MECHANICAL HARVESTER DEVELOPMENT AT THE CALIFORNIA AGRICULTURAL EXPERIMENT STATION

Roy Bainer 1/

The objective of the harvesting studies carried on at the California Agricultural Experiment Station during the past year has been to remove machine-topped beets from the ground reasonably free of clods and to load them into a truck ready for delivery to the dump in one operation. In addition to this work, several Marion wheel beet harvesters were tested under different field conditions.

The 1943 model of the experimental harvester was mounted on a Model C Allis-Chalmers row-crop tractor. Accessory equipment consisted of coulters and jointers, mounted 10 inches apart on the front axle of the tractor, for cutting and removing leaf streamers, trash, and soil from the area adjacent to both sides of the row. This provided the necessary clearance for the ends of the topping knife to prevent fouling of the blade.

The variable cut topping unit was mounted under the tractor about midway of the wheel base. The basic principles underlying the construction of this topping unit were presented by Powers at the 1940 and 1942 meetings of the American Society of Sugar Beet Technologists. (1) (2) For this reason, a description of the topper will be omitted. The topping unit has proved to be functionally satisfactory. Some changes in the form of simplification and more rugged construction are contemplated in further development work.

Three different systems have been demonstrated for handling the tops from the experimental topper. They are (1) a horizontal single conveyor, (2) a vertical double draper conveyor and (3) a revolving leaf deflector. With either of the first two methods, the tops may be windrowed, piled, or loaded into a hopper and carried to the end of the field. A simple rotary deflector was used during the past season since the development work was concentrated on the recovery of beets. The leaf deflector left the tops in single rows.

The beet recovery system employs a double-pointed plow having helical shaped blades. The blades were made from pieces of 3/8 inch by 3 inches plow steel 20 inches long, warped in such a manner that one edge of the blade remains straight throughout, and the other edge is revolved 90° about the straight edge as an axis. The blades which were attached to standards had their lead-

(1) Powers, J.B. Basic Principles Used in the Development of an In-Place Type Variable Cut Sugar Beet Topper. ASSBT Proceedings. 266-273, 1940.
(2) Powers, J.B. A Mechanical Beet Topper, ASSBT Proceedings 1942. In press.

1/ Agricultural Engineer, University of California.

ing edges 8 inches apart and nearly vertical and their trailing edges 2 inches apart in a horizontal position. The action of the plow is two-fold. First, as the soil passes between the blades, sufficient pressure is applied to crumble it. Since the top side of the points operate approximately 3 inches below the ground surface, slabs of soil of that depth ride over the plow. Second, the warped surface of the blades exert an upward force against the soil adjacent to the beets thereby lifting them, and at the same time, providing an upward force against the center of the slab of soil riding over the plow. Spring loaded chains, driven at ground speed and located just inside of each plow standard, ride over the slab of soil flowing over the plow, thereby exerting downward forces near the outer edges of this slab. The downward pressure exerted by the chains at the outer edges of the slab, when combined with the upward force exerted by the warped surface of the plow at the center, cause longitudinal fracturing of the slab throughout its central axis along the beet row.

A pair of lugged gathering chains, operated around idlers attached to the underside of the horizontal sections of the plow blades, engage the lifted beets by their tap roots as they emerge at the rear of the plow throat. These chains are operated in an inclined position (25°) with respect to the ground and are driven approximately 10 percent above ground speed. As the machine moves forward, the beets are elevated above the ground to be transferred later into a conveyor. The frame that supports the chains, and protects them from dirt is put together to form an inverted "V", or roof. As the pieces of broken soil slab slide onto this rooflike section, they are shed off laterally to each side, thus effecting a separation of large soil particles or clods from the beets. Since the gathering chains grasp the beet by the tap root in a soil-free area immediately below the plow, there is no opportunity for them to engage anything other than the beet tap roots. Ruffled belts attached to the inside of the sloping ground chains tend to steady the large beets thus preventing them from toppling over and breaking loose from the gathering chains.

The beets are discharged from the inclined gathering chains when about 15 inches above the ground. Since they are all oriented by the plow mechanism as they are carried up, this orientation is maintained in the final elevator. The final lifting elevator was built in L section with V-shaped flights spaced on 3-inch centers. The beets are deposited on the horizontal leg of the L with their axis perpendicular to the flights and with their crowns leading. A second ruffled belt hugs the beets against the flights as they are turned 90° to the vertical leg of the L and elevated upwards. The vertical section of the elevator is 6 feet long. The beets are discharged from this leg of the elevator into a chute which extends into a combination bin and conveyer. The wide spaces between the elevator flights permit a maximum separation of entrained and adhering soil from the beets. The fact that most of the beets are oriented while in the elevator permits high-speed operation thus inducing a jolt to the beets against the deflecting shield as they leave the elevator. This contributes to further separation of adhering soil from the beet.

A conveyer bin, 18 inches wide, 12 inches deep, and 15 feet long, mounted at an angle of 15° with the horizontal over and along one side of the tractor, received the beets from the chute. The discharge end of the conveyer is approximately 8 feet above the ground and extends forward beyond the front of the tractor which permits loading directly into a truck. The capacity of the conveyer is about 1000 pounds and the floor conveyer speed is regulated to receive the beets as they are harvested. The 1/2-ton conveyer-bin capacity took care of 400 feet of row in beets yielding 33 tons per acre. When the bin was ready for unloading, a gear shift device permitted unloading into a truck in 10 seconds Five tons were loaded onto a regular beet truck by repetition of this method without resorting to hand placement.

During the past season, this machine was used for harvesting approximately 125 tons of beets. Attempts were made throughout the harvest to improve the unit rather than try for quantity production. Considerable improvement resulted as the season progressed. Early in the season a valve actuated through a linkage from the topper was added to the hydraulic system of the plow lift. As the topper followed the contour of the ground surface adjacent to the beet row, the plow depth was automatically controlled at a fixed distance below the level of the topper. A steering indicator was added, making it possible for the operator to use the position of the topper finder instead of the coulters for guiding the unit. This helped considerably because the finder operates nearer to the plow, thereby giving a better indication of the position of the row with reference to the plow throat.

The greatest single factor influencing the proper operation of the machine was that of operating on row. The unit performed satisfactorily when held fairly close to the row. The small tractor, upon which the harvester was mounted, was deficient in power, traction and stability. Lugged steel wheels were finally substituted for the rubber tires and a small towing tractor was used to take part of the load late in the season. These changes helped materially in keeping on-row. Field experience indicated the plow, which is now mounted behind the rear axle, should be moved forward at least to the center line of the rear wheels in order to provide better control.

The use of a suitably powered tractor no doubt would lend stability to the operation. At the same time, a larger tractor would be capable of carrying a conveyer bin with at least twice the capacity of the present one. This would make it possible to carry the beets accumulated in a 1/4-mile row where the yield is not over 20 tons per acre.

The experimental harvester was operated at speeds of $2\frac{1}{2}$ to 3 m.p.h., which provides a harvesting rate of 3 to 4 acres per day, depending upon the availability of hauling equipment and the length of the rows. In short runs where turning consumes a higher proportion of the time, the acres harvested per day will be less.

Approximately one-half of the test runs were made under dry soil conditions. The average dirt tare at the dump amounted to 6.6 percent which shows satisfactory separation of beets from clods under dry soil conditions. Beets harvested the second day after a 1-1/4-inch rain carried 18 percent dirt. The amount of dirt carried up with the beets decreased to 12.9 percent on the fourth day following the rain. Most of the dirt hauled in with the beets following the rain was loose soil that could be readily separated through the use of an open conveyer in place of the tight bottomed chute that was used between the vertical elevator and the final conveyer. The factory tare (top tare) averaged 3.9 percent for 125 tons hauled in from the machine. Unfortunately the only beets available, for trial runs made late in the season when the machine through development finally was capable of continuous operation, were some grown on the University farm. The yield for these plots ran between 30 and 34 tons per acre, and the root sizes ranged from 1 inch to 13 inches in diameter and up to 30 inches long. Clearance had been provided in the design only for 10-inch beets with the result that an occasional large beet stopped the final elevator requiring removal by hand.

The experimental harvester is now capable of at least 90 percent recovery, either in wet or in a cloddy soil. Missed beets are left on the surface of the ground in a convenient position for recovery by hand scavenging. Principles have been developed which when operating in sequences appear capable of solving the five problems of beet harvesting. Namely, (1) topping, (2) top recovery, (3) beet recovery, (4) soil removal, and (5) mechanical beet loading. The implementing of these principles in the 1943 unit has been admittedly poor, but late seasonal experience indicated they had commercial possibilities. The next step in our harvesting program is to construct a controllable properly powered field-worthy unit with which to conduct field tests on a practical scale.

The Marion Wheel Sugar Beet Harvester was originally developed by L. Schmidt and A. M. Jongeneel of Ryer Island, California. Thirty-five units were built for use during the past year by the Blackweler Machine Shop of Rio Vista, California. Most of the units were used in the Delta and Holland land districts of the lower Sacramento Valley. However, trials were made in sections where the soil was of the heavier sedementary types.

The machine consists of a 6-foot steel wheel with a 10-inch face, keyed to a 2-3/8-inch axle shaft and carried on a rigid frame by two ball bearings. Curved spikes (452 in number) are bolted to the wheel rim with the points leading approximately 3/4 inch when viewed from the top. The spikes are 5/16 inch in diameter and 3 inches long. They have a square shank which prevents them from turning when fastened in place. The spikes are located 2 inches apart in each direction. They are mounted four abreast which gives a width of 6 inches to the spike section.

A double-bladed plow is mounted on 3/4-inch by 6-inch standards in a position to be operated below and slightly to the rear of the center of the wheel. The plow operates approximately

10 inches below the wheel with an opening of 4½ inches between the points and 6 inches at the heel. An auxilary single-blade plow is mounted 37½ inches ahead and in line with the left standard. The purpose of this plow is to loosen the soil so that high beets can be forced down into the ground as the wheel rolls over them. The action of the plow is to break up the soil, loosen the beets and force the whole mass against the spiked wheel so that each beet will be impaled. Two 18-inch coulters mounted ahead of the plow standards assist in cutting trash.

The topping is done by a set of 5 stripper points located at a fixed distance (1½ to 2 inches) on the tangent to the surface of the wheel. The stripper points (chisels) are 1¼ inches wide and 6 inches long and slip over the ends of 15-inch arms. They operate between the rows of spikes with only 3/32 of an inch clearance on each side. The topped beets slide over the stripper points and arms onto a 4 roll Rienks screen which delivers them to an elevating conveyer for delivery to a truck. Another set of stripper points operated on contact with the surface of the wheel and immediately below the first set, clear the wheel of beet crowns and dirt. A cross draper receives this material conveying it to one side and depositing it in a windrow along side of the machine. The tops, in addition to being mixed with dirt, are run over by the trucking equipment, thus leaving them in a poor condition for feeding.

The wheel is driven through contact with the ground and beets. Other working parts are driven with a 3-5 h.p. engine. The wheel is raised by means of a power lift. The power required to pull the unit is a full load for a 35 or 40 h.p. tractor.

Data was taken on the machine operating under four different field conditions, The results are shown in the accompanying tables. Field conditions on the Peter Cook Ranch were the most favorable for the machine. The beets had been well thinned (96 percent stand), were uniform in size and did not extend much above ground level. The tops were small. The field had been irrigated with a rain machine so there was a total absence of furrows, The soil was friable in nature. On the Lawler-Parella Ranch the tops were quite heavy, the stand was spotted (80 percent in the test row) and the beets had grown up out of the ground 4 to 6 inches. The high-topping loss was attributed to heavy tops, high beets and to the fact that this machine did not have the auxilary plow ahead of the regular plow. The soil was somewhat heavier than that found on the Cook Ranch.

The soil to the Cardin Ranch is classified as Yolo sandy loam. It has a tendency to cement together upon drying with the result that it usually breaks up quite cloddy. The condition of the beets was quite similar to that found on the Cook Ranch, except that the stand was a little heavier (107 percent). The beets were planted 18 inches by 22 inches and furrow irrigated. While the number of unacceptably topped beets was slightly higher than on the Cook Ranch, the total loss of beets was less.

The run on the University Farm was made under very severe conditions. The yield of beets was high (36.6 T/A) and the tops were also heavy. (25.6 T/A - green weight). In addition, the large beets had grown out of the ground 6 inches or more and the thinning was poor (155 percent stand). Under these severe conditions, the machine recovered 97.4 percent of the beets, but did a poor job of topping. The unacceptably topped beets amounted to 46.6 percent by number - 25.9 percent by weight of the beet harvested.

In observing the machine in operation, many beets appear to come up loosely held. In fact, if it were not for the tops being matted in the spikes with tops of adjacent beets, they probably would not be lifted. It is difficult, if not impossible, for the machine to top these loosely held beets. In general, the recovery of beets is good but the topping is poor. Beets from the machine could not be stored for any length of time. Just how the high-top tare affects the processing of the beets is a problem, for the refiner.

The single-row machine will handle 3 to 4 acres a day. Two-row units will be available for next season. It has been estimated that the 35 machines handled about 6,000 acres during the past season.

The high overhead, partially due to high first cost, limits the economical use of the machine to large growers (100 acres or more), joint ownership, or contract operators.

TEST ON MARION WHEEL SUGAR-BEET HARVESTER

Operating on Peter Cook Ranch on the Holland Tract.
Length of run - 213 feet
Speed 4.2 mph. Yield 26.3 tons per acre. Light tops.

180 beets acceptably topped,	377.1 pounds
Top tare on above samples,	15.6 pounds
Percentage tare,	4.14 %
25 beets unacceptably topped, (12. % by number - 6.6% by weight)	26.7 pounds
Top tare on above sample.	6.0 pounds
Percentage tare,	22.4 %
205 beets harvested (total),	403.8 pounds
Top tare on total sample,	21.6 pounds
Percentage tare on total sample,	5.35 %
7 beets missed in row,	9.4 pounds
Beet loss as percentage of tared sample,	2.41 %
16 tap roots left in ground,	9.1 pounds
Tap root loss as percentage of tared sample,	2.33 %
Dirt and trash,	11.3 pounds
Dirt and trash as percentage of tared sample,	2.86 %
Topping loss,	6.9 pounds
Top loss as percentage of tared sample,	1.77 %
Top loss plus tap root loss plus beet loss,	6.51 %

Operating on the Lawler-Parella Ranch
Length of run - 230 feet
Speed 3.35 mph. Yield 15.4 tons per acre. Heavy tops.

146 beets acceptably topped,	203.2 pounds
Top tare on above sample,	6.0 pounds
Percentage tare,	2.95 %
40 beets unacceptably topped, (21.5 % by number - 16.3 % by weight)	39.8 pounds
Top tare on above sample	8.8 pounds
Percentage tare,	22.1 %
186 beets harvested (total),	243.0 pounds
Top tare on total sample,	14.8 pounds
Percentage tare on total sample,	6.07 %
Weight of beets missed,	0.0
17 tap roots left in ground,	8.1 pounds
Tap root loss as percentage of tared beets,	3.54 %
Dirt and trash.	12.2 pounds
Dirt and trash as percentage of tared beets,	5.07 %
Topping loss,	20.7 pounds
Top loss as percentage of tared sample,	8.36 %
Top loss plus tap root loss,	11.9 %

MARION WHEEL TESTS CONTINUED

Operating on Morris Cardin Ranch
Length of run - 219.0 feet
Speed 2.85 mph. Yield 21.0 tons per acre. Light tops.

171 beets acceptably topped,	277.6 pounds
Top tare on above sample,	8.8 pounds
Percentage top tare,	3.08 %
64 beets unacceptably topped, (27.2 % by number - 17.3 % by weight)	58.2 pounds
Top tare on above sample,	12.0 pounds
Percentage top tare,	17.1 %
235 beets harvested (total),	335.8 pounds
Percentage of tare on total sample,	5.84 %
5 beets missed in row - (2 in row, 3 with tops)	1.2 pounds
Beet loss as percentage of tared sample,	0.35 %
7 tap roots left in ground,	1.7 pounds
Tap root loss as percentage of tared sample,	0.50 %
Dirt and trash (clods - 12.5),	33.5 pounds
Dirt and trash as percentage of tared sample,	9.1 %
Topping loss,	14.5 pounds
Top loss as percentage of tared sample,	4.15 %
Top loss plus tap root loss plus beet loss,	5.0 %

Operating on University Farm
Length of run - 129.5 feet.
Speed 2.5 mph. Yield 36.3 tons per acre.
Weight of green tops 25.6 tons per acre.

102 beets acceptably topped,	287.5 pounds
Top tare on above samples,	23.0 pounds
Percentage top tare,	7.4 %
88 beets unacceptably topped, (46.6 % by number - 25.9 % by weight)	67.4 pounds
Top tare on above sample,	22.4 pounds
Percentage top tare,	25.0 %
190 beets harvested (total),	354.9 pounds
Percentage of tare on total sample,	11.3 %
8 beets missed - (6 with tops, 2 in ground)	4.7 pounds
Beet loss as percentage of tared sample	1.31 %
Tap roots left in ground,	2.0 pounds
Tap root loss as percentage of tared sample,	0.56 %
Dirt plus trash,	42.2 pounds
Dirt plus trash as percentage of tared sample,	10.6 %
Topping loss,	1.4 pounds
Top loss as percentage of tared sample,	0.39 %
Top loss plus tap root loss plus beet loss,	2.26 %