DEVELOPMENT OF A FLORIDA MECHANICAL CABBAGE HARVESTER

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Abstract

An experimental prototype cabbage harvester was redesigned from a first version, rebuilt and successfully field tested. It is a one-row, once-over, tractor-mounted, hydraulically-driven machine which grips the heads, cuts the stem above ground level, and conveys the severed heads to a receiving vehicle in register with the harvester. It is designed for a two man harvesting operation, one driving the tractor and controlling the harvester and one driving the receiving vehicle. Gripping of the heads is performed by two horizontally-opposed, cleated, flat, spring-loaded belts traveling rearward at the forward velocity of the harvester. Cutting is performed by a circular crosscut saw. Conveying is performed by two conveyors, one to convey the heads rearward from the side-mounted header and a second to convey across the rear and to elevate to the receiving vehicle. Cutting height is adjusted by hydraulically raising or lowering the header mechanism. A description of the harvester is presented as well as aspects of its expected performance in a total harvesting system.

INTRODUCTION

Cabbage for fresh market is an important vegetable crop in Florida's agricultural economy. The total value of the crop has averaged over 9 million dollars per year (4) for the past five years. Acreage harvested has averaged about 17,000 per year in the same period.

Costs for picking and packing cabbage in Florida (including hauling) averaged from $0.18 to $0.30 per crate (2) in three production areas over the past five years. This cost consists mostly of labor (2) and is increasing rapidly. It represents about 17% of the total crop costs, or a cost of over one million dollars per year to Florida growers.

The objectives of the development of this cabbage harvester were to reduce total production costs by substituting machinery for labor in the harvesting operation, to upgrade the quality and reduce the level of drudgery of labor remaining in the harvesting and packing operations, and to reduce the degree of dependence upon an increasingly less dependable and less available supply of labor.

LITERATURE REVIEW

The need for an improved harvesting system for cabbage was recognized as long ago as 1957 by Holmes and Halsey (7) who developed a harvesting aid which resulted in reduced labor requirements and reduced damage. A few years later projects to develop cabbage harvesters were independently initiated, first at Michigan State University (12), then at North Carolina State University (13) and at Cornell University (9, 10). It was recognized early in these programs that the physical properties of the cabbage head were important in determining how a harvester might function, and in each program such measurements were made. Other investigations in Florida by Halsey, et. al. (5, 6) centered on the relationships of yields and physical properties to the mechanical harvesting of cabbage.

The cabbage harvesters resulting from research at the other universities were quite different from each other. The Michigan State harvester was essentially a modification of a sugar beet harvester in which cabbages were guided by fingers to a V belt lifting mechanism which pulled up the entire plant; the plant was then transported to a pair of disc knives which cut the head from the root. The North Carolina
State harvester used a pair of discs to cut excess lower leaves from the undisturbed plant which was then gripped by two pair of spring loaded V belts until the head was cut from the root by a bandsaw blade. The Cornell harvester used two large discs to orient and to begin lifting the heads which were pulled from the soil and transported upward by a double chain and an overhead hold-down conveyor to a circular saw which cut off the root as the head was held between two wheels.

Recently several cabbage harvesters have been built by small manufacturers or individuals (1, 10) in Ohio and New York. Also, there has been considerable research effort in certain other countries, particularly Russia, to mechanize cabbage harvesting; evidently the Russians have built several machines using different approaches. Rehkugler, et. al. (9) has referenced several of these publications.

Functional Development of the Cabbage Harvester

Two approaches for mechanizing the harvest of any vegetable crop are once-over and multiple-harvest. Cabbage might be treated to either approach. The relatively low production costs, the relatively low value, and the relatively concentrated maturity are factors favoring a once-over harvest rather than a multiple-harvest. Efforts are being made through breeding programs and modification of cultural practices to obtain uniformly maturing cabbage, therefore increasing the likelihood of an economically feasible once-over harvest. In particular, direct seeding to eliminate variability introduced upon transplanting may ultimately result in greater uniformity. Growers are now harvesting as much as 80-90% of the heads at a single harvest; often it is not economically feasible to return for subsequent harvests to get those remaining. Shumaker (11) found several varieties with over 85% of the heads acceptable at a single harvest date. Another factor favoring a once-over harvest is that a selective harvester for multiple-harvesting would increase harvesting costs through increased fixed and operating costs. Therefore, the approach taken in this work was that of a once-over cabbage harvester.

The primary functions reasonably provided by a once-over cabbage harvester are: (1) Severing the head from the stem and (2) transporting the heads to a receiving vehicle. Secondary functions might include aligning the heads prior to cutting, locating the cutting point at some optimum location, removing excess leaves, pulling up the entire plant before severing head from stem, rejection of undesirable heads, and others.

It was decided to base the development of a cabbage harvester on the primary functions of severing the head from the stem immediately above ground level and delivering all heads to a receiving vehicle in register with the harvester.

Such a harvester easily integrates with present harvesting systems used in Florida by simply replacing the crew selecting, cutting and loading cabbages. It allows either a continuation of the present packing methods at the side of the field or the development of permanent packing facilities. It allows continued utilization of the high-wheeled cabbage carts, although the capacity of such vehicles may be less than optimum for a mechanized harvesting system.

A cabbage harvester severing the heads from their stems at a fixed height immediately above ground level will not cut all heads at an optimum location to leave the desired number of wrapper leaves. Due to the natural variability in height of the cabbage heads, a fixed cutting blade height will result in a percentage of the heads cut too low, necessitating trimming, some percentage will be cut within an acceptable range, and possibly some will be cut too high and be downgraded or discarded. What constitutes an acceptable range is open to question; if the acceptable range is taken as between the point where the head is hand cut and the lowest leaf, Halsey et. al. (6) showed that a fixed cutting height can be found for each field so that 2.5% of the heads will be cut too high and a varying percentage dependent upon variety and location will be cut too low. The percentage cut too low was not determined but can be inferred from their data to range from almost zero to slightly above 50%. On the other hand it would be very difficult to sense the proper cutting height for each head and adjust the cut to that elevation.

Three alternatives are possible to accomplish proper trimming of those heads not cut at an acceptable height. Such heads could be trimmed by hand at the packing location; this alternative would require a high labor input. It is possible that a trimmer might be developed and incorporated into the harvester, possibly requiring no additional labor but making the harvester
much more complex. Or, a rather simple trimmer based upon the concepts of Parsons and Rehkugler (8) could be developed in which hand-held heads would be moved across a slot underneath which a saw would cut off excess stem and leaves. This third solution might possibly be incorporated into the total system either as part of the harvester or as part of the packing operation.

Based on these functional considerations a prototype experimental cabbage harvester was developed. The harvester performs the primary functions of severing the heads from their stems and delivering the heads to a receiving vehicle. Two secondary functions performed are aligning the heads prior to cutting and removing dirt clods from the plant bed surface to prevent their interfering with the cutter.

THE HARVESTER

The prototype cabbage harvester which was developed is a one-row, once-over, tractor-mounted, hydraulically-powered machine which grips the heads, cuts the stems above ground level, and conveys the severed heads to a receiving vehicle in register with the harvester. It is designed for a two-man harvesting operation, one driving the tractor and controlling the harvester and one driving the receiving vehicle.

The cabbage harvester was built around and mounted to a high clearance tractor (Ford 4000) (Figure 1). The header, comprised of grip belts, cutter and frame was mounted on the right side of the tractor between the wheels. An intermediate conveyor to elevate the heads backward was located under the right rear axle. A loading conveyor was mounted across the rear of the tractor. A hydraulic control system was mounted at the right of the operator and its reservoir behind the tractor seat.

The header (Figure 2) was supported and had its height, and therefore the cutting height, adjustable by a hydraulic cylinder. It was suspended by a four bar parallel linkage so that the header remained level with the ground independent of its height. The horizontally opposed belts were 10 inches wide, supported by pulleys mounted on spring loaded linkages, and had low cleats spaced approximately 8 inches apart. The grip belts accommodated cabbages having diameters ranging from approximately 5 to 10 inches. The grip belts were driven at approximately ground speed so that their velocity with respect to the cabbage heads was approximately zero. They converged on a head from the sides, improving its alignment perpendicular to the row if necessary, and supported the head past the cutting point. The grip belts were driven by a hydraulic motor through a single roller chain. The cutter was an 18 inch diameter circular
crosselect saw blade driven at approximately 2400 rpm by a hydraulic motor through a gearbelt drive. The blade was tilted forward from horizontal 3 degrees, preventing the stump remaining in the ground from acting as a disc brake on the blade and lifting the severed heads slightly.

A schematic diagram of the hydraulic power and control system with brand names and model numbers included is given in Figure 3. The pump was mounted on the tractor PTO shaft.

The grip belts deposited the severed heads on the intermediate conveyor. This conveyor was 8 inches wide with low cleats. It delivered into the loading conveyor which was 12 inches wide and had 4 inch flights spaced 12 inches apart. Both conveyors were powered by individual hydraulic motors through roller chain drives.

In operation the driver operated the tractor and adjusted the functions of conveyor speeds, grip belt speed and header height. Conveyor speeds were coupled through the design of the hydraulic system and were adjusted to the lowest speed required to handle the product (provision has also been made to adjust the conveyor speeds relative to each other). Grip belt speed was adjusted to equal or slightly exceed ground speed. Header height was adjusted so that the greatest percentage of heads were cut to not require trimming. This was most easily determined by the operator observing the heads on the intermediate conveyor as they rolled while moving backward.

**Performance and Discussion**

During the winter of 1968 the experimental prototype cabbage harvester was successfully field tested in short runs several times during which slight modifications and adjustments were made. The harvester's potential was clearly demonstrated. It has not yet been tested to the extent necessary to obtain reliable data on optimum operating speed, amount of damage, amount of trimming necessary, etc. A preliminary estimate of the amount of marketable heads requiring trimming is 50%.

One favorable characteristic of the cabbage harvester is that less damage to the cabbage is expected using it as compared to the hand har-
Table 1

Cost Analysis Factors of Cabbage Harvester System

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvester original cost</td>
<td>$4,000</td>
</tr>
<tr>
<td>Cart original cost</td>
<td>$500</td>
</tr>
<tr>
<td>Life of harvester (to obsolescence)</td>
<td>5 yr</td>
</tr>
<tr>
<td>Life of cart (to wear out)</td>
<td>15 yr</td>
</tr>
<tr>
<td>Salvage value</td>
<td>0</td>
</tr>
<tr>
<td>Interest rate</td>
<td>7%</td>
</tr>
<tr>
<td>Yearly harvester repair costs</td>
<td>5% initial cost</td>
</tr>
<tr>
<td>Yearly cart repair costs</td>
<td>6% initial cost</td>
</tr>
<tr>
<td>Yearly insurance costs</td>
<td>1/2% initial cost</td>
</tr>
<tr>
<td>Yearly taxes</td>
<td>1% initial cost</td>
</tr>
<tr>
<td>Harvester operator wage rate</td>
<td>$2.00/hr</td>
</tr>
<tr>
<td>Driver wage rate</td>
<td>$1.80/hr</td>
</tr>
<tr>
<td>Harvester operating speed</td>
<td>0.75 mph</td>
</tr>
<tr>
<td>Harvester field efficiency</td>
<td>70%</td>
</tr>
<tr>
<td>Plant spacing in rows</td>
<td>12 in.</td>
</tr>
<tr>
<td>Livability</td>
<td>95%</td>
</tr>
<tr>
<td>Cart capacity</td>
<td>1,300 heads</td>
</tr>
<tr>
<td>Yearly tractor ownership costs</td>
<td>18.05% initial cost</td>
</tr>
<tr>
<td>Total Annual tractor use</td>
<td>500 hr</td>
</tr>
<tr>
<td>Harvester's tractor initial cost</td>
<td>$3,500</td>
</tr>
<tr>
<td>Cart tractors initial cost</td>
<td>$2,800</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>0.06 gal/Hp hr</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>$.30/gal</td>
</tr>
<tr>
<td>Round trip unloading time</td>
<td>30 min</td>
</tr>
<tr>
<td>Heads per 50 lb crate</td>
<td>20</td>
</tr>
</tbody>
</table>

1/ includes depreciation, interest, insurance, housing taxes and repairs.
vest system. In the hand harvest system it is usual for cabbages to be tossed as much as 15 or 20 feet to the cart, potentially bruising cabbages upon impact. The harvester drops the heads from the loading conveyor up to 5 feet (into an empty cart) with perhaps one half the potential for bruising. There seems to be little other opportunity for bruising to occur as cabbages pass through the harvester.

In order to allow a reasonable judgment to be made of the cabbage harvester on an economic basis a cost analysis was performed. Assumptions and values used are listed in Table 1.

Two carts with tractors and drivers would be the minimum required to facilitate a continuous harvesting operation, based on the data in Table 1. Ownership and repair costs of the harvester are $1260/year. Ownership and repair costs of two carts total $192/year. Operating costs of the harvester's tractor (35 Hp) are $1.88/hr. and those of the two cart tractors (20 Hp each) total $2.44/hr. Wages for the three men total $5.30/hr. This system could harvest 2605 heads per hour or 0.21 acre/hour based on a 40 inch row spacing (0.15 acre/hour at a 28 inch row spacing.)

In order to complete the harvesting and packing system a trimmer located at a fixed packing facility is hypothesized. Two workers receive cabbages from a conveyor emptying a receiving bin, pick them up and inspect, orient those requiring trimming stem downward, and pass them across a slot underneath which a rotating saw trims the heads. The cabbages are then graded and packed. Initial cost of such a trimmer is estimated at $2000, life to obsolescence at 5 years, yearly repair costs at 5% initial cost, and power costs at $.20/hour. It is estimated that two workers would be required to handle about 2600 heads per hour. Other pertinent factors are taken from Table 1. Grading and packing is performed conventionally requiring an estimated 0.03 man hours of labor per crate.

Figure 4 shows the cost of the harvesting and hauling portion of the system, the costs of the trimming and packing portions and their total as functions of total production. A single one-row harvester could handle up to approximately 100 acres in a 3 month season.

Total costs of a complete harvesting and packing system using the cabbage harvester for
Two entirely different approaches have been taken, that of pulling up the plant and then severing stem from head, and that of severing stem from head at ground level. According to Rehkgler (10) they found it impractical to use a ground level cutting device because of stones. Also their approach let them better orient the cabbages for a cut in which about 80% of the heads were cut acceptably, requiring no subsequent trimming.

The Florida cabbage harvester, cutting the heads immediately above ground level, is, in comparison, a much simpler machine than the others and is suitable for the conditions in this state.

**Summary**

A simple, rugged, flexible cabbage harvester was developed suitable to Florida’s conditions. It will conform both to the present harvesting and handling systems and to one using packing at a centralized location.

**Acknowledgments**

The authors wish to recognize previous contributions to this research by J. F. Beeman and William W. Deen, Jr., by the development of an

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**Table 2**

<table>
<thead>
<tr>
<th>Michigan State</th>
<th>Cornell</th>
<th>N. Carolina State</th>
<th>Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orient (fingers)</td>
<td>Orient (discs)</td>
<td>Orient (V belts)</td>
<td>Orient (flat belts)</td>
</tr>
<tr>
<td>Pull plant (V belts)</td>
<td>Pull plant (chains)</td>
<td>Grip head (V belts)</td>
<td>Grip head (flat belts)</td>
</tr>
<tr>
<td>Elevate plant (V belts)</td>
<td>Elevate plant (chains)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut head (disc knives)</td>
<td>Cut head (circular saw) (bandsaw blade)</td>
<td>Cut head (circular saw)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4.—Estimated costs of a Cabbage Harvesting System.

harvesting range from $0.487/crate at a production of 10 acres/year to $0.185/crate at a production of 100 acres/year. This compares to costs ranging from $0.18 to $0.30/crate averaged over the past five years recorded by Brooke (3). A production level of from 20 to 100 acres/year would be required to justify the proposed system including the cabbage harvester assuming present costs are comparable to the five year average. As costs rise the proposed system will become even more competitive.

If the round trip time for unloading should require longer than 30 minutes it would be necessary to either provide at least three receiving vehicles and tractors or provide larger capacity vehicles. The latter, if feasible, would produce lower costs.

One way in which costs might be reduced for a small grower would be to use an intermittent harvesting operation and only one receiving vehicle, although this alternative is less efficient in utilizing the harvester operator’s time.

The four cabbage harvesters developed by university research teams in the U.S. can best be compared on a functional basis (Table 2). The comparison continues through to cutting the head from the stem after which elevating and loading was accomplished similarly by all four harvesters.
earlier version of this harvester which proved feasible certain of the principles used by this harvester.

REFERENCES


INFLUENCE OF POLYETHYLENE MULCH COLORS AND SOIL FUMIGANTS ON STRAWBERRY PRODUCTION

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ABSTRACT

Three polyethylene mulches—black, gray, and clear—were evaluated with various soil treatments, including a complete soil fumigant, a nematicide, and a herbicide, in strawberries. In a second study, black and clear mulches were evaluated in combinations with complete soil fumigants, a nematicide, and no soil treatment. When black mulch was used, plant growth and early yields were comparable with Telone, Dowfume MC 33, Brozone, Vorlex, and methyl bromide. Maximum total yields, however, were produced with Dowfume MC 33, Telone, and methyl bromide. With clear or gray mulch, maximum yields were associated with fumigants that also provided weed control. These included methyl bromide, Brozone, and Dowfume MC 33. Use of the herbicide DCPA in combination with Telone under clear or gray mulch did not provide adequate weed control. Maximum and minimum soil temperatures under the clear mulch were generally higher than under the gray and black mulches.

INTRODUCTION

The use of black polyethylene mulch and soil fumigation, generally a nematicide, has been standard treatment for strawberries grown in Florida since 1960. One of the contributing factors to the 45 percent or more yield increase with the use of polyethylene mulch (2) is an increase in soil temperature (6, 7, 8). Soil temperatures are increased with clear, gray, or black polyethylene mulch as compared to bare soil (4, 6, 7). In addition, film color has been shown to influence soil temperatures differentially. During the day, soil temperatures are higher under clear and lower under black mulch. With such a crop of strawberries, grown during the cooler part of the year, this difference in soil temperature due to mulch color may influence crop growth and fruit yields. However, due to the transmission of light through the clear film, weed growth is a problem unless controlled.

In California, where Verticillium wilt is a problem, broad spectrum fumigants such as a mixture of methyl bromide and chloropicrin effectively control soil diseases and weeds (1). The use of such fumigants in combination with clear mulch has significantly increased early