for good white or green-tipped spears.

The mixed green-and-white cutting (schedule A) was included in the test program at the suggestion of canners who were hopeful that enough green asparagus would be produced to meet an appreciable portion of their demand for this product. The results were disappointing in that only about 15% of the good spears were all-green, whereas over 25% were part white with more than 1½ inches of green. At present, the canners can see no potential market for these part-white spears.

Hand-cut yields

Total hand-cut production per plot and machine-versus-hand yield ratios for the entire test period are summarized in the table. The production of good hand-cut spears in the peat plot during the 50-day period represented a yield of 1,650 lbs per acre, based on the 7-inch weights. The good hand-cut yield in the clay loam plot was about 70% as great as for the peat plot during the same period.

Three considerations regarding the yield ratios should be kept in mind: (1) the overall ratio tends to become smaller as the season progresses (or if the tests are extended) because the effect of the machine advantage gained in the first cutting becomes less –as illustrated on graph 4 showing cumulative yields; (2) the 1964 season was unusually cool and experience with green asparagus indicates that hot weather tends to favor hand cutting more than nonselective machine cutting; and (3) the hand-cut yields obtained by University personnel

in these tests were undoubtedly higher than would have been obtained with a commercial crew.

Additional studies are needed to obtain yield information for other field and environmental conditions and to determine the long-range effects of nonselective harvesting upon yields and growth characteristics.

Cost comparison

A one-row mechanical harvester operating at 3½ miles per hour in a field having a 7½-ft row spacing should average about 2½ acres per hour. One machine, operated for a maximum of 10 hours per day, could then handle about 175 acres under schedule A or 125 acres under schedule B.

A rough cost analysis was made, based on the above capacities and making assumptions needed to estimate the various cost factors. The charge for loss of yield was based on a hand-cut selling price of 12 cents per pound (7-inch length). Hand harvesting costs were assumed to be 4 cents per pound for cutting and sledding, plus $25 to $30 per acre for miscellaneous costs (housing, labor supervision and transportation, sled carts, etc.).

This analysis indicates break-even yield ratios of about 0.65 for the green-and-white treatment (A) and 0.67 for the machine-white treatment (B). At the break-even yield ratio the total cost of mechanical harvesting, including a charge for yield loss, is equal to the saving resulting from the elimination of hand cutting and sledding. Harvester overhead and operating costs (labor not included) represented only 10 to 20% of the calculated total costs at the break-even ratios. The most important factor affecting overall cost relations is the ratio between the cutting-and-sledding cost per pound and the selling price.

The 0.72 yield ratio obtained for good spears in the peat B schedule is slightly better than the break-even ratio indicated by the rough cost analysis. Thus, nonselective mechanical harvesting of white asparagus appears to be economically
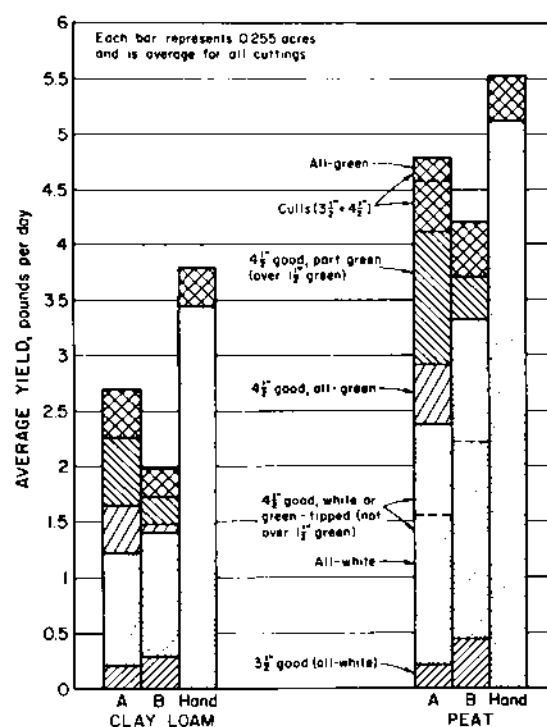

GRAPH 3, COMPARATIVE YIELDS AND SPEAR CLASSIFICATIONS FOR ALL TREATMENTS IN BOTH TEST PLOTS.

feasible under the conditions encountered in the 1964 peat-field tests.

R. A. Kepner is Professor, Department of Agricultural Engineering, University of California, Davis. Assisting in the tests were R. E. Cowden and J. L. Koon, Department of Agricultural Engineering; M. Zahara, Department of Vegetable Crops; W. L. Sims, Extension Specialist in Vegetable Crops; and J. P. Underhill, County Director, Agricultural Extension Service, Stockton. The tests were conducted in fields owned by the M & T Company (Clair Davis, field manager) and Louis Sartini.

GRAPH 4, CUMULATIVE YIELDS FOR THE THREE TREATMENTS IN THE PEAT PLOT. PLOTTED POINTS REPRESENT CUTTING DATES.
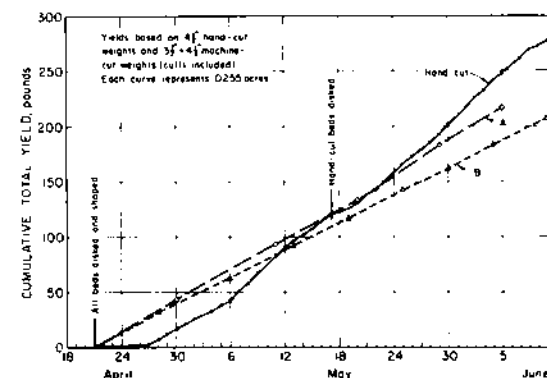
SUMMARY OF COMPARATIVE YIELDS

Field and cutting schedule	Total time, days	Total 4½" hand-cut yield, lb*	Yield ratio, machine : hand		
			Total, good + culls	Good, all colors	Good, white + green-tipped + all-green†
Peat A	45	250	0.87	0.80	0.63
Peat B	50	278	0.75	0.72	0.72
Clay loam A	31	119	0.71	0.65	0.46
Clay loam B	29	109	0.53	0.51	0.48

* Yields in this column are for about ¼ acre and include culls.
† Machine yields used for the last column include enough part-white spears with more than 1½ inches green to represent 10% of the total white + part white (the present hand-cut tolerance allowed by canneries).